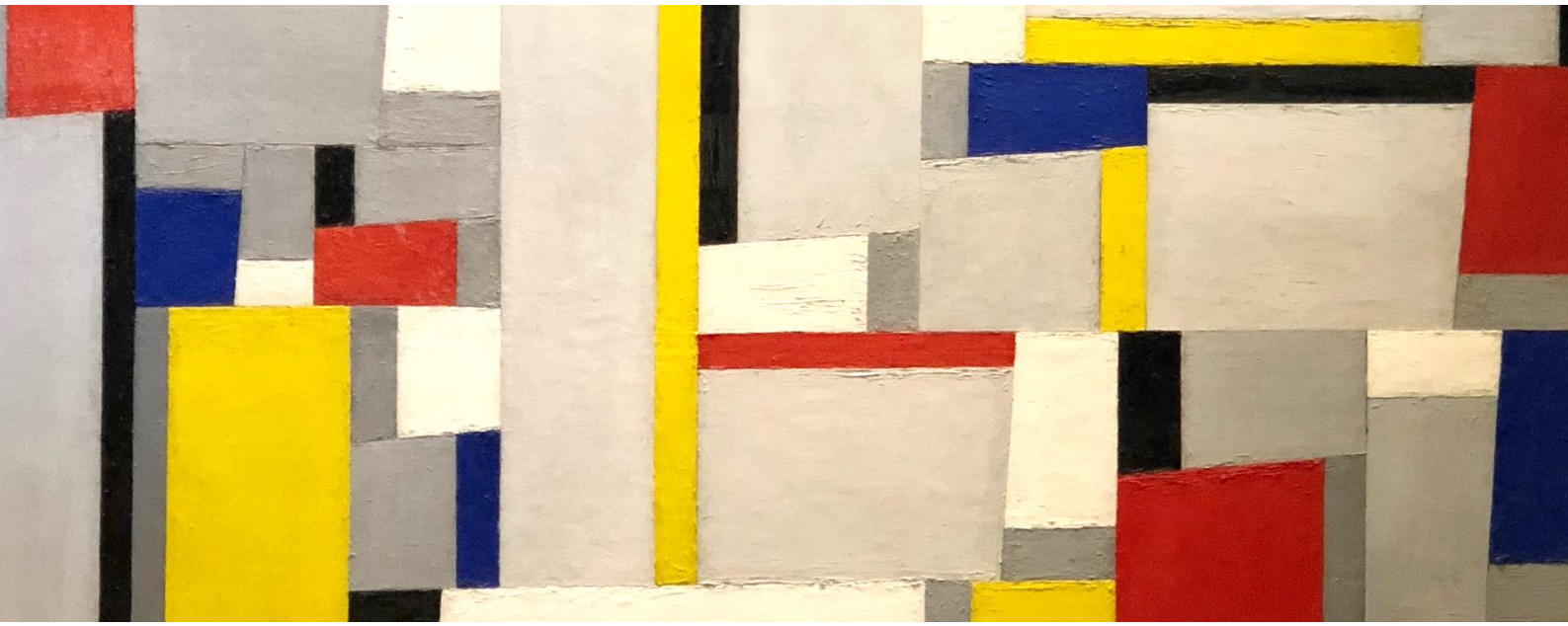
No.4 2018 OCCASIONAL POLICY PAPERS SERIES ON THE LEAST DEVELOPED COUNTRIES

ENHANCING STI IN AFRICA THROUGH THE TECHNOLOGY BANK FOR THE LDCs



UN-OHRLLS
UNITED NATIONS OFFICE OF THE HIGH REPRESENTATIVE FOR THE LEAST DEVELOPED COUNTRIES, LANDLOCKED DEVELOPING COUNTRIES AND SMALL ISLAND DEVELOPING STATES

NOTE

The purpose of this occasional policy papers series, published by the United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States (UN-OHRLLS), is to analyse policy issues relating to the development of the least developed countries (LDCs), stimulate discussions and promote international cooperation. In keeping with this objective, the authors are encouraged to express their own views, which do not necessarily reflect the views of the United Nations or its member States.

