Chapter 5

Africa's Science, Technology and Innovation Policies—National, Regional and Continental

> *Today, no country can secure higher levels of scientific advances and technological progress without interacting with its peers and neighbours. The ability of countries and firms to innovate, both in technical and managerial ways, is largely determined by strategic alliances they forge both within their industrial landscape and across sectors. (New Economic Partnership for Africa's Development, Africa's Science, Technology Consolidated Plan of Action)*
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> *We aspire that by 2063, Africa shall be a prosperous continent, with the means and resources to drive its own development, and where... well educated and skilled citizens, underpinned by science, technology and innovation for a knowledge society [, are] the norm....* (African Union Commission, 2015)

The two excerpts above express the theme of this chapter and provide evidence that Africa's leaders recognize the critical role that science, technology and innovation (STI) could play in the foundation of a modern economy. The dynamic and organic relationship between scientific development and technological innovation and their application in producing, distributing and consuming goods and services forms one of the key drivers of the rapid, profound and pervasive changes humanity has experienced since the beginning of the industrial revolution.

This chapter provides an overview of the concept and rationale of science, technology and innovation policies, highlighting the following:

- Africa's science, technology and innovation policies in over a dozen countries and at regional and continental levels.
- The performance of science, technology and innovation policies at these levels.
- Key messages to enable African governments to use science, technology and innovation policies better.

Concept and rationale

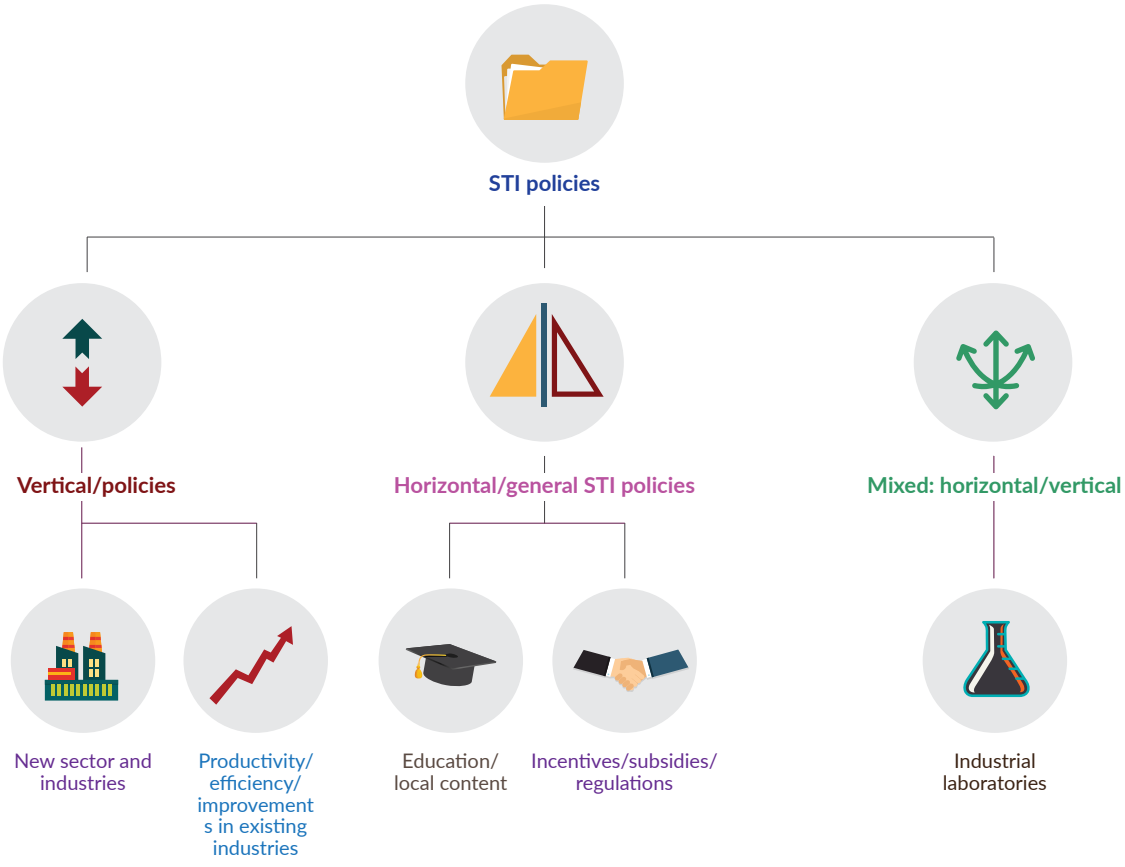
No unifying definitions exist for all three terms—S, T or I. For this chapter, science, technology and innovation policy is defined as" the set of actions that governments can take to deal with a range of problems in the intersecting and complementary domains of science, technology and innovation to achieve a clearly defined (national) objective when private incentives provided by free markets systematically perform poorly" (Weimer and Vining, 1989).

STI policies can be classified into vertical (sectoral), horizontal and mixed policies (figure 5.1). Sectoral policies reflect government-identified national development priorities. Sectoral policies may represent governments' attempts to choose (that is, pick) "winners" and "losers" and are frequently criticized because of their potentially distortionary effects. But they can also drive the concentration of national efforts to achieve global leadership positions in some sectors or areas of science and technology.[86] Sectoral policies can result in the creation of new sectors either through technology transfer or through endogenous science and technology efforts such as chemicals and pharmaceuticals (as in Ethiopia), a space sector (Nigeria) or green technology (South Africa). Sectoral policies may also focus on improving the efficiency and competitiveness of existing sectors like agriculture and manufacturing.

Horizontal science, technology and innovation policies are general, supporting across sectors, and therefore bridge sectoral divides and can attenuate the shortcomings of vertical policies. They follow a market approach in providing general principles and guidelines and are thus less vulnerable to the charge that they represent government efforts to pick winners and losers science, technology and innovation. However, while they are infrequently distortionary, they seldom provide impetus

Figure 5.1.

Science, technology, and innovation policies classified by coverage



Source: Based on Nwuke (2015).

for creating new sectors. Examples include education and human resource development policies, local content policies and market incentives (taxes and subsidies) that do not target specific sectors.

Mixed policies combine the attributes of horizontal and sectoral policies and are set out in national theme-specific policy documents on, for example, biotechnology, energy or information and communications technology (ICT). Countries may choose not to have an explicit science, technology and innovation policy but instead to nest or embed science, technology and innovation aspirations in national policy on education, training and human resource development. Countries may also outline their science, technology and innovation policies sectorally in national development plans, annual budgets, industrial policy, intellectual property legislation or trade policy.

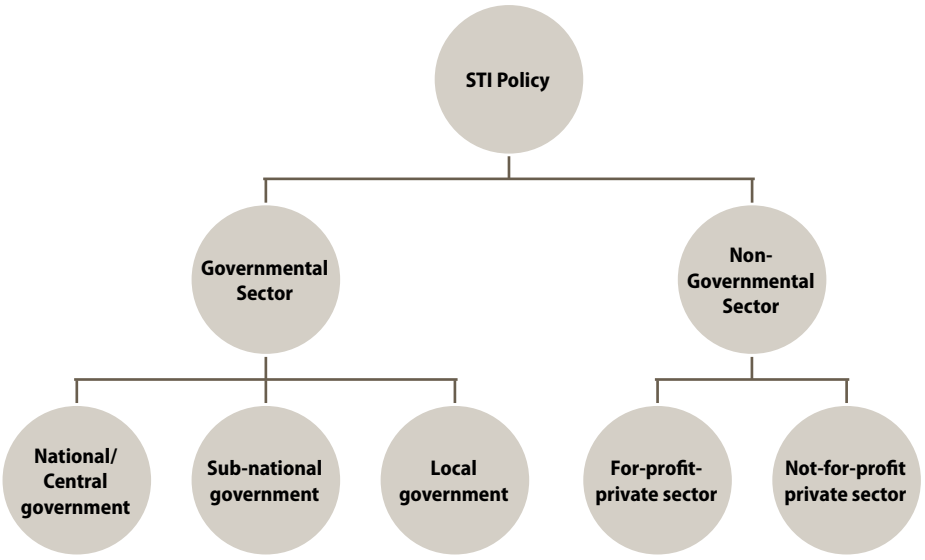
Another way of classifying national science, technology and innovation policy is by jurisdiction or inclusivity (figure 5.2), an approach common in advanced countries with large research-focused companies.

