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Education, Research, and Innovation in Africa

Forging Strategic Linkages for Economic Transformation

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Introduction and Summary[1]

Africa is a youthful continent: nearly 41% of its population is under the age of 18. To address the unique challenges of this demographic structure, the African Union (AU) has adopted a 50-year Agenda 2063 to help guide the socioeconomic transformation of the continent with particular reference to the youth. One of the objectives of Agenda 2063 is to reposition the continent as a strategic player in the global economy through improved education and application of science and technology in development. The AU's Science, Technology and Innovation Strategy for Africa, 2024 (STISA-2024) provides an intial 10-year framework for pursuing this goal.

Achieving the objectives of STISA-2024 will require aligning education, research and innovation with long-term socioeconomic objectives. This paper argues that the AU's Specialized Technical Committee on Education, Science and Technology (STC-EST) is well-positioned to play a strategic role in guiding and fostering the reforms needed to improve the integration of education, research and innovation.

The paper proposes the creation of "Innovation Universities" that combine research, teaching, community service and commercialization in their missions and operations. They would depart from the common practice where teaching is carried out in universities that do little research, and where research is done in national research institutes that do not undertake teaching. Under this model, there is little connection with productive sectors.

The idea therefore is not just to create linkages between those activities but to pursue them in a coordinated way under the same university structure. Innovation universities can be created in diverse fields such as agriculture, health, industry, services, and environment to advance sustainable development and inclusive growth.

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There are two strategies for pursuing innovation universities. The first is to strengthen research, community service, and commercialization in existing teaching universities. The second is to set up new innovation universities in line ministries, public corporations, private enterprises, and development agencies. This paper focuses on the second strategy, given that the first one is being pursued already. The ministries or agencies responsible for higher education will need to be creative and flexible enough to foster the creation of such universities while granting the autonomy necessary for them to advance their specialized innovation objectives.

Creating such innovation universities will have two important budgetary implications. First, it will broaden the base for funding innovation by enabling specialized actors to design and operate new universities using their own budgets. Second, this will reduce the need to rely on funding from ministries of education. It will help to reduce the potential competition for funds between tertiary education and lower levels of education.

Creating innovation universities will require high-level coordination because of the increase in number of governmental and nongovernmental actors. High-level coordination of these activities must be strengthened within the offices of presidents and prime ministers. To support heads of state and government in coordination, it is strongly recommended that an Office of Science and Innovation Advice be created in every country, taking into account the prevailing constitutional order.

Such offices should be created by law with clear mandates to focus on advisory functions and not operational activities, which should reside in the line ministries. Such offices would be analogous to offices of chief economists who support heads of state and government by giving advice while leaving operational activities in line ministries.

1. Innovation and Development

Africa's innovation strategies are at a crossroads. The African Union's 10-year Science, Technology and Innovation in Africa Strategy aims to reposition the continent as a technology-driven economy, away from being viewed mainly as a supplier of raw materials for export markets with limited scope to develop local processing industries. To resolve the tension between mineral dependency and innovation, policymakers stress the importance of adding value to natural resources.

Yet there is little evidence to suggest that countries industrialize by adding value to their raw materials. Rather, the causality runs the other way—countries add value to raw materials because they already have the technological capacity to do so. In fact, commodity booms are often a consequence of policy incentives, improvements in exploration technology, and investment in commodity-related public research. Africa currently lags far behind in such efforts.

Africa's most significant challenge is to invest in capacity building through enhanced education in science, technology, engineering, and mathematics. Such investments will enable the continent to leverage the world's available scientific and technical knowledge and use it to diversify the economy away from a historical dependence on natural resources. The urgency to diversify African industry has been reinforced by China's economic slowdown and its negative impacts on African raw material exporters.

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Africa can look to Taiwan, Finland, Kenya, Brazil, and China as examples of countries that shifted from exporting primary products such as mushrooms, lumber, tea and coffee, sugar, and rice to becoming technological powerhouses in semiconductors, mobile phones, mobile money transfer, aeronautics, and solar photovoltaics, respectively. The secret of these countries lies in their ability to create new institutions through which they

could acquire, domesticate, and diffuse new technologies in the economy. The process involved building up the social capabilities for technological catch-up (Abramovitz, 1986; Fagerberg and Srholec, 2008).

Even more important, they were able to identify emerging technologies that could serve as a platform for producing a wide range of products and associated services. In some cases they were able to leapfrog to the frontiers of technological innovation not simply by following the frontrunners but by creating new technological pathways to prosperity (Chen and Li-Hua, 2011; Lee, 2014.).

Technological versatility is a critical element of economic development. Some technologies offer greater opportunity for product and knowledge diversification than others, which gives countries greater opportunities for generating new economic combinations through the creation of novel products, processes, and markets as well as new raw materials and organizational form (Juma, 2014). Innovation is thus a recombinant process that builds on the absorption and deployment of prior knowledge (Camisón and Forés, 2010). Firms, universities, and research institutions are the primary vehicles through which knowledge is absorbed, transformed into goods and services, and then diffused throughout the economy.