The series is prepared under the general guidance of the Under Secretary-General and High Representative and the overall supervision of the Director of the UN-OHRLLS.

UN-OHRLLS
United Nations Secretariat
New York, NY 10017
United States of America

Cover image: section of mural by Fritz Glarner at United Nations Headquarters

ENHANCING STI IN AFRICA THROUGH THE TECHNOLOGY BANK FOR THE LDCs

Miniva Chibuye and Americo B. Zampetti[1]

1. Introduction

Twenty years ago, the World Bank underscored the crucial role of "knowledge" for development. It noted that

> knowledge is critical for development, because everything we do depends on knowledge. Simply to live, we must transform the resources we have into the things we need, and that takes knowledge. And if we want to live better tomorrow than today, if we want to raise our living standards as a household or as a country—and improve our health, better educate our children, and preserve our common environment—we must do more than simply transform more resources, for resources are scarce. We must use those resources in ways that generate ever-higher returns to our efforts and investments. That, too, takes knowledge, and in ever-greater proportion to our resources. (World Bank, 1998, page 16)

In 2001, the Human Development Report stressed that "technologies are tools of human development that enable people to increase their incomes, live longer, be healthier, enjoy a better standard of living, participate more in their communities and lead more creative lives" (UNDP, 2001, p. 27). This awareness of the role of knowledge and technology for development has not subsided but rather increased ever since.

Least Developed Countries (LDCs)[2] are characterised by many economic and structural challenges that impede progress in eradicating poverty and attaining sustainable development. One of their main structural deficiencies lies in the areas of science, technology and innovation (STI). STI serve as crucial drivers of economic prosperity, social advancement and environmental protection as shown by a large empirical literature which has sought to estimate the effects of various aspects of STI on growth and sustainable

[1] The authors are both with the United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States (UN-OHRLLS). The opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the United Nations. Comments on an earlier draft from Aggery Ambali, Abdoulaye Yero Baldé, Bitrina Diyamett, Xiaolan Fu and Mohamed H. A. Hassan are gratefully acknowledged.

[2] For the LDC identification, see the following link: https://www.un.org/development/desa/dpad/least-developed-country-category/ldc-criteria.html.

development. This is true for the 47 LDCs, and particularly true for the 33, which are in sub-Saharan Africa.[3]

The importance of STI is recognised both in the Istanbul Programme of Action for the Least Developed Countries for the Decade 2011-2020 (IPoA)[4] and the 2030 Agenda for Sustainable Development,[5] which set out respectively the international community's support agenda for the LDCs and the universal blueprint to achieve a sustainable future. A key institutional tool called for in these two documents to promote STI advancement in the LDCs is the creation of a "Technology Bank for the LDCs". The United Nations (UN) General Assembly established this new entity in late 2016.

This paper focuses on how this newly formed UN institution can specifically benefit the African LDCs by cooperating with African STI initiatives. By way of introduction, we briefly highlight the STI challenges of the LDCs. The paper then reflects on the mandate of the Technology Bank and how this fits within the efforts to advance the use of knowledge for the sustainable development of the LDCs. The paper then looks at the role that the Technology Bank can play to catalyse action within the African continent. It briefly reviews some key African STI initiatives and assesses how the Technology Bank can contribute to and promote already existing structures and programs within Africa. In this regard the paper conducts a mapping of the coherence and expected synergies between the Technology Bank objectives and ongoing African initiatives. The paper concludes that the Technology Bank fits well within the efforts to enhance the utilization of knowledge as global public good for the development of the LDCs and that it holds the promise to spur and support the African initiatives directed at advancing STI in the continent.