Many governments adopt vertical or horizontal policies for economic or political reasons.[87] The vertical policies are intended largely to prevent or rectify market failures that signify problems with market mechanisms. The horizontal policies may require action to guide socio-economic development while safeguarding national interests (including economic and political sovereignty). Political interventions may also be needed to induce a certain type of educational behaviour—for instance, seeking to influence the choice of university courses and specializations as part of efforts to encourage enrolment in science, technology, engineering and mathematics (STEM).

STI policy can help promote competitiveness, which relies on innovation and diffusion of technological innovations. As national economies become more integrated, policies are set at various levels from national to global, and science, technology and innovation

Figure 5.2.

STI policies classified by jurisdiction



Source: Based on Nwuke (2015).

policies form a key component of the policy mix. Evidence abounds of the transformative impact of policies promoting science, technology and innovation on all spheres of human endeavour, most recently in East Asia, where they led to rises in competitiveness and thus economic growth.

African experience of science, technology and innovation policies

National approaches

Early on, newly independent African countries formulated national education and science and technology policies. The government of Ghana, for example, created the Ghana Research Council in 1959, barely two years after independence;[88] Nigeria established the National Council for Scientific and Industrial Research in 1966 and Kenya established the National Council for Science and Technology in the late 1970s These institutions focused on supporting specific, strategic industries.[89] Practically all science and technology policies were sectoral, carried out by government sectoral ministries and departments.

During the 1960s and 1970s, African governments also established and expanded their higher education sectors by setting up universities and dedicated science and technology research institutes to tackle development challenges and, later, governance institutions to oversee national efforts. However, these efforts were generally poorly coordinated; institutions had inadequate funding and outcomes were often disappointing. Over time, as the shortcomings of this vertical governance structure became obvious, some governments turned to horizontal governance. Some created a super-ministry for science and technology,[90] while others attached science and technology to an existing ministry.[91]

Governments recognized these weaknesses in the sectoral framework as well as the failure of science and technology to contribute to development. In response African leaders met under the auspices of the Organization of African Unity in Monrovia, Liberia, in 1979. There they adopted the Monrovia Declaration, in which they committed "individually and collectively on behalf of our governments to put science and technology in the service of development by reinforcing autonomous capacity in the field." This commitment was reaffirmed in the Lagos Plan of Action adopted at the end of the Organization of African Unity Extraordinary Summit in Lagos, Nigeria, in 1980. The Lagos Programme of Action called on member States to "formulate national policies on science and technology plans to be incorporated in the overall national development, as science and technology are a fundamental input to the development of all other sectors …."[92]

The adoption of the Lagos Programme of Action marked a structural break in science and technology policy making in Africa, because African countries committed to musings policy as an instrument to advance economic growth and structural change. This section reviews the African experience since 1980, drawing heavily on the experience of 15 countries[93] selected mainly for quantity and quality of available data. The sample is nonetheless roughly representative.

Response to the LPA

African governments did not respond speedily to their Lagos Programme of Action commitments, with several signatory countries in the sample not adopting their first policies until two or more decades later (figure 5.3). Organization of African Unity The slow pace may be attributable to several factors: economic stress caused by structural adjustment programmes; cutbacks in higher education financing (also influenced by creditors and donors); migration of qualified scientists and technologists from universities to the domestic private sector or to foreign (mostly Western) countries; and the contraction of manufacturing. The turnaround started in only the early 1990s.[94]

Policy objectives and priorities

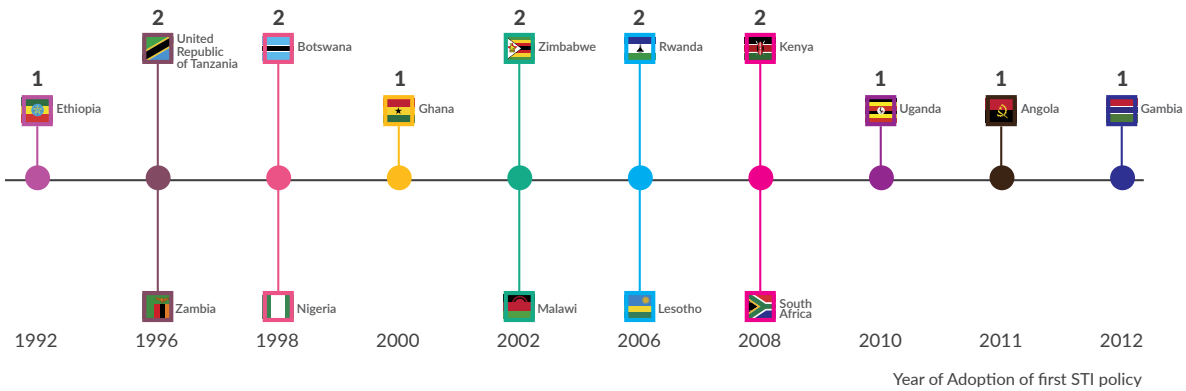
By 2002—the year the African Union ratified the successor development framework to the Lagos Programme of Action, the New Partnership for Africa's Development (new Economic Partnership for Africa's Development)—eight of the 15 countries had an explicit science, technology and innovation policy. Annex 5.1 summarizes elements of science, technology and innovation policy in the sample countries. Most countries seek to harness the transfer and adaptation of knowledge and technology. However, the sheer number of objectives complicates monitoring and evaluation (M&E) and makes it costlier.

The following features emerge from an analysis of these policies:

- Excluding South Africa, the countries show striking similarities in structure.
- Common priorities include education and human resources development, agriculture, energy, health, environment, industry, intellectual property protection, and transport and communications.
- Each national science, technology and innovation policy defines a set of key national priorities ranging from six for South Africa to 18 for Nigeria. South Africa has horizontal, the rest sectoral, policies.
- Some priorities mirror the national context (though many do not, and seem to reflect a standardized approach that does not vary across countries) and build on areas where countries either have a capacity to be at the frontier of knowledge or believe that science, technology and innovation can help them address pressing development challenges and accelerate catch-up.[95] The policies show a cross-cutting weakness, that is, the inability to estimate cost of implementing them. This weakness may explain the poor outcomes. Institutional reform, includ-

Figure 5.3.

STI policy adoption in 15 African countries since the Lagos Programme of Action



Note: Zimbabwe and South Africa joined the Organization of African Unity in 1980 and 1994, respectively.

Source: Based on Nwuke (2015).

ing legislation and creation of new governance or administration institutions, is an implementation mechanism common to science, technology and innovation policies.