Pursuing such strategies requires building up the capacity to identify, acquire, and domesticate emerging technologies. Such competence usually resides in science, technology, and engineering departments in universities and research institutes.

In fact, most African nations already possess pockets of such capabilities in their institutions of higher learning and research. They just need to capitalize on these by reforming their national systems of innovation (Metcalfe and Ramlogan, 2008). In doing so, they will need to stress the role of universities as drivers of economic transformation (Mok, 2012). To achieve this, they must focus on innovation.

2. Higher Education, Research and Innovation

2.1 Historical context

Reforming African universities to bring them in line with STISA-2024 will be one of the most challenging tasks in Africa's technological transformation. The current low level of investment in higher technical training and research is a barrier. The policy agenda recommends allocating 1% of each country's GDP to research and development (R&D). This focus is a politically appealing and simplified recommendation that fails to account for the magnitude of the challenges. Additional approaches are needed to harness knowledge for broader development.

Poor institutional arrangements for research and higher education in most African countries were created to train functionaries in the 1960s, and they are holding the continent back. Very few African universities have updated curricula or use teaching methods that promote innovation. In fact, the mission of most African universities is still to teach and confer degrees, whereas much of the world is experimenting with new university models that focus on transforming the economies of the regions in which they are located (Trencher et al., 2014).

One way to promote innovation is to connect the functions of universities with research institutes, which are typically kept separate. The current approach is dysfunctional because universities use established teaching methods without incorporating new research, resulting in graduates with outdated worldviews and skill sets that are not suited to contemporary needs. They are usually unemployable and can hardly create enterprises to employ others. Research institutes lack the means to disseminate findings to the public through practical business or community outreach without students. These functions need to be pursued in an integrated way under one institutional structure.

2.2 Grand challenges for engineering and technological catch-up

The world faces a number of grand challenges that are gaining public attention. According to the U.S. National Academy of Engineering, these challenges fall into four main categories: sustainability (make solar energy economical, provide energy from fusion, develop carbon sequestration methods, and manage the nitrogen cycle); health (provide access to clean water, engineer better medicines, advance health informatics, and reverse engineer the brain); security (secure cyberspace, prevent nuclear terror, restore and improve urban infrastructure); and life enrichment (enhance virtual reality, advance personalized learning, and engineer the tools for scientific discovery).

Shorter timeframes between research and commercialization have changed the nature of technology forecasting. In many fields, the future of technology and engineering appears to be now. There is widespread awareness of rapid scientific advancements and the availability of scientific and technical knowledge worldwide. This exponential growth feeds on previous advances following inner self-propelling momentum, making it possible to find low-cost, high-technology, engineering solutions to persistent problems. These technologies are reshaping the political landscape in unprecedented ways, opening up new technological opportunities through technological catch-up and leapfrogging (Cusmano, Morrison and Rabellotti, 2010).

In many fields, the future of technology and engineering appears to be now.

Advances in science, technology, and engineering will therefore make it possible to solve problems that have previously been unattainable. This is not a deterministic view of society but an observation of the growth in the global ecology of knowledge and the feasibility of new technical combinations that are elicited by social consciousness.

Following this, Africa has the ability to leapfrog and adapt existing technologies to address local problems as a result of greater access to scientific and technical knowledge that advanced countries had in their early stages

of industrialization. Indeed, the pace at which latecomer economies such as China have been able to leapfrog in certain technologies underscores the possibilities (Chen and Li-Hua, 2011).

The role of technological innovation in society is gaining influence. Historically, technological innovation was perceived as a slow process, which was true in the past. Today, however, exponential growth is evident in the rapid rate at which new technologies and engineering solutions are generated. This is occurring faster than society can design new complementary institutions.

The social implications are phenomenal, as reflected in the public reaction to the erosion of privacy as a result of advancements in technology. Second, in many fields innovation cycles are shorter. This enables new products to reach the market faster than in the past. Finally, the globalization of industrial value chains has created new opportunities for the rapid diffusion of new technology and engineering practices (Pietrobelli and Rabellotti, 2011).

3. Creating New Innovation Universities

3.1 Trends

Most of Africa's universities are dedicated to teaching with few incentives for research or commercialization of research results. There are, however, a few African universities that have demonstrated leadership in innovation. For example, Stellenbosch University in South Africa became one of the first higher education institutions in the developing world to build and launch a satellite. The Jomo Kenyatta University of Agriculture (JKUAT) in Kenya pioneered in the commercialization of tissue culture bananas and other agricultural products. In fact, the charter that established JKUAT envisaged it as an innovation university that would bring together teaching, research, extension, and product commercialization.