2. Science Technology and Innovation challenges in African LDCs

STI play a critical role in the LDCs' efforts to expediting poverty eradication, transitioning to sustainable development and becoming globally competitive. The rising importance of knowledge across the board, from economic competitiveness in the context of increasingly complex global value chains, to progress in virtually all social development areas, such as health and education, from communication to governance, from environmental protection to disaster resilience, has been recognised in the literature on economic development and in international discussions and negotiations for decades.[6] However, the

[3] Equatorial Guinea graduated from the LDCs category on 4 June 2017 and as a result is no longer included in the list of LDCs. Note however that in the rest of the analysis, Equatorial Guinea is included because all LDCs that graduate from the LDC category can remain a beneficiary of the activities of the Technology Bank for a period of at least five years, see Article 3.b of the Charter of the Technology Bank (UN, 2016).

[4] United Nations (UN), "Programme of Action for the Least Developed Countries for the Decade 2011-2020", UN doc. A/CONF.219/3/Rev.1 (23 May 2011).

[5] UN, "Transforming our world: the 2030 Agenda for Sustainable Development", General Assembly resolution 70/1 of 25 September 2015.

[6] UNCTAD, Transfer of technology and knowledge sharing for development. Geneva, 2014 (UNCTAD Current Studies on Science, Technology and Innovation, No. 8) available at: http://unctad.org/en/PublicationsLibrary/dtlstict2013d8_en.pdf.

challenges LDCs face are becoming even more acute as a result of the speed at which new technologies are emerging. This led the World Economic Forum to recently pustulate that the world may be experiencing the "Fourth Industrial Revolution" (Davis, 2017), with far-reaching consequences in terms of the global ability to attain a developmental path which is truly sustainable.

Despite great advances in technologies including, nanotechnology, biotechnology, Artificial Intelligence (AI), 3D printing and robotics, LDCs, in particular those in Africa, are still lagging behind in nearly every STI metric.[7] As was recently argued by Xavier and Maloney (2017), despite the vast potential returns to innovation, developing countries invest far less, measured along a variety of dimensions, than advanced countries. UNCTAD (2010) suggests the use of STI indicators around five dimensions: a) Research and Development (R&D), b) human resources, c) patents, d) innovation and e) technology balance of payments (TBP). The analysis below will largely focus on the first four indicators and related metrics.

a) *Research and Development* - Since R&D drives both imitation and invention, data on this indicator captures important dimensions of the process of innovation. It facilitates advances at the technological frontier and enables catch-up through absorptive capacity (Cirera and Maloney, 2017). Authors including Lee and Kim (2009) and Lee and Mathews (2013) suggest that countries that have managed to sustain catch-up growth have done so through increasing the level of expenditure on R&D and related innovation capabilities. Lee and Kim (2009) contrast Latin American countries with some East Asian countries. They highlight that in 2000, none of the Latin American countries had passed the 1 per cent mark in the R&D to Gross Domestic Product (GDP) ratio while Korea's R&D to GDP ratio exceeded 2 per cent in the early 1990s. China has been strongly pushing for more R&D expenditure. It finally reached the 1 per cent ratio in 2000, earlier than most of the Latin American middle-income countries. Between 2012 and 2014, China's R&D expenditure, as a share of GDP was about 2 per cent.[8] As argued by Ross (2016, p. 66), "with nearly 2 per cent of China's mammoth GDP going toward R&D, it now has the statistical edge over Europe, and the United States is struggling to retain its lead".

The 1980 Lagos Plan of Action for the Economic Development of Africa, 1980–2000 outlined a vision for socioeconomic transformation driven by STI and addressing challenges such as food insecurity, poverty, energy deficiencies, health issues, pollution, water scarcity, and lack of industrialization. In this context, African countries pledged to increase their R&D

[7] This does not mean that there are no examples of emerging technologies in the LDCs (see post by Annette Becker, "LDCs and the technological revolution", 30 August 2017, available at: https://www.un.org/ldcportal/ldcs-and-the-technological-revolution/). For instance, Rwanda is using drones to deliver blood across the country. The first phase involves 15 drones delivering the blood to hospitals in rural western Rwanda. The service is operated by Zipline, a startup based in the United States. The blood packages are dropped by parachute. Although the cost is roughly the same as by motorbike or ambulance, it is much faster (UN-OHRLLS, 2017b). The challenge for LDCs in general and the African LDCs in particular, is to understand how to use the new technologies to improve the way that products are produced. Ultimately, in order for African LDCs to catch-up, they should embrace these new technologies while ensuring that these technologies do not further disadvantage those that are already poor and furthest behind.