Institutional arrangements

The institutional arrangements for science, technology and innovation policy implementation show wide divergence (table 5.1 and figure 5.4). [While most science, technology and innovation policy is implemented through a ministry responsible for science, technology, education and research, some countries have created other special bodies. Table 5.1 and figure 5.4 illustrate the wide variety of institutional arrangements that different African countries have adopted for their science, technology and innovation policies.

Understanding the importance to industry and society of industrial research institutes as specialized knowledge developers and as a bridge between basic research and industrial production, African countries have founded several industrial research institutes (box 5.1).

STI finance

Most African science, technology and innovation policies provide for financing. Financing arrangements often include commitments to increase investment in R&D to at least 1 per cent of GDP, reflecting Lagos Programme of Action aspirations and those of other Organization of African Unity/African Union frameworks, sometimes combined with provisions for creating a science and technology development fund. Some have provisions for public–private partnerships (PPPs) and for the private sector (table 5.2).

Table 5.1.

Institutional arrangements and legal and regulatory frameworks of national science, technology and innovation policies in 15 African countries

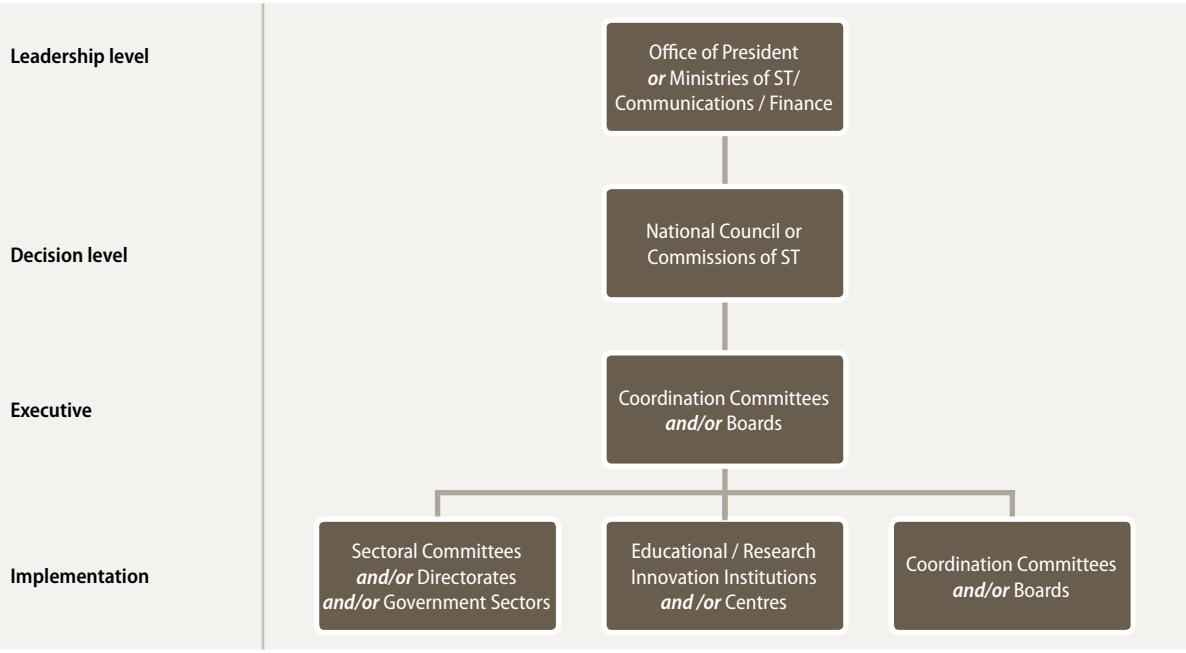
Country	Institutional arrangements	Legal and regulatory frameworks
Angola	• Ministry of Higher Education and Science and Technology, established in 2010.	• Presidential Decree of the National Strategy for Science, Technology and Innovation
Botswana	• Ministry of Communications Science and Technology	• Administrative issuance • The Department of Research, Science and Technology under the Ministry of Infrastructure, Science and Technology to propose policy and legislation
Ethiopia	• National Science, Technology and Innovation Council • The Ministry of Science, Technology and Innovation	• Policy is enforced through parliamentary proclamations, regulations and directives
The Gambia	• Ministry of Higher Education, Research, Science and Technology	• N/A
Ghana	• The Ministry of Environment, Science and Technology	• N/A
Kenya	• Ministry of Science and Technology • National Council for Science and Technology	• Government acts and provisions
Lesotho	• Ministry of Communication, Science and Technology	• Science and Technology Act • • Science and Technologies Institution Bill, 2007
Nigeria	• National Innovation Research Council • The Federal Ministry of Science and Technology • State Innovation and Research Council	• Science and Technology Act (No. 16 of 2003)
Rwanda	• Ministry in the President's Office in Charge of Science, Technology and Scientific Research;	• National Science and Technology Act
South Africa	• The Department of Science and Technology; • Technology Innovation Agency	• N/A
Tanzania	• Ministry of Science, Technology and Higher Education	• Legislation
Uganda	• Ministry of Finance, Planning and Economic Development	• Uganda National Council for Science and Technology Act (1990)
Zambia	• Ministry of Science, Technology and Vocational Training	• Parliamentary acts
Zimbabwe	• Ministry of Science and Technology Development	• Statutory instruments under the Science and Technology Act

Note: N/A = not available

Source: Compilation based on Nwuke (2015).

Figure 5.4.

Science, technology and innovation administration system in most countries



Source: Nwuke (2015).

Box 5.1.

Industrial research institutes

Three cases provide some insight into the workings, accomplishments and challenges of African industrial research institutes.

National Institute for Scientific and Industrial Research, Zambia

Established in 1967, the National Institute for Scientific and Industrial Research provides technological services to industries, rural communities and government agencies, encourages promotion and transfer of technology to small and medium-sized enterprises, trains researchers and technologists and provides advisory and consulting services to government and industry.

The National Institute for Scientific and Industrial Research developed and transferred the non-alcoholic Maheu drink technology to the (at the time) small firm Trade Kings Limited, which since has grown and now exports the drink to seven countries. Research conducted by the National Institute for Scientific and Industrial Research with Zambia Sugar has helped Zambia become the only country in Africa (outside of North Africa) to fortify sugar. The National Institute for Scientific and Industrial Research collaborated with New Economic Partnership for Africa's Development and the Council for Scientific and Industrial Research to develop the first effective herbal medicine for managing HIV/AIDS. Lack of funding and declining numbers of researchers are the main obstacles.

Source: ECA, 2013.

Institute of Industrial Research, Ghana

Founded in 1998, the Institute of Industrial Research is the country's main R&D institution. Its goals include reducing poverty through cost-effective environmentally and commercially viable industrial technologies. Its strengths include product and process design and development, adaptive technology promotion and scientific instrumentation and calibration.

Some of its accomplishments include provision of processing technologies to the local salt industry, transfer of ceramic and glaze technologies to the local pottery industry and design and production of small machinery for the local agro-processing industry. Challenges

Continued

Box 5.1.

Industrial research institutes (continued)

include lack of funds for research activities, underequipped laboratories and decreases in number of researchers and, consequently, research output.

Source: ECA, 2013.

Council for Scientific and Industrial Research, South Africa

Established in 1945, the Council for Scientific and Industrial Research's goal is to improve the quality of life of the people of South Africa through scientific or industrial development, either on its own or with principals from the private or public sectors. It uses photonics, robotics and ICT at its modelling and research facilities for its work in energy, health, industry, defence and security, and the built or natural environment.