Some African universities have served as incubators of businesses without having explicit mandates to do so. For example, the University of Zambia's Physics Department incubated Zamnet, the country's first Internet provider (Konde, 2004). Yet many new businesses or technologies created by entrepreneurial students in universities fail because of the lack of policy and managerial support. Others fail because of the absence of risk capital (Ben-Ari and Vonortas, 2007; Bjørgum and Sørheim, 2015). Others lack innovation ecosystems that can support the emergence and development of new industries (Lee and Tee, 2009).

The sources of such failures can be addressed through a comprehensive national strategy for fostering innovation. The strategy would place particular effort on the role of innovation universities. It is not necessary, however, to wait until such a strategy is in place. The formulation of the strategy can go hand-in-hand with the creation of innovation universities. The first entry point is to strengthen research in existing universities. Much of this is being carried out but with varying degrees of success and effectiveness. It requires changes in the incentive structures for higher education to create space for research. An additional approach is to upgrade

carefully selected national research institutes (NRIs), technical colleges, and research institutes located in line ministries into innovation universities. Other opportunities for creating innovation universities lie in public corporations and large infrastructure projects. There are several reasons for pursuing this strategy.

First, Africa's NRIs provide a strong foundation upon which to create new colleges and graduate schools combining research, teaching, community service, and commercialization. Creative approaches are needed to add graduate teaching functions to the institutes. For example, many African agricultural NRIs work on the cutting edge of life sciences, especially in agriculture and health. They could be upgraded to push into frontier fields such as synthetic biology for health, industry, agriculture, and environmental conservation. For example, the Kawanda Agricultural Research Institute in Uganda has sufficient in-house expertise to form the basis for Africa's first biotechnology innovation university. A detailed assessment of the institutional assets and capabilities would reveal a large number of potential candidates that could be upgraded into innovation universities.

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Second, most African line ministries and public corporations have their own research and training institutes that could be upgraded to serve as graduate schools focusing on the missions of each ministry. Countries such as China have extensively used this model to create new technical universities. In 1955 the Chinese Ministry of Posts and Telecommunications created the Beijing Institute of Posts and Telecommunications. In 1998 the institute was renamed the Beijing University of Posts and Telecommunications following a series of mergers with its affiliate vocational school and the ministry's Science and Technology University. This is an example of the creation of a line ministry university through a series of upgrades and mergers. It is important to note that the creation of the university was part of the larger "Project 211" that sought to upgrade research universities so that they could contribute to national socioeconomic development. The project was launched in 1995 and by 2000 nearly US$2.2 billion had been

distributed to 100 key universities. The target was to reposition China's entry into the 21st century with 100 key national universities and colleges, hence the abbreviation Project 211. In 2000 the university was transferred to the Ministry of Education following adjustments of the country's institutions of higher education.

Variants of such a strategy are within reach for many African countries. One obvious African opportunity is upgrading aviation training schools so that they can function as graduate research and entrepreneurial universities, which would allow airports to function like teaching hospitals. Leading African public corporations such as Ethiopian Airlines could expand their internal training programs into world-class innovation universities with an initial focus on engineering, logistics, and entrepreneurship. Similar approaches could be adopted by Africa's mobile communications firms, which could initially focus on electronic and electrical engineering.

The value of this approach is to retain the universities or schools in their line ministries so they continue to be relevant to the specific sector. An example is the Uganda University of Military Science and Technology under the Uganda People's Defence Force. Among other skills, the university trains railway engineers. Tanzania has also created three new innovation-oriented universities under the Ministry of Telecommunications, Science and Technology. Ethiopia recently created 24 new universities and has started migrating some of them to operate under the Ministry of Science and Technology.

Third, private and public enterprises can also help expand higher technical training through in-house programs. Firms can help to consolidate training activities across industries to create dedicated training and research programs, improving upon the current emphasis on firm-specific training. With proper incentives such activities could contribute to the firms as well as to the wider economy. Such training facilities could also be embedded in existing universities. For example, Safaricom is financing a namesake academy at Strathmore University in Kenya that offers a Master of Science degree in mobile telecommunications and innovation.

Fourth, large infrastructure projects offer unique opportunities for expanding technical training and innovation. Infrastructure projects are important reservoirs of technical skills and entrepreneurial talent that could be consolidated into an in situ engineering and business university. South Korea's high-speed rail shows how infrastructure projects can be used to build up the associated engineering and managerial capabilities. One of its key outputs was the establishment of the Korean Rail Research Institute in 1996. The aim of the institute is to develop railway transportation and enhance competitiveness in the sector.

Adding engineering colleges to large infrastructure projects could be justified as part of the costs of long-term maintenance. In fact, any such projects should provide for higher technical training from the outset. The failure to design the projects as learning centers is a wasted opportunity to promote innovation universities.

Adding engineering colleges to large infrastructure projects could be justified as part of the costs of long-term maintenance.