[8] World Development Indicators (R&D, % of GDP), World Bank. Data downloaded on 26 July 2017.

spending to least 1 per cent of GDP (ACBF, 2017). The 2006 Khartoum Decision of the Executive Council of the African Union called on Member States to promote Africa's R&D and develop innovation strategies for wealth creation and economic development by allocating at least 1% of Gross Domestic Product (GDP) of national economies by 2010.[9] A report by the African Union, the Economic Commission for Africa and the African Development Bank show that various African LDCs, for example Ethiopia, Uganda, Tanzania and Zambia, have reflected in their national policies the goal of ensuring 1 per cent of GDP or more towards STI activities (AU, ECA and AfDB, 2016; see also NEPAD, 2014).[10]

However, lack of data in most of the African LDCs makes it difficult to accurately assess the average expenditure spent on R&D as a share of GDP. The median ratio estimated from the World Bank's World Development Indicators (WDI) scanty data on R&D as a share of GDP, shows that since the 1990s (when the first data was available), the ratio has been consistently lower than 0.5 per cent. Focussing on the years with the most data points,[11] the median ratio of R&D expenditure as a share of GDP was only between 0.15 and 0.38, much lower than the commitment made by the African countries.

R&D spending is likely to lead to growth through its positive effect on innovation and total factor productivity (Romer, 1990; Lucas, 1988; Blanco, Prieger and Gu, 2013). While still lower than the 1 per cent target, the LDCs with slightly higher share of R&D expenditure in GDP also exhibited higher growth, relative to the other LDCs.[12] For example, based on the data from the World Development Indicators (World Bank, 2013), Tanzania and Ethiopia allocated 0.53 and 0.6 of their GDP to R&D. Between 2011 and 2015, Ethiopia and Tanzania grew at 10.4 and 6.4 per cent, respectively (average GDP growth for LDCs between 2011 and 2015 was 4.9 per cent).[13]

This trend separates the LDCs also from many others in the developing world, which in recent years have heavily invested in STI, placing them in a competitive position with countries in the North. The United Nations Educational, Scientific and Cultural Organization (UNESCO), in its Science Report 2010, stressed the dramatic increase of investments in science and technology by leading nations in the developing world and their positive impact on economic growth, while observing that, "by contrast, the group of least developed countries … still plays a marginal role" (UNESCO, 2010. P. 5).

[9] See Executive Council, Eighth Ordinary Session, 16-21 January 2006, Khartoum, Sudan, Decision on the Report on the Conference of Ministers of Science and Technology – Doc. EX.CL/Dec.254 (VIII). This call was reiterated at the Assembly of the African Union African Union Eight Ordinary Session, 29-30 January 2007, Addis Ababa, Ethiopia, Decision on the Report of the Extraordinary Conference of Ministers of Science and Technology – DOC. EX.CL/315 (X).

[10] Rwanda committed to allocating 5 per cent of the government budget towards National research fund. Lesotho committed to allocating 1 per cent of Gross National Product (GNP).

[11] 2004, 2005, 2008, 2009 and 2010 had at least seven to nine data points.

[12] This assertion does not claim causality.

[13] In order to achieve sustained, equitable and inclusive economic growth in LDCs, the recommended annual GDP growth target for the IPoA implementation period is at least 7 per cent.

b) *Human resources* - As the new technologies require skilled workers, basic factors like education are extremely important.[14] Manyika et al., (2017) highlight that in the 19th century, technological changes raised the productivity of lower-skill workers and created new opportunities for them, at times replacing the craftsmanship of higher-skill artisans. However, with the advent of information technology and the internet, the reverse has happened: the productivity of higher-skill workers, especially those engaged in abstract thinking, or with creative and problem-solving skills, has increased, while the relative demand for lower-skill workers has not.