The Council for Scientific and Industrial Research has partnerships with big multinational companies such as Eskom (on laser leak-sealing technology), Boeing (for titanium powder manufacturing) and ArcelorMittal South Africa (laser processing for continuous caster foot rolls of steel). Its accomplishments include the Tellurometer (the world's first microwave distance-measuring instrument, used by telecommunication companies and surveyors) and the heavy-vehicle pavement simulator (to predict the condition of a paved road after 20 years' use). It has patented and licensed its lithium-ion rechargeable battery material to multinational companies.

Via the Council for Scientific and Industrial Research-Meraka Institute, it has helped launch start-ups such as the Dr. Math mobile tutoring service, through which users can access tutors on their mobile phones. It has transferred technology underlying CoroCAM, which inspects eye corona discharge, to UViRCO technologies.

Source: Council for Scientific and Industrial Research (South Africa), 2015; 2013a; 2013b; 2010; defenceWeb, 2013; Ittmann, 2010; Ministry of Science and Technology of India, 2015; National Geo-Spatial Information (South Africa), 2013.

Regional collaboration among countries

Many of the 15 countries have regional science, technology and innovation policies. Ethiopia, for instance, seeks to "encourage cooperation with developed and developing countries as well as with various international and regional organizations."[97] Others do not mention New Economic Partnership for Africa's Development or regional economic community (REC) policies.[98]

Some countries, like Ghana, explicitly link efforts to subregional commitments as defined by the ECOWAS Revised Treaty, which urges member States to ensure proper application of science and technology for the development of priority sectors, and some link to the African Union/New Economic Partnership for Africa's Development Consolidated Plan of Action for Science, Technology and Innovation. Box 5.2 provides an example of regional cooperation.

The country experience summarized

The science, technology and innovation policies can be classified generally as either "leap-frog" or "catch-up/late-comer." Some are a mix.[99] Countries with a leap-frog policy will undertake more R&D, publish more, collaborate more, allocate more resources to science and technology research and obtain more patents than countries seeking to catch up through transfer of foreign technologies (as seen in the discussion below on patents). science, technology and innovation progress in countries with catch-up/late-comer policies should be assessed with a different set of metrics. Categorizing national policies in this way thus has implications for R&D funding and for the relevance of commonly used metrics, such as patent count. For example, the LPA's target funding level of 1 per cent of GDP along with subsequent decisions by the Organization of African Unity and the African Union Commission, is too close to one-size-fits-all, as catch-up may not require a 1 per cent funding level. Each country must cost its science, technology and innovation policy individually.

The policies also contain a mix of types of measures. Some are "nudges"[100] to change the behaviour of actors, others are explicit regulations and still others are based on market incentives. The diversity mirrors differences in ideological orientation, particularly views on the roles of the state and markets. Countries that subscribe

Table 5.2.

STI financing arrangements and goals for 13 African countries[96]

Country	Financing arrangement or goal
Botswana	Attain Gross Expenditure on Research and Development (dedicated to science and technology research and innovation by 2016) of at least 2 per cent by 2016 from the government budget and private contributions.
Ethiopia	STI activities in all sectors are to receive 1.5 per cent of GDP from a 1 per cent profit contribution from all service and productive sectors for an innovation fund for R&D activities and from the government budget.
Ghana	Achieve Gross Expenditure on Research and Development of 1 per cent of GDP from the government budget and via public-private partnerships.
Kenya	Reach Gross Expenditure on Research and Development of 2 per cent of GDP from the government budget channelled through the National Research Fund.
Lesotho	Attain Gross Expenditure on Research and Development of 1 per cent of GNP from the government budget channelled through the Lesotho Innovation Trust Fund and through private and donor contributions.
Malawi	Achieve funding from the Science and Technology Fund, appropriated by Parliament.
Nigeria	Attain Gross Expenditure on Research and Development of 1 per cent of Gross National Product from the national budget, channelled through the National Research and Innovation Fund and public-private partnerships.
Rwanda	Secure funding from the Rwanda Innovation Endowment Fund; 5 per cent of the government budget to go to the National Research Fund; and funding via public-private partnerships.
South Africa	Receives funds from the National Research Foundation and the Technology Innovation Agency.
Uganda	Reach Gross Expenditure on Research and Development of 1 per cent of GDP funded by private actors, public-private partnerships, and the government budget.
Tanzania	Achieve Gross Expenditure on Research and Development of at least 1 per cent of GDP through the government budget.
Zambia	Government to allocate 3 per cent of GDP to science and technology activities.
Zimbabwe	Attain Gross Expenditure on Research and Development of at least 1 per cent of GDP through the government budget channelled through the Innovation and Commercial Fund.

Note: Angola and Gambia were omitted due to lack of information.

Source: Authors.

Box 5.2.

Pan African Rinderpest Campaign

In 1986 the African Union Inter-African Bureau for Animal Resources launched the Pan African Rinderpest Campaign. This regional body coordinated national projects in 35 African countries, helping build national capacities of veterinary services for disease diagnosis and developing regional coordination, vaccine control and vaccine-production centres in several countries. It also mobilized stakeholders at all levels and improved cross-border flows of information, personnel and materials. It boosted the quality and supply of vaccines by upgrading science and technology and institutional capacities and provided training to community workers.

The Campaign had $200 million in support from the European Union. It ultimately eradicated rinderpest in Africa through a sustained vaccination campaign, and in 2011 the disease was declared eradicated worldwide.

Source: Tambi (1999), Roeder (2011), Food and Agricultural Organization of the United Nations and World Organization for Animal Health (2011).

to the developmental state concept, such as Ethiopia, Rwanda and South Africa, have policies favouring a leading role for the state.

Regional policies

African regional economic communities recognize the central role of science, technology and innovation in integrating their regions. They also recognize that a wider economic space—free of entry barriers—can spur innovation and creativity.

In regional markets, innovative firms can exploit economies of scale and of scope and so increase their competitiveness. And as knowledge is a public good at all levels, it can be harnessed to tackle many regional challenges (infectious and contagious diseases, poverty, environmental degradation and so on). Against this background, the science, technology and innovation policies of five of the eight African Union–recognized regional economic communities are surveyed.

COMESA

Article 3 of the Treaty Establishing COMESA commits member States "to co-operate in the creation of an enabling environment for foreign, cross border and domestic investment including the joint promotion of research and adaptation of science and technology for development" (p. 9). Member States also commit to sharing knowledge on research developments and science and technology in various areas of cooperation such as meteorological services (Article 94, p. 49): "The Member States shall exchange information and expertise concerning new developments in meteorological science and technology including the calibration and comparison of instruments." Chapter 17 (p. 65) of the Treaty spells out the role of science in socio-economic and cultural development and technological progress. The chapter provides member States scope for cooperation (Article 127, p. 65) and guidelines for the promotion of science and technology (Article 128, pp. 65–66).

EAC

The Treaty Establishing EAC exhorts member States in Article 80 to "promote industrial research and the transfer of technology, acquisition, adaptation and development of modern technology" and "disseminate and exchange industrial and technological information."

Article 102 concerns the development of human resources and of science and technology. In Article 103 EAC member States undertake to promote cooperation in science and technology. EAC member States signed in 2013 the Protocol establishing the East African Science and Research Council[101] as an anchor institution to serve as the region's "leader in the promotion and coordination of the development and application of science and technology for sustainable socio-economic development in Partner States." The Council has 19 objectives, including formulating a regional science and technology policy; carrying out regular reviews of that policy; guiding, monitoring and evaluating implementation; establishing and supporting joint science and technology research institutions; creating a conducive environment for promoting science and technology and promoting the use and development of indigenous knowledge and technologies. Financed by contributions from member States, it is also tasked with determining priorities for regional research.