One obvious example that could serve as platform for the creation of an innovation university is the Square Kilometer Array (SKA) radio telescope to be built in Australia and South Africa with outstations in Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia and Zambia. SKA will be the world's most sensitive and largest radio telescope. It will be nearly 50 times more sensitive and with survey speed that is 10,000 faster than existing radio telescopes. SKA is strategic research infrastructure that will include a wide range of engineering skills as well as data analysis capabilities beyond its core astronomical objectives. It can form a suitable basis for creating a regional innovation university on all aspects of space engineering.

Another example is the US$5 billion Grand Ethiopian Renaissance Dam (GERD), which could train young people in diverse engineering skills related to the design, construction and implementation of hydropower projects. In addition, subjects such as economics, sociology, anthropology, and political economy can be offered to provide the full breadth of

knowledge needed for effective infrastructure projects. The range of skills extends to the consumer sector. The production of power is only one step in a series of activities that includes promoting access. It takes a wide range of skills to design, produce, and sell electrical appliances.

Students who learn these skills could apply them to the wider economy. Electrical engineers, for example, could apply their skills to other forms of power generation. Similarly, those who learn about civil engineering could transfer the knowledge to other forms of construction.

Fifth, the rise in the number of private universities across Africa offers new avenues for strengthening national innovation capabilities. Proactive government policies and incentives can help encourage private investors to create engineering-oriented universities. Examples that illustrate the feasibility of such an approach include the creation of the Future University in Sudan and the Nile University in Egypt. Both are private universities that focus on information and communications technologies.

Creating innovation universities outside the traditional structure of education ministries may help to broaden the base for funding and reduce the pressure on budgets allocated to primary and secondary education. Financial support for such universities would come from line ministry budgets. Many of the technical ministries have private sector partners that might be interested in providing additional funding.

In some cases, the new universities could be created as joint efforts between private or public enterprises with education ministries. An example of such an approach is the Pohang University of Science and Technology (POSTECH), which was set up in 1996 as a joint venture between South Korea's POSCO (an iron and steel public corporation) and the ministry of education. In this case, POSCO provided scholarships to the students and the government ensured that POSTECH had access to the top students in the country. In 10 years after its establishment, POSTECH was voted as one of the best science and technology universities in Asia. This was in part due to its proximity to a public enterprise with highly-skilled professionals.

One of the main reasons such upgrades do not occur is because of the power struggle between line ministries and higher education ministries or commissions. A combination of creativity across sectors and flexibility in government policy would go a long way in helping Africa to reinvent its higher education systems to encourage young innovators. For the system to work, bodies responsible for higher education would need to see themselves as champions of expanding the sector across the economic landscape. They should serve as midwives for the new universities wherever they are located.

3.2 **Strategies**

The challenges facing African economies will require fundamental changes in the way universities train their students. Part of the problem arises from the traditional separation between research (carried out in NRIs) and teaching (in universities) with little connection between the two in most African countries.

The NRIs operate a large number of research programs that provide a strong basis for building new initiatives aimed at upgrading their innovation capabilities. In effect, policymakers should strengthen the educational, commercialization, and extension or commercialization functions of the NRIs.

More specifically, clustering these functions would result in dedicated research universities whose curriculum would be modeled along full value chains of specific commodities. For example, innovation universities located in proximity to coffee or textile production sites should study the entire value chain of these industries. Such dedicated universities would help to connect higher education to the productive sector through continuous interaction with businesses, government, and civil society organizations.

Internally, the new universities should allow their curricula to adjust to the challenges facing the continent. Governance systems that allow for such continuous feedback to universities must be established. One way to

achieve this would be to ensure that the governing bodies of innovation universities include the relevant stakeholders or beneficiaries of the universities. Trade associations, for example, might be interested in serving on the boards of such universities and be able to provide input on the kinds of courses that benefit their members.

3.3 **Reforms**

The reform process of the educational system must include specific measures. First, innovation universities need clear visions and strategic plans that focus on practical applications and include comprehensive roadmaps for moving research from the lab to the marketplace. They also need to define how to best recruit, retain, and prepare future graduates. These plans should be prepared in partnership with key stakeholders.

Second, in addition to ensuring that their curricula address local needs, they should also serve as innovation hubs. Taking this approach may involve the relocation of some university departments to serve specific industrial clusters. For example, countries that are exploring the creation of commodity-based innovation universities could merge or cluster different university departments and research institutes closer to where the commodity is produced. A cocoa university in Ivory Coast, for example, could be created by relocating parts of research facilities to a center of cocoa production. The same can be done for cotton and other commodities.

There is a precedent for such mergers. Taiwan's intellectual powerhouse, Industrial Technology Research Institute (ITRI), was established in 1973 by merging several research institutes left behind when Japanese occupation of the island ended. Many of the leading Taiwanese firms such as the United Microelectronics Corporation (created in 1980) and the Taiwan Semiconductor Manufacturing Company (created in 1987) were ITRI spinoffs.