Among African LDCs, gross enrolment in secondary education increased slightly from 32.2 per cent in 2010 to 37.6 per cent in 2014. In comparison, the LDCs in Asia and the Pacific recorded 50.5 per cent and 57.6 per cent, respectively. The share of tertiary enrolment accounted for only about 5.9 per cent and 8.2 per cent in 2010 and 2014, respectively among the African LDCs.[15] As argued by authors such as Nelson and Phelps (1966) and Picketty (2014)[16], higher level of education should speed up the process of catching up with technological frontier. A recent report by OHRLLS and ITU (2018) found that secondary school enrolment has by far the highest explanatory power for Internet use. There is clearly a need to improve education and training in African LDCs, if they are to compete in the global economy.

Another illustrative way to depict STI achievements in the LDCs is to estimate the number of publications in peer reviewed journals. Yet again, LDCs lag far behind. Based on the 2013 data on scientific articles and technical journals published, for the African LDCs only 7 scientific and technical journal articles were published for every 1 million people. In comparison, in the OECD area, about 1,100 scientific and technical journal articles were published for every 1 million people. [17]

Information and Communication Technology (ICT) also plays a very important role in STI. ICT is enabling many changes in the economy and the innovation process that help make other economic sectors more innovative (OECD, 2000). In 2015, only about 11 in every 100 people used the internet in African LDCs. Among others, broadband applications and services can contribute to innovative solutions for the LDCs in various areas that are important for their development, including e-health, e-education e-banking and, e-

[14] Lee and Kim (2009) argue that during the first transition from low- to middle-income level, basic factors like institutions and primary/secondary education are significant, whereas in the upgrading from middle- to high-income stage, factors like tertiary education and technological innovation begin to play a significant role.

[15] Based on data from the WDI. During the same period, the average for LDCs was about 13 per cent.

[16] Picketty (2014, p. 21) argues that knowledge and skill diffusion is the key to overall productivity growth as well as the reduction of inequality both within and between countries. These facets also enhance the process of catching up with the advanced countries.

[17] Data for 2013 is latest available at the time of writing. Scientific and technical journal articles refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences (see https://data.worldbank.org/indicator/IP.JRN.ARTC.SC). The methodology for assessing this data raises questions on under-estimation of contributions from authors in LDCs, given that a number of LDC nationals may be authoring articles while based at institutions outside their countries of origin.

government (UN-OHRLLS, 2017b). However, in 2015, fixed, higher quality broadband penetration in LDCs represented less than 1 per cent of subscriptions and mobile phone broadband less than 20 per cent of subscriptions. By comparison, in developed countries, the penetration rate is about 30 per cent for fixed broadband and 90 per cent for mobile broadband (ITU, 2016). Hjort and Poulsen (2016) empirically established that broadband connectivity has a positive causal net effect on job creation. They found that in Senegal, Tanzania and Uganda, broadband connectivity enables firms to export more, partly due to use of websites. In Ethiopian manufacturing firms, the authors found an increase in number of workers (in particular skilled positions per firm), firm level productivity, and the productivity of workers in skilled positions. Increasing access to the Internet, including broadband, among African LDCs is crucial. This will require responding to issues of significantly increasing access to the internet and ensuring that it is affordable (see for example, OHRLLS and ITU, 2018). In addition, investing in human capital and enabling local content is important for Internet uptake in LDCs.

c) *Patents* - In order to create adequate incentives for private sector technological innovations that drive economic growth, governments need to create an effective and targeted regulatory environment that promotes innovation (Bordoff, et al., 2006). However, technological change, especially in developing countries, is not only about innovating at the frontier, but also about adapting existing products and processes to achieve higher levels of productivity as applicable to their local contexts. Connecting local technological needs to international technological opportunities is a particular challenge for many developing countries.