ECOWAS

Under Article 3 of the ECOWAS Treaty, "harmonization and coordination of national policies and the promotion of integration programmes, projects and activities… particularly in science and technology" is one of the aims of the Community. Article 22 established technical commissions including one for industry, science and technology and energy "to prepare community projects and programmes and ensure the harmonization of Community projects and programmes."

Article 27 lists member States' science and technology commitments. For example, they pledge to strengthen national science and technology capabilities to bring about socio-economic transformation; ensure the proper application of science and technology to the development of priority sectors; and to reduce their dependence on foreign technology and promote their individual and collective technological self-reliance. They also commit to cooperate in the development, acquisition and dissemination of appropriate technologies, to strengthen existing scientific research institutions, and to take all necessary measures to prepare and implement joint scientific research and technological development programmes.

The Treaty further states that member States shall harmonize, at regional economic community level, their national policies on science and technology research with a view to facilitating their integration into national economic and social development plans. They are to coordinate their applied research and development research programmes and science and technology services and harmonize their national technological development plans by emphasizing indigenous and adapted technologies and regulations on industrial property and transfer of technology. However, unlike SADC and EAC, ECOWAS does not have a separate body charged with harmonizing science, technology and innovation policies or determining its priorities.

In 2012, the Second Conference of ECOWAS Ministers for Science and Technology adopted an ECOWAS regional policy on science and technology and its action plan.[102] The policy gave directives to create a directorate for science, technology and innovation; to implement, monitor and evaluate the policy; to create a one-stop science and technology window from its Solidarity Fund; to finance R&D and facilitate funding support from partners; to

strengthen financial capacities of science and technology research institutions and to promote regional and international cooperation in science, technology and innovation, mainstreaming it in national and Community sectoral policies.

IGAD

Article 7 of the Agreement Establishing IGAD[103] identifies steps to "[f]acilitate, promote and strengthen cooperation in research, development and application in the fields of science and technology" as one of the key aims of the Authority. Article 13A implores member States to "cooperate in the gradual harmonization of their national policies in science and technology research and development, transfer of technology, and their policies on capacity building in science and technology in the subregion."

SADC

The SADC Treaty[104] is thin on science and technology. Article 5.2(f) states that member States "shall promote the development, transfer and mastery of technology" and "improve economic management and performance through regional integration." Article 21 identifies science and technology as an area of cooperation. Subsequently, member States adopted the SADC Declaration on science, technology and innovation in 2006, given legal effect in 2008 by ratification of the SADC Protocol on Science, Technology and Innovation. The Protocol's objective is "to foster cooperation and promote the transfer and mastery of science, technology and innovation in Member States" to "promote the development and harmonization of science, technology and innovation policies in the region; resources for scientific, technological development and innovation within the region; and optimize public and private investment in research and development... and leverage external contributions." Member States committed themselves "to act in common pursuit of the objectives" of the Protocol, which also created institutional mechanisms for managing and administering science, technology and innovation at regional level.

Pan-African policy initiatives

The African Union and its predecessor, the Organization of African Unity, have been influential in developing science, technology and innovation policies, beginning with the Lagos Programme of Action in 1980. The importance of a comprehensive science, technology and innovation policy was reiterated in the Cairo Declaration and Cairo Plan of Action, adopted at the 2000 Africa-Europe Summit, which "encouraged the formulation of comprehensive programmes in the development and transfer of technology with special emphasis on science and technology, indigenous technologies, the development of educational and training systems, and information technology."

The African Union placed yet greater emphasis on science and technology. Article 13 of its Constitutive Act empowers its executive council to "coordinate and take decisions on policies of common interest to the member States including in science and technology" and to "establish a system of African awards, medals and prizes."[105] In article 14, the Act set up specialized committees, including one on industry, science and technology, energy and natural resources. These committees are charged with preparing, coordinating and harmonizing African Union initiatives.

In 2002, the African Union ratified the New Economic Partnership for Africa's Development, adopted by the African Heads of State and Government of the Organization of African Unity the previous year. The New Economic Partnership for Africa's Development identified science, technology and innovation as the key means of implementation of its agenda. In 2005, the African Union Commission adopted the Consolidated Plan of Action for Science, Technology and Innovation to concretize the continent's approach to science, technology and innovation. The Consolidated Plan of Action for Science, Technology and Innovation had a vision of "Africa that is free of poverty and well integrated into the global knowledge economy." Its principal goals were "to enable Africa to harness and apply science, technology and related innovations to eradicate poverty and achieve sustainable development; and to ensure that Africa contributes to the global pool of scientific knowledge and technological innovations." The Consolidated Plan of Action for Science, Technology and Innovation also identified four science, technology and innovation priority areas: biodiversity, biotechnology and indigenous knowledge; energy, water and desertification; material sciences, manufacturing, laser and post-harvest technologies; and ICT, space science and technologies. In the African Union Declaration on science and technology[106] in 2007, African leaders committed to "[i]

ncrease funding for national, regional and continental programmes for science and technology and support the establishment of national and regional centres of excellence in science and technology."

In 2014 the Consolidated Plan of Action for Science, Technology and Innovation was replaced by the Science, Technology and Innovation Strategy for Africa 2024. This strategy identifies six science, technology and innovation priorities: eradicating hunger and achieving food security; preventing and controlling disease; building communication and transport infrastructure (for physical and intellectual mobility); protecting the integrity of African resources and "space"; "live together—build the society"; and wealth creation. Carrying out these priorities rests on four pillars: building or upgrading research infrastructure, enhancing professional and technical competencies, promoting entrepreneurship and innovation and providing an enabling environment for science, technology and innovation development.

Under the Science, Technology and Innovation Strategy for Africa-2024, "continental, regional and national programmes will be designed, implemented and synchronized to ensure that their strategic orientations and pillars are mutually reinforcing, and achieve the envisaged developmental impact."[107] The strategy proposes a monitoring and evaluation framework,[108] funding mechanisms and a pan-African African Science and Technology Innovation Fund. It aims to fulfil the continental initiatives set out in two policy framework documents, the Common African Position on the Post-2015 Development Agenda and Agenda 2063, both of which identify science, technology and innovation as undergirding the achievement of African aspirations.

To report on progress on the science, technology and innovation priorities of the African Union and its member States, New Economic Partnership for Africa's Development's Office for Science and Technology conducts regular indicator surveys and reports the results every few years in the publication African Innovation Outlook.

At the June 2015 African Union Summit, African leaders reiterated their commitment to harnessing science, technology and innovation for Africa's development. Leaders decided to establish a committee of 10 Heads of State and Government (two from each region) whose members will serve as the continent's champions of education and science and technology. The committee will report to the African Union Summit once a year.[109]

The above makes clear that, at pan-African level, leaders take science, technology and innovation policies extremely seriously. But there is scope for more practical collaboration at regional and continental levels to address the under-provisioning of regional public goods such as public health, to perform collaborative research on regional challenges and to improve the competitiveness of firms and other economic operators.

STI policy performance—not so impressive

The science, technology and innovation policies reviewed above[110] have not improved Africa's science, technology and innovation performance. African countries still perform poorly on three main indicators: tertiary education institutions, intellectual property and innovativeness and productivity and competitiveness.