Many of the NRIs can foster long-term working relationships with nearby productive facilities. They can also branch into new knowledge-based fields. For example, NRIs located close to breweries can build up expertise in biotechnology using fermentation knowledge as a foundation. Similar arrangements can be created with other agro-based industries such as sugar mills and fish factories.

Many of the NRIs can foster long-term working relationships with nearby productive facilities.

Third, the universities should give students more opportunities to gain work experience outside the classroom. This can be done through research jobs, traditional internships, or community service. These activities will help facilitate the transfer of knowledge from universities to local communities and vice versa: students would bring back practical feedback and lessons that could make curriculum more relevant. These activities should be an integral part of the academic calendar. But universities could go further and incorporate an experiential teaching method capable of imparting direct skills. More important, such training should also include the acquisition of entrepreneurial skills and other forms of experiential learning.

Fourth, NRIs have a mandate to conduct outreach programs to work directly with farmers, industrialists, and other producers. A "reverse outreach" approach under which entrepreneurs can selectively participate in "open classroom" programs would help to strengthen innovation and would give faculty and students the opportunity to interact with entrepreneurs in a classroom setting.

Fifth, research universities must incorporate vocational training or experiential training into their curricula. They can contribute to "factory or farm schools" or conduct programs in conjunction with high schools. These links will be particularly important considering Africa's demographic structure. With the majority of the population in school, educational institutions form an integral part of the community.

Sixth, one of the main teaching missions of innovation universities is to teach students how to translate ideas into goods and services through

enterprise creation. This entrepreneurial function can be done in partnership with financial institutions such as banks, cooperatives, and development organizations. Such activities may also lead to the emergence of rural-based angel funding or venture capital facilities. Similarly, sources of support such as rural development funds could be redirected to help translate ideas from such universities into new enterprises.

Seventh, continuous faculty training and research are critical for maintaining high academic standards. The new universities should invest more in undergraduate educators to promote effective research and teaching and to design new courses. Researchers at NRIs would only need minimum training to acquire the necessary pedagogical skills. In fact, many of them are involved in extensive field training activities, so they already teach without having the title. Additional support to the NRIs can be provided by education departments in existing universities. Where needed, teacher training institutes could create special courses aimed at offering training in experiential pedagogy.

Finally, providing awards or prizes for exemplary teaching raises the profile of teaching and improves education. Such prizes are particularly important given the low status that is accorded to teachers in society. Most teachers work in environments that discourage departures from established practices despite their contributions to learning in particular and society in general.

The reforms could also extend to strengthening vocational education in its own right. Currently most vocational training is separate from mainstream higher education. There are two strategies for strengthening vocational education. The first is to incorporate experiential training in higher education. This will not only help to make university education more practical, but it will also help to raise the profile of vocational education. The second strategy is to help upgrade technical and vocational schools so they can offer higher-level training while retaining their practical focus. In fact, they possess the potential to evolve into innovation universities.

An example of such efforts is the Mondragon University in the Basque Country of Spain. The university started in 1943 as a polytechnic to

support the mission of its parent cooperative, Mondragon Corporation (founded in 1941). The key lesson here is that adding an educational component to productive facilities needs to be part of the initial planning of the business.

All these reforms will require greater creativity on how to manage quality as part of a long process of upgrading educational systems. There are many countries such as the United States that have over the centuries developed quality management systems that take into account the diversity of higher education models. Their experiences could be relevant for Africa. What is not helpful, however, is imposing a uniform system of quality control for higher education institutions serving different objectives.

There is considerable interest across the world in regional and international university rankings, in which African institutions feature poorly. There have also been discussions about creating rankings that are unique to the African situation. This preoccupation may be of interest to a small number of African universities, but for the rest of Africa the most urgent work is putting universities on a path that makes them relevant to the continent. This is like worrying about a beauty contest for people whose main need is finding clothes that fit them for their daily routines.

4. Role Models for Africa

4.1 Trends in innovation universities

Many countries around the world consider enterprises to be the primary driver of economic transformation. Underlying the role is enterprises' know-how on turning knowledge into goods and services. There are many role models that offer valuable lessons for Africa. The key is studying specific case studies and their lessons rather than seeking to emulate the experiences of a particular country. The key attribute of effectiveness appears to be the ability to bring education, research, teaching, extension, and commercialization under coordinated or single institutional structures.

Knowing this, Africa is increasing its investments in enterprise development. But the growing awareness of technical knowledge and entrepreneurship will require forging close connections between business and academia. As businesses grow, they demand more technical knowledge. Some of this can be generated internally. Focusing on scaling up businesses, therefore, increases a country's knowledge base. As firms grow, they also produce new technical knowledge that makes them suitable locations for training future generations.

The growing awareness of technical knowledge and entrepreneurship will require forging close connections between business and academia.