In this regard, patent[18] indicators offer a useful measure to characterize the STI environment where both firms and researchers operate and also provide a more standardised measure of a particular type of knowledge output (Cirera and Maloney, 2017). The number of patents filed by residents of African LDCs in their own countries and abroad remains meagre. As illustrated in Table I, the total number of patents filed between 2001 and 2016 by the 34 African LDCs was just over 4,000, significantly less than half of the total for all LDCs. Therefore, the majority of patents for all LDCs are filed by the Asian LDCs, which are much fewer in number. By comparison during the same period, Kenya and South Africa, two African non-LDC respectively filed a total of 2,438 and 116,736 patent applications, while 6,253,918 patents were filed by China.[19] A further analysis of the patents data indicates that the larger share of the patents filed by African LDCs are in pharmaceuticals (figure 1), with the lowest being in electrical machinery and basic materials, chemistry.

[18] A patent is an exclusive right granted for an invention, which is a product or a process that provides, in general, a new way of doing something, or offers a new technical solution to a problem. To get a patent, technical information about the invention must be disclosed to the public in a patent application (see http://www.wipo.int/patents/en/).

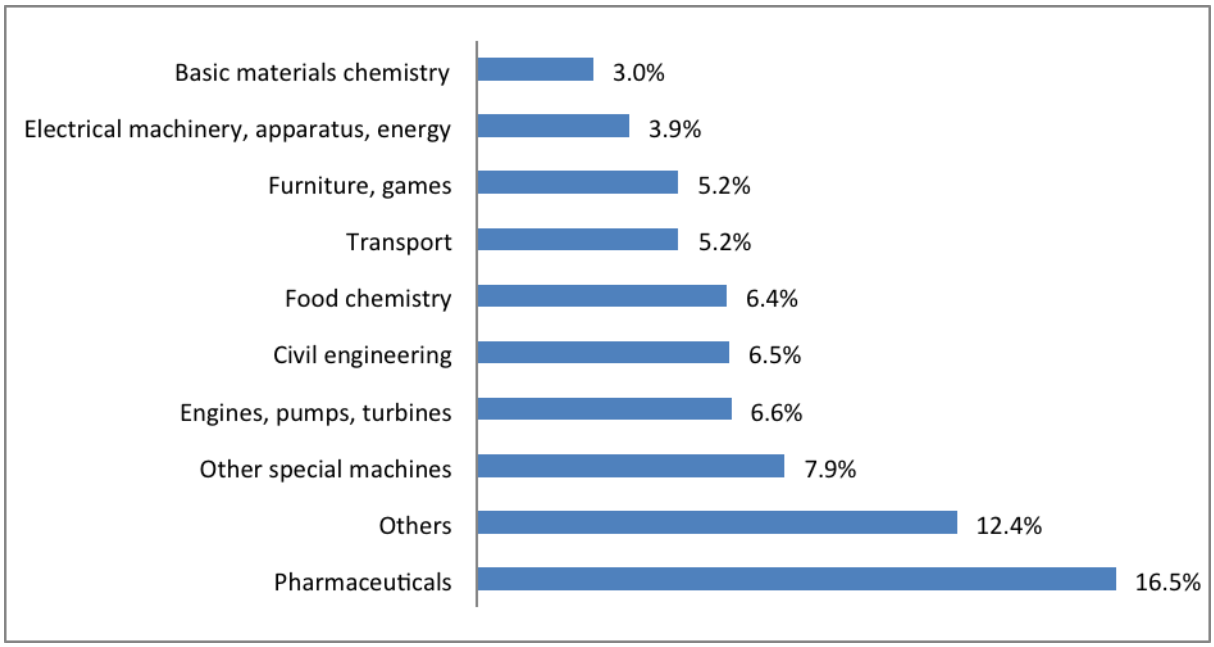
[19] Data downloaded from the World Banks's WDI on 14 June 2018. Available online at http://data.worldbank.org/indicator/IP.PAT.RESD and https://data.worldbank.org/indicator/IP.PAT.NRES.