Tertiary education institutions

African universities have very low rankings globally. The latest findings (2015–2016) of the Quacquarelli Symonds ranking, introduced in 2004, ranks universities from only five African countries (table 5.3). Quacquarelli Symonds assesses thousands of universities, but among African universities only the universities of Cape Town, Stellenbosch and Witwatersrand rank in the top 400 universities worldwide.

IP and innovativeness

African countries perform poorly on intellectual property generation, too, suggesting that policies have not yet stimulated intellectual property and innovations based either on research and development or routine learning and practice. No African country ranks in the top 20 countries for patent applications, according to the World Intellectual Property Organization (WIPO). The 12 countries that lead Africa in patents show a wide range in numbers of patents granted by the United States Patent and Trademark Office—as few as two between

Table 5.3.

Quacquarelli Symonds ranking of African universities in 2015–2016

Institution	Global QS rank	Score (out of 100 per cent)
University of Cape Town (South Africa)	171	57.8
University of Stellenbosch (South Africa)	302	42.3
University of Witwatersrand (South Africa)	331	39.7
University of Pretoria (South Africa)	501–550	Not indicated
University of Johannesburg (South Africa)	601–650	Not indicated
Makerere University (Uganda)	701+	Not indicated
University of Dar es Salaam (Tanzania)		
University of Ghana Legon (Ghana)		
University of Nairobi (Kenya)		
University of the Western Cape (South Africa)		

Note: The criteria are: academic reputation (40 per cent), employer reputation (10 per cent), student-to-faculty-ratio (20 per cent), citations per faculty ratio (20 per cent), international faculty ratio (5 per cent), and international student ratio (5 per cent). The top 400 universities are ranked individually, while the rest are ranked in groups from 401–410 to 701+.

Source: QS World Ranking of Universities 2015–2016. Available at: http://www.topuniversities.com/university-rankings-articles/world-university-rankings/qs-world-university-rankings-methodology.

2001 and 2014—and their performance is dominated by South Africa (figure 5.5). And on intellectual property generation and ownership, Africa is the worst performer of all the global regions (figure 5.6).

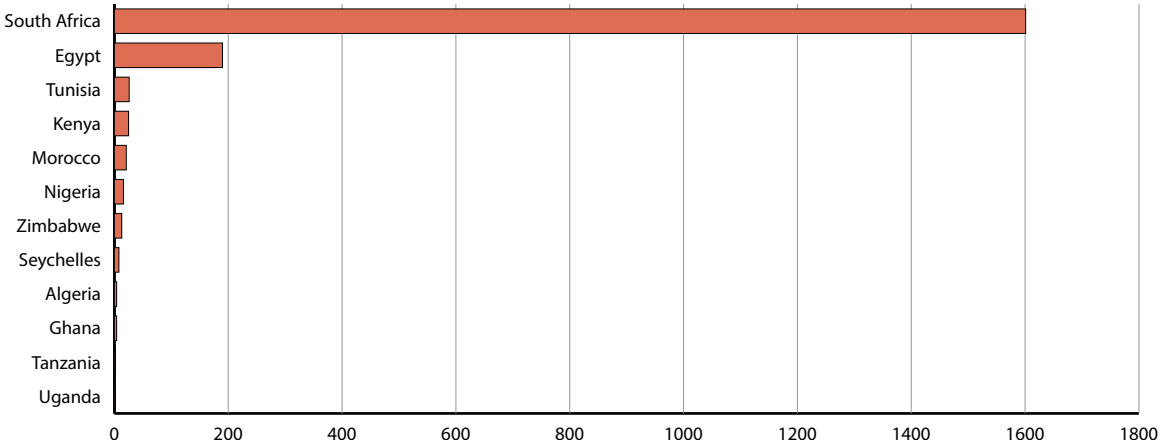
Productivity and competitiveness

Growth in most of African countries from 1995 to 2010 derived from factor accumulation and not gains in input combinations that can be measured by total factor productivity (table 5.4). Nigeria reported positive total factor productivity growth for the 15 years except for 2001 to 2004. In 2010 total factor productivity growth in Nigeria stood at an enviable 8.79 per cent, the highest among the countries in the table. But with excess labour and high youth unemployment, Nigeria should focus on growth driven by factor accumulation rather than efficiency. In contrast, South Africa, the continent's most scientifically and technologically advanced country has been mired in low total factor productivity growth, reporting just 0.04 per cent growth in 2010.[111] This could suggest that the country is caught in the middle-income trap.[112] Ethiopia had a negative total factor productivity growth rate from 2005, evidence that much of its recent economic growth has been driven by factor accumulation rather than productivity growth.

Most African countries are still on the lowest ranks of competitiveness, regardless of the indicator used (see chapter 3 and the CIP index). The ratio of Africa's high

Figure 5.5.

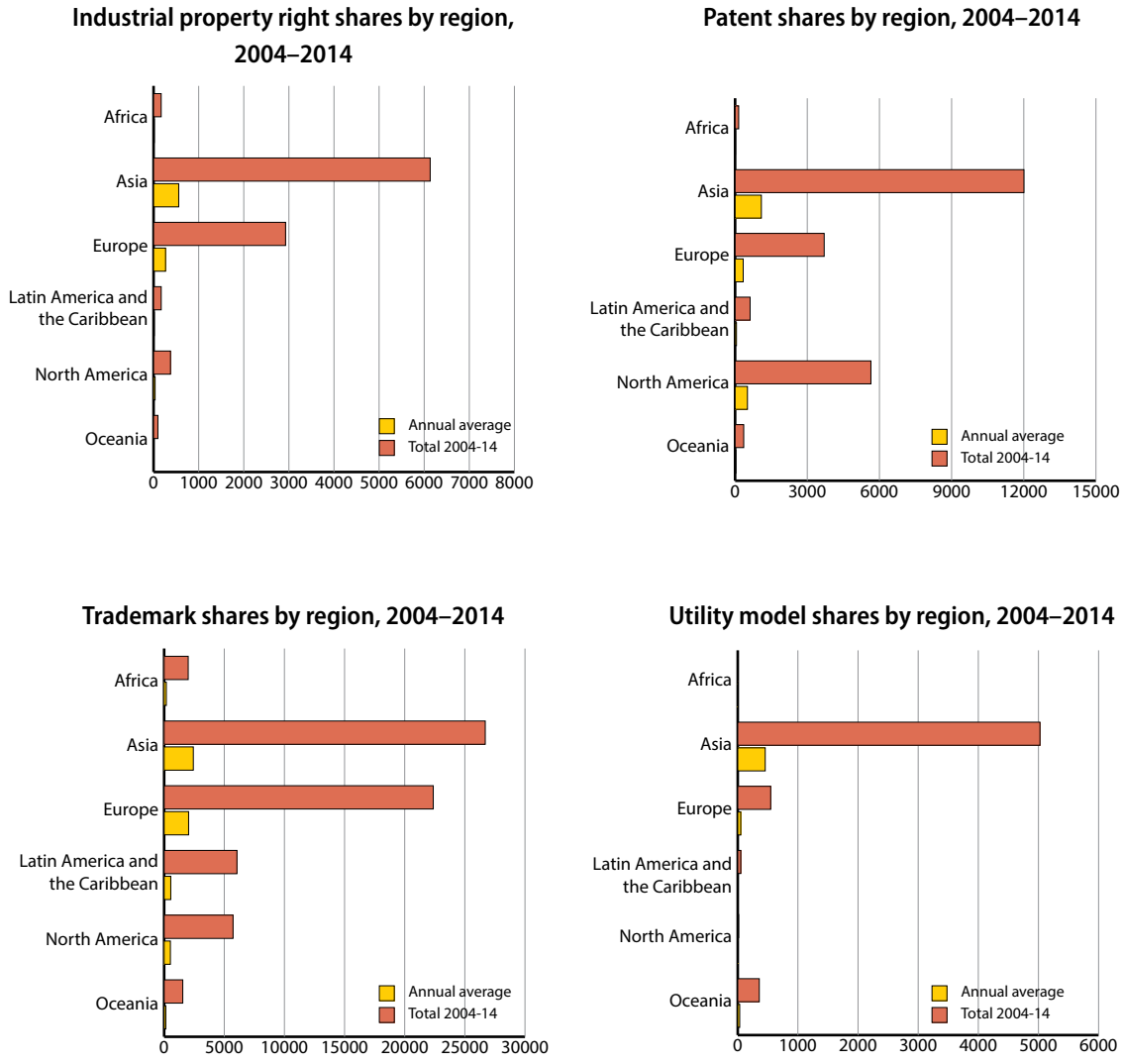
Top 12 African countries by number of United States Patent and Trademark Office patents, 2001–2014



Source: United States Patent and Trademark Office/ www.uspto.gov/.