Other ways to spur entrepreneurship include using universities as incubators for new companies. Similarly, enterprises can play a key role in expanding higher technical training by creating knowledge-based universities. Public and private firms sponsor in-house and external training. Some of these activities could be consolidated across industries to create enterprise-based colleges and universities.

Africa can learn from the experience of several countries in supporting enterprises to create universities. Several large private or public firms such as Infosys (India), Samsung (South Korea), Petrobras (Brazil), Petronas (Malaysia), and the Abu Dhabi National Oil Corporation operate universities that serve their internal missions.

Development agencies and nongovernmental organizations (NGOs) are usually engaged in work that involves innovation and could also help to incubate innovation universities. An example of such prospects is the Uganda-based African Rural University for Women (ARU) founded in 2009. The university was created by the Uganda Rural Development and Training Program (URDT), an NGO founded in 1987. It is the first African university devoted to training rural women.

The trends and examples shown above illustrate the changes that are occurring in higher education. There is considerable scope for Africa to learn from experiments going on worldwide on bringing sections of higher education in line with innovation objectives. As the examples show, Africa is itself a source of important lessons. The next section examines how the case of EARTH University in Costa Rica illustrates the importance of reform in curricula and pedagogy in the effective functioning of innovation universities.

4.2 **The case of EARTH University, Costa Rica**

Origins

A pioneering example in curriculum reform is the agribusiness-based EARTH University in Costa Rica (Juma, 2015). The university aims to produce a new generation of agents of change who focus on creating enterprises rather than seeking jobs. EARTH University's origins mirror large parts of rural Africa today: economic stagnation, high unemployment, ecological decay, and armed conflict. EARTH University is a nonprofit, private, international university focusing to sustainable agricultural education in the tropics. Located in the Atlantic lowlands of Costa Rica, EARTH University admits about 110 students annually and has a total student

population of about 400 from 24 countries (mainly in Latin America and the Caribbean) with faculty from 22 countries.

EARTH University has developed an innovative, learner-centered, and experiential academic program that includes direct interaction with the farming community. Its educational process stresses the development of attitudes necessary for graduates to become effective agents of change. They learn to lead, identify with the community, care for the environment, and be entrepreneurial. They are committed to lifelong learning. There are four activities in particular within the curriculum embodying EARTH University's experiential approach to learning.

Work experience and community service

The first is the work experience activity, which is taken by all first-, second-, and third-year students and continues in the fourth year as the professional experience course. In the first and second years, students work on specific projects on EARTH University's 3,300-hectare farm. In the first year, the work is largely a routine activity and the experience centers on the acquisition of basic skills, work habits, and general knowledge and familiarity with production. In the second year, the focus changes to management strategies for these same activities. Work experience is later replaced with professional experience.

In this course, students identify work sites or activities on campus that correspond with their career goals. Students are responsible for contacting the supervisors of the campus operations, requesting an interview, and soliciting "employment." Upon agreement, supervisors and students develop a joint work plan that the student implements, dedicating a minimum of 10 hours per week to the "job." The second activity is an extension of the work experience course. Here third-year students work on an individual basis with small, local producers on their farms. They also come together in small groups under the community outreach program that is integral to the learning system. Community outreach is used to develop critical professional skills in students, while at the same time helping to improve the quality of life in nearby rural communities.

The third-year internship program emphasizes experiential learning. The 15-week internship is required for all students in the third trimester of their third year of study. It is an opportunity for them to put into practice all they have learned during their first three years of study. For many of them, it is also a chance to make connections that may lead to employment after graduation. The international character of the institution allows many students the opportunity to follow their interests, even when they lead to internship destinations other than in their home country.

Innovation and entrepreneurial skills

The fourth activity is the Entrepreneurial Projects Program. EARTH University's program promotes the participation of its graduates in the private sector as a critical means by which the institution can achieve its mission of contributing to the sustainable development. The development of small- and medium-sized enterprises (SMEs) is a powerful way to create new employment and improve income distribution in rural communities.

For this reason, the university stresses the development of an entrepreneurial spirit and skills. Courses in business administration and economics, combined with practical experience, prepare the students to engage in business ventures upon graduation. This program provides students the opportunity to develop a business venture from beginning to end during their first three years at EARTH University.

Small groups of four-to-six students from different countries decide on a relevant business activity. They conduct feasibility studies (using financial, social, and environmental criteria), borrow money from the university, and implement the venture. This includes marketing and selling the final product. After repaying their loan, with interest, the group shares the profits. This entrepreneurial focus has permeated all aspects of the university's operations and has prepared students to become job creators and agents of change rather than job seekers.

The university also manages its own profitable agribusiness, which has resulted in strong relationships with the private sector. When the university

acquired its campus, it decided to continue operating the commercial banana farm located on the property. Upon taking over the farm, the university implemented a series of measures designed to promote more environmentally sound and socially responsible production approaches.