Table I: Total Number of Patents Filed by African LDCs and Select Countries, 2001-2016

	Residents	Non-residents	Total Applications
African LDCs	2,528	1,606	4,134
All LDCs	3,662	6,952	10,616
Kenya	1,178	1,260	2,438
South Africa	15,490	101,246	116,736
China	5,908,449	1,468,411	7,376,860

Source of data: World Development Indicators, World Bank

Figure 1: Patents issued by Technological Sector in African LDCs



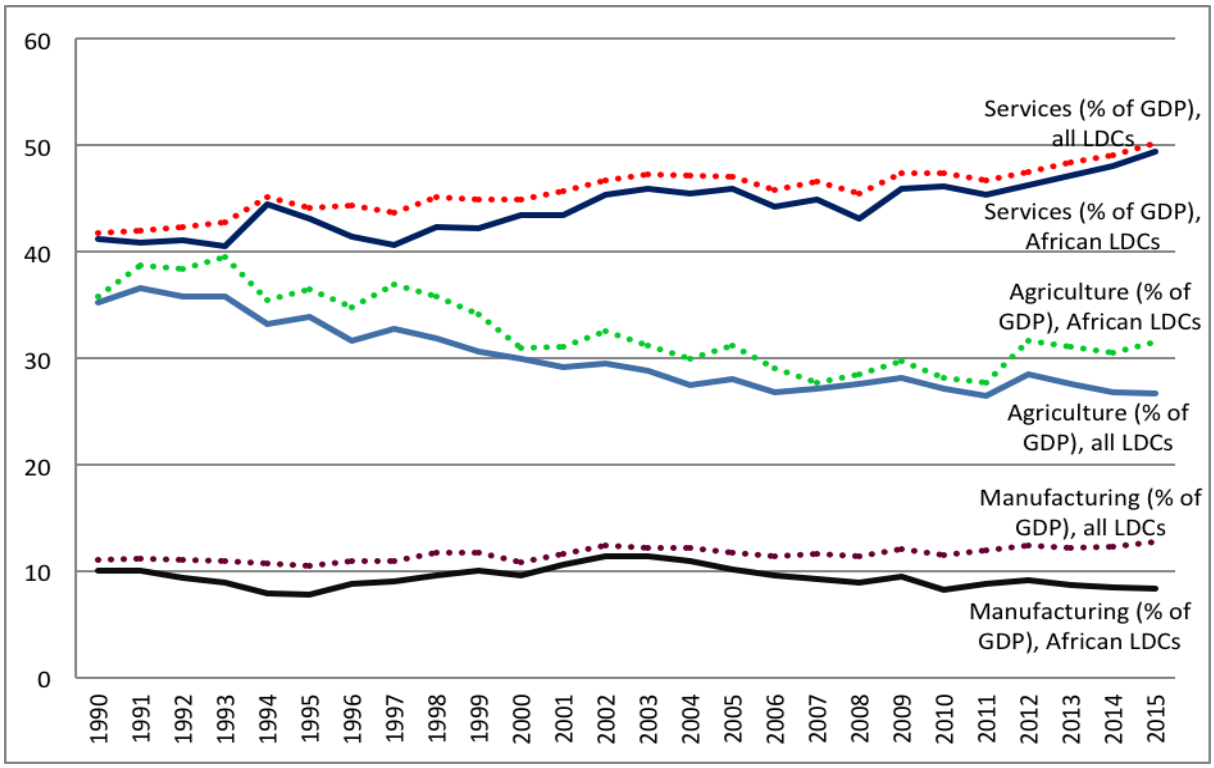
Source of data: World Intellectual Property Organisation (WIPO)

d) *Innovation* - The analysis above shows that African LDCs need to significantly invest in innovation in order to catch up with not just the other LDCs, but also, become globally competitive. The 2017 Global Innovation Index, which measures the innovation performance of 127 economies (Cornell University, INSEAD, and WIPO, 2017), showed that

among the African LDCs that are included in the analysis, only Tanzania (96), Rwanda (99) and Senegal (100) are ranked among the first 100 countries. Cirera and Maloney (2017) show that countries that have been unable to innovate and apply technological advances to their existing industries are unlikely to do so in new industries. As such, in order to achieve economic development, building innovation capacity is an extremely important policy priority.

The gaps identified thus far in the area of STI in Africa, could explain why the structure of the African economies on average, is weaker, relative to the LDC