Figure 5.6.

Africa in global intellectual property performance



Source: Computed by author, based on statistics, available at: http://ipstats.wipo.int/ipstatv2/keysearch.htm?keyId=203, accessed on 8 February 2016.

technology exports relative to GDP, though rising, is also low. Overall, Africa's suboptimal performance can to a very large extent be attributed to its lack of effective capacity, which hinders countries from setting out on a sustainable economic growth and development trajectory driven by structural change.

Table 5.4.

Change in total factor productivity, 1995–2010 (per cent)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Angola	1.1	1.09	0.99	1.08	1.07	0.94	-14	-19.2	-19	-13	-4.1	3.4	7.96	9.3	8.44	6.66
Botswana	1.01	1.04	1.05	1.08	1.07	1.04	1.86	-0.03	-1.5	-2.5	-2.9	-2.8	-2.45	-1.83	-1.12	-0.4
Ethiopia	1.01	1.02	1	0.95	1.05	1.08	8.57	7.18	4.16	0.53	-2.7	-4.7	-5.16	-4.25	-2.38	-0.2
Gambia	0.95	0.97	1.05	0.96	1.1	1.06	2.89	-0.49	-3.5	-5.2	-5.2	-3.6	-1.1	1.58	3.58	4.35
Ghana	1.04	1.01	0.94	1.02	1	1.09	11.8	12.19	10.2	6.51	2.25	-1.7	-4.58	-6.06	-6.09	-4.9
Kenya	1.02	1.01	1.01	1	0.98	1	0.31	0.9	2	0.89	0.4	-0.2	-0.57	-0.74	-0.63	-0.3
Lesotho	0.9	0.92	1.03	0.98	0.98	1.01	2.44	3.18	3.5	3.48	3.21	2.78	2.26	1.71	1.18	0.7
Malawi	1.27	1.08	1.04	0.99	1.05	1	-2.9	-3.7	-3.6	-3	-2	-1	0.01	0.68	1.05	1.13
Nigeria	1.05	1	1.12	0.97	0.85	0.78	-26	-23.6	-16	-6.1	4.57	13.3	18.3	18.94	15.38	8.79
Rwanda	1.31	1.13	0.97	1.06	1.06	1.02	-0.1	-1.97	-3.2	-3.5	-3	-1.9	-0.51	0.76	1.67	2.08
South Africa	1	1	1.01	0.99	1.01	1.01	1.04	0.74	0.3	-0.1	-0.5	-0.7	-0.66	-0.5	-0.24	0.04
Uganda	1.02	1.02	1.01	0.99	1	0.97	-4	-4.24	-3.9	-3	-2	-0.9	0.05	0.8	1.26	1.46
Tanzania	1.02	1.03	0.92	1.11	1.04	2.2	0.99	-0.37	-1.6	-2.4	-2.7	-2.5	-1.76	-0.76	0.32	1.03
Zambia	0.96	1.04	1.05	1	1.01	1.02	1.09	0.412	-0.2	-2.4	-0.9	-0.8	-0.55	-0.23	0.09	0.31
Zimbabwe	0.99	1.09	0.98	1.02	0.98	0.96	-4.7	-4.52	-3.8	-2.4	-2	-1.2	-0.52	-0.07	0.2	0.34

Note: Values for 2001–2010 are forecasts of total factor productivity growth.

Source: Based on United Nations Industrial Development Organization, 2015; https://www.unido.org/data1/wpd/Index.cfm.

Science, technology and innovation key policy messages

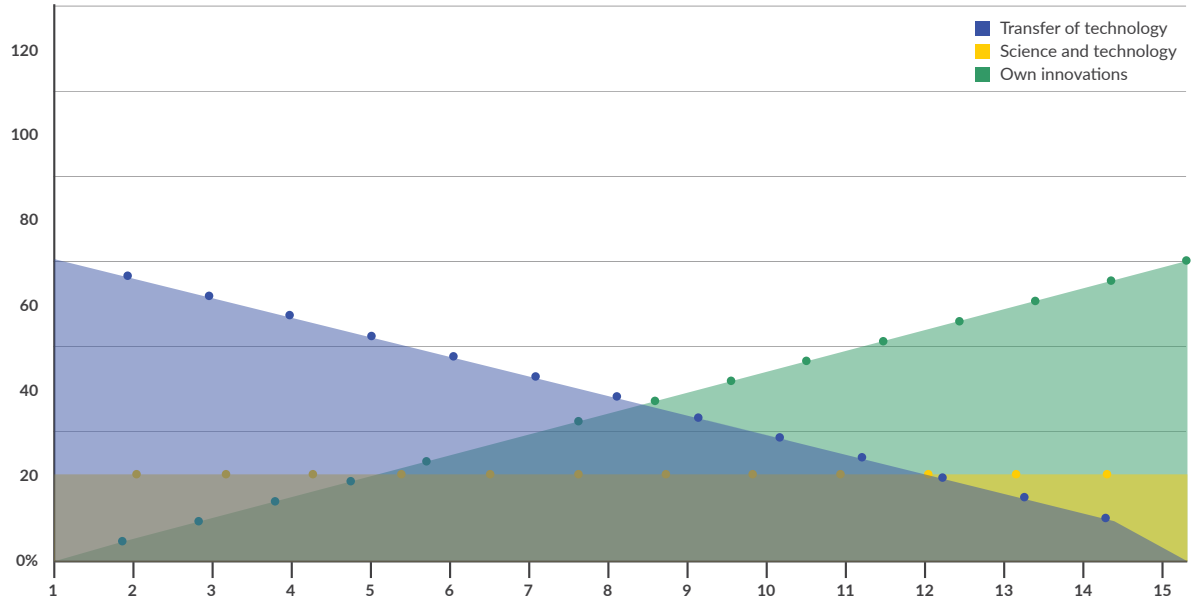
African governments can use science, technology and innovation policies more effectively by heeding these recommendations:

- Governments should raise spending on high-quality tertiary education.
- African science, technology and innovation policies should be pragmatic and pursue a phased approach to innovation, as decades of science, technology and innovation policy rhetoric has not translated into increased STI capacity.
- STI policies should take into account the intervention environment, which usually varies by country. Countries' policies look quite similar, suggesting little linkage to country particularities.
- Governments should strengthen funding for research and development. African countries are far from achieving a critical mass of research and development finance and human capital, largely owing to fiscal constraints. Resource paucity also often affects African businesses, exacerbating matters.
- Countries should boost domestic funding for developing capacity rather than rely on support from development partners as is common across Africa. Such support may help, but there is no evidence that any country has develop edits capacity through development assistance.
- A mixed approach to policy, blending horizontal policies and vertical policies, as well as governmental (regulatory) and non-governmental (incentive) policies, would be prudent. Most urgently, governments should design and adopt an M&E framework for development processes.