Commercialization

EARTH University has internationalized its operations. It signed an agreement with U.S.-based Whole Foods Market to be the sole distributor of bananas in their stores. The university also sells other agricultural products to the U.S. market, among others. This helps to generate new income for the university and for small farmers while providing an invaluable educational opportunity for the students and faculty, as well as contributing to the EARTH University scholarship fund. The university uses part of the income to fund sustainable and organic banana and pineapple production research. Over the years the university has worked closely with African institutions and leaders to share its experiences and currently has students from 14 African countries.

After many years of sharing experiences with colleagues from a number of African universities, hosting delegations, and offering workshops in several African countries, EARTH has become widely recognized as an innovative institution whose educational model has great relevance for the African continent. The model can be applied in a diversity of sectors and industries. Its strength lies in the focus on experiential learning, innovation, and entrepreneurship.

5. Roadmap for Action

The Specialized Technical Committee on Education, Science and Technology (STC-EST) should serve as Africa's premier champion of the proposed reforms. It should also serve as the forum for sharing experiences across and beyond Africa. Its mission should be to improve the policy environment for both the evolution of higher education and research and the development of technical skills.

Many models show how to focus on training as a way to improve practical activities such as farming. Ministries and enterprises in African countries should create innovation universities, polytechnics, and vocational schools that address development challenges. Such institutions could link up with counterparts in developed or emerging economies as well as institutions providing venture capital and start to serve as incubators of rural enterprises. Establishing such institutions will require reforming the curriculum, improving pedagogy, and granting greater management autonomy.

Ministries and enterprises in African countries should create innovation universities, polytechnics, and vocational schools.

5.1 Map emerging trends, technologies, and institutional landscapes

One of the key sources of innovation is the ability to identify worldwide trends and to assess their relevance for development. The first area of mapping could include a better understanding of trends in higher education and innovation around the world. The mapping should also include detailed assessments of the policies and incentives used in various countries to promote innovation and entrepreneurial activities in universities.

The second area could include mapping emerging technologies of relevance to African development. Emphasis should be on identifying technologies that offer opportunities for leapfrogging. These could be in

fields such as robotics, unmanned aerial vehicles or drones, additive manufacturing or 3D printing, and synthetic biology including gene editing and renewable energy. Many of these ideas could be framed as grand challenges for engineering.

There is little knowledge of the science and technology landscapes in African countries. There are many institutions that have strong knowledge foundations upon which new innovation universities could be built.

The STC-EST could achieve this objective by establishing high-level expert panels tasked with mapping specific trends and institutional capabilities. The panels would report the trends to the STC-EST for deliberation and action. The panels could include international experts with current knowledge of the trends being examined. The panels could also work with various scientific academies around the world that already undertake such mapping exercises.

5.2 **Promote policy and legislative reform**

The process of creating innovation universities will require supportive policies and possible legislative reform. The policy framework for such actions may already exist in national and regional strategies for economic transformation.

New legal instruments such as amendments in existing laws or the creation of new laws may be needed to foster the creation of new research-oriented universities. Amendments to laws on higher education, science and technology, research, or agriculture could provide for innovation universities that include research, training, commercialization, and extension. New laws could lead to the creation of a separate regime that could be managed by line ministries in cooperation with higher education authorities. In some cases it may be sufficient to introduce regulations that govern the management of universities for innovation under existing laws without legislative reform.

The key element of such laws and regulations would be to grant sufficient autonomy to the new institutions while fostering excellence in research and practice. Policies and laws for such universities should be flexible so that other institutions that meet established criteria—whether private or public—can be designated as innovation universities.

5.3 **Build innovation management capacity**

Finding a cadre of people with expertise in innovation management can be achieved by offering executive education courses to high-level leaders responsible both for policy promotion and for the ultimate implementation of innovation programs. In the long run, such courses should be part of the curriculum of the new universities and should be required for those seeking to work as innovation managers.

The newly established Technology, Innovation, and Entrepreneurship in Africa (TIE-Africa) Executive Program at Harvard Kennedy School is an example of a way to strengthen innovation management capacity.

Inspired by STISA-2024, TIE-Africa was launched in 2015 with a US$1 million gift from the Schooner Foundation for an initial two years. The program represents a unique opportunity for helping to build innovation management capabilities among African high-level policymakers as well as universities. African ministers are committed to strengthening capacity in research, technology, and innovation management. The AU Commission for Human Resources, Science, and Technology will work with HKS to develop modalities for the implementation of the cooperation.

Such training programs could be supplemented by study tours that provide opportunities for African leaders to learn first-hand from practical experiences around the world. Such study tours may be a more effective use of financial resources than the common practice of conferences and workshops.

5.4 Initiate national pilot projects

Champions are needed to pilot the idea of innovation universities at the national level. Pilot initiatives will result in best practices for advancing the idea of innovation universities. Pilot projects must be carefully chosen to maximize the chances of success and not necessarily to determine the viability of the idea. The lessons learned from the execution of the pilots should be regularly shared by African countries. Countries could use incremental strategies starting at polytechnic or college levels with the aim of upgrading successful initiatives into universities.

5.5 Mobilize additional financial resources

Financing Africa's research and higher education has always been contentious. The perceived high cost of running institutions of higher learning has contributed to the dominant focus on primary education. This policy, however, has prevented leaders from exploring avenues for supporting higher technical education. Creating incentives for domestic mobilization of financial resources is essential for leveraging external support.

African policymakers must leverage the global wealth of knowledge on how to finance innovation. Approaches include public as well as private funding. A comprehensive review of known options needs to be undertaken as a matter of urgency. This should include planned infrastructure projects that offer opportunities to serve locations for technical training.

5.6 Strengthen regional and international partnerships, including diaspora

Regional and international partnerships among various institutions are critical to support and develop joint programs. These partnerships should pursue horizontal relationships and open networking to generate more synergy and collaboration, encourage sharing of resources, and foster the exchange of students and faculty. This can be accomplished through

regional exchanges that involve the sharing of research facilities and other infrastructure.

Such collaboration could be extended to bodies such as the OpenCourseware Consortium, a free and open digital publication of educational materials organized as courses from hundreds of higher education institutions and organizations. Its mission is to advance education and empower people worldwide through open courseware. This could also serve as a vehicle for leveraging the expertise of Africans in the diaspora. Governments and private enterprises can help strengthen these partnerships by facilitating access to broadband infrastructure.

5.7 Recognize innovation and reward excellence

Prizes for outstanding contributions to innovation would go a long way toward recognizing the dedication, courage, and commitment of leaders who undertake the tasks described above. The prizes would recognize achievements in research, teaching, commercialization, and extension. The prizes could be awarded during meetings of the STC-EST.

5.8 Strengthen science and technology advice

Governments and other economic actors undertake a wide range of activities that contribute to education, research, and innovation. Many of these activities fall under the jurisdiction of ministries whose primary functions are not education, research, or innovation. Given the primacy of these activities for the continent's long-term economic transformation, it is important to create high-level mechanisms that support their coordination. One way to achieve this is to create Offices of Science and Innovation Advice under the President or Prime Minister.

Such offices should use open and transparent procedures that enhance the integrity of their advice (Feuer and Maranto, 2010). The mandate should be

limited to providing the head of state with advice so there are no conflicts with operational ministries. This would maximize the impact of the activities of the various ministries through better coordination and effective functioning. It can also help to identify new innovation actors. For example, the rising field of science and innovation diplomacy requires greater coordination with foreign ministries.

The office would emulate the functions of chief economists. Although many countries have this type of dedicated office, so far no African country has followed suit, despite the importance of science, technology, and innovation as drivers of economic growth. The time has come for African leaders to create such offices and enshrine them in law (Juma and Lee, 2005).

Conclusion

Africa's Agenda 2063 provides a framework for embarking on long-term institutional reforms needed to reposition the continent as a strategic player in the global economy. The Science, Technology and Innovation Strategy for Africa, 2024 (STISA-2024) provides an initial 10-year framework for implementing the relevant aspects of Agenda 2063. But achieving this goal will require reforms to align education, research, and innovation with long-term socioeconomic objectives. The African Union's Specialized Technical Committee on Education, Science and Technology is well-positioned to foster the reforms needed to improve the integration of education, research, and innovation.

A starting point could be to create a new generation of innovation universities in diverse fields such as agriculture, health, industry, services, and environment. The universities would seek to bring research, teaching, community service, and commercialization under one roof. The efforts could benefit from lessons learned from similar efforts around the world. Creating innovation universities will require high-level coordination by offices of the presidents and prime ministers. To support the presidents and prime ministers, it is strongly recommended that Offices of Science and Innovation Advice be created in every country, taking into account the diverse constitional arrangements across Africa. Such offices should be created by law with clear mandates to focus on advisory functions and not operational activities.

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Science, Technology, and Globalization Project (STG)

The Science, Technology, and Globalization Project is a subset of the Science, Technology, and Public Policy Program (STPP).

The aim of the Science, Technology, and Globalization Project is to undertake research, conduct training, provide policy advice, and disseminate information on interactions between technological innovation and globalization, with particular emphasis on implications for developing countries.

Agricultural Innovation in Africa (AIA)

The Agricultural Innovation in Africa Project is funded by a generous grant from the Bill and Melinda Gates Foundation for the purpose of providing support to efforts that contribute to agricultural science and technology policy improvement. The project seeks to engage high-level policymakers on science, technology, and innovation policy in Africa, with a focus on the agricultural sector.

More information can be found on STG's website at www.belfercenter.org/global or from the Project Coordinator Katherine Gordon (katherine_gordon@hks.harvard.edu) at Harvard Kennedy School, 79 JFK Street, box 53, Cambridge, MA 02138 USA.

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