The departure point is to recognize the need for reform of higher education to generate a pool of graduates in STEM disciplines. These skills and capabilities are critical because they develop capacity and readiness for technological diffusion (crucial in the earlier phases of development) and technological innovations (more prevalent in the long run). Figure 5.7 illustrates the complementarities between such diffusion and innovation. But a country's own technological innovations, which depend on capabilities in STEM disciplines for sustainable competitiveness, are also important.

Figure 5.7.

Indicative distribution of science, technology and innovation efforts to develop competitive domestic innovative capacities



Annex 5.1. Objectives, priorities and M&E frameworks of African national science, technology and innovation policies

Country	Objectives	Priorities	M&E mechanisms
Angola	The advancement of technological innovation in parallel with the transfer of technologies in the productive sector for the sustainable development of the economy of Angola	1. Education, culture and professional training 2. Higher education 3. Agriculture and fishery 4. Telecommunications and information technologies 5. Industry, oil, gas and mineral resources 6. Health 7. Water resources 8. Energy 9. Environment	Annual assessment to determine the progress and difficulties encountered in implementing this policy.
Botswana	The adopting, development, generation and transfer of suitable technologies for poverty reduction	1. Agriculture 2. Education and HR development 3. Health 4. Meteorology 5. Mining 6. Wildlife 7. Population planning and human settlement 8. Transport and communications 9. Tourism 10. Water	M&E strategies outlined in the policy document.
Ethiopia	The transfer of suitable technologies for sustainable economic development and betterment of the livelihood of Ethiopian people	1. Technology transfer 2. Human resources development 3. Manufacturing and service-providing enterprises 4. Research 5. Financing and incentive schemes 6. National quality infrastructure 7. Universities, research institutes, TVET institutions and industry linkages 8. IP system 9. Science and technology information system 10. Environmental protection and development 11. International cooperation	No explicit M&E mechanisms are specified
Gambia	STI knowledge transfer, adopting and diffusion to find solutions to the social, economic and cultural challenges facing the country	1. Education and training 2. Medical and public health 3. Economy 4. Trade and industry, innovation and entrepreneurship 5. Energy 6. Agriculture, environment & natural resources 7. Transport 8. National security 9. Sports and recreation 10. Tourism and hospitality 11. Youth and innovation	No explicit M&E mechanisms specified

Country	Objectives	Priorities	M&E mechanisms
Ghana	Promotion of science and technology culture, that fosters the transfer of technologies for the development of the economy	1. Agriculture 2. Health 3. Education 4. Environment 5. Energy 6. Trade 7. Industry 8. Natural resources 9. Human settlements and communications 10. Tourism 11. Youth innovation 12. Basic research 13. Sports and recreation 14. Nuclear science and technology 15. Building and construction 16. Information and communications technology 17. Science acceleration 18. Natural resources	Explicit M&E mechanisms not yet specified, but planned
Kenya	Identify and develop new knowledge-intensive industries	1. Agriculture 2. Human resource development 3. Industry and entrepreneurship 4. Physical infrastructure 5. Energy 6. Environment and natural resources 7. Education and training 8. Information and communications technology 9. Health and life sciences	Explicit M&E mechanisms not yet specified, but planned
Lesotho	The transfer of technologies for the betterment of the lives of the people of Lesotho	1. Education 2. Biotechnology 3. Agriculture 4. Tourism and culture 5. Health and social welfare 6. Energy 7. Environment 8, Wildlife and tourism 9. Meteorology 10. Industry and trade 11. Natural resources 12. Mining 13. Gender equity in science and technology 14. Standardization and quality assurance 15. Private sector and parastatals	Explicit M&E mechanisms not yet specified, but planned

Country	Objectives	Priorities	M&E mechanisms
Nigeria		1. Agriculture 2. Water resources 3. Biotechnology research 4. Health research and innovation 5. Energy 6. Environmental science and technology 7. Mines and material development 8. Ferrous and non-ferrous materials chemical technologies 9. Information and communications technology 10. Space research and investment 11. Industrial research, development and production 12. New and emerging technologies 13. Transport 14. Youth, sport and tourism development 15. Works, land, housing and urban development 16. Raw materials and manufacturing 17. Defence and national security 18. Works, land, housing and urban development	Explicit M&E mechanisms not yet specified, but planned
Rwanda		1. Agriculture and animal husbandry 2. Biotechnology 3. Health 4. Environment 5. Education 6. Transport 7. Energy 8. Information and communications technology 9. Geo-information 10. Industry 11. Private sector 12. Water and sanitation 13. Tourism	Explicit M&E mechanisms not yet specified, but planned Chief Scientific Advisor will be appointed who will oversee a system of independent evaluation of science policy and programmes across a range of issues.
South Africa		1. Human capital development 2. Knowledge generation and exploitation R&D 3. Knowledge infrastructure 4. Expanding the limits of space science and technology 5. Search for energy security; embracing renewable energy technologies 6. Responding to global climate change	Explicit M&E mechanisms not yet specified Annual review to be conducted by Department of Science and Technology plans to conduct an annual.
United Republic of Tanzania	The establishment of conducive legal environment for the development and transfer of technology	1. Food and agriculture 2. Industry 3. Energy 4. Natural resources 5. Environment 6. Health, sanitation and population planning 7. Transport and communication 8. Science and innovation education and manpower	Explicit M&E mechanisms not yet specified or planned.

Country	Objectives	Priorities	M&E mechanisms
Uganda	To build a strong national conducive system for the generation, transfer and application of technologies in line with Uganda's development objectives	1. Technology forecasting, assessment and transfer 2. Industrial development 3. intellectual property management 4. Traditional, conventional and emerging technologies 5. Gender and equity 6. Sector financing and investment 7. Human capital development and retention 8. science, technology and innovation infrastructure 9. Research 10. Technology incubation 11. science, technology and innovation safety regulations 12. Standards and quality assurance in science, technology and innovation 13. Public awareness and appreciation of science, technology and innovation 14. Information management system 15. Sector coordination and partnerships	Explicit M&E mechanisms not yet specified Management information management system planned
Zambia	To promote science and technology in key sectors to encourage competitiveness in the production of quality goods and services	1. Gender concerns in science and technology 2. Technology diffusion, transfer, innovation and commercialization 3. Standardization, quality assurance and environmental protection 4. Development of appropriate skills 5. Gathering and dissemination of information 6. Cultural and public awareness 7. Regional and international cooperation in science and technology 8. Mechanism for funding for science and technology R&D	Explicit M&E mechanisms not yet specified, but planned

Country	Objectives	Priorities	M&E mechanisms
Zimbabwe	The adaptation, use and implementation of new emergent technologies for the development of the economy	1. Education 2. Institutions and infrastructure development 3. Biotechnology 4. Information and communications technology 5. Space sciences 6. Nanotechnology 7. Indigenous knowledge systems 8. Technologies yet to emerge 9. Commercialization of research results 10. Search for scientific solutions to emergent environmental challenges 11. Mobilize resources and popularize science, technology and innovation 12. Foster international collaboration in science, technology and innovation	M&E mechanisms not yet outlined in the policy document

Source: Compilation based on Nwuke (2015).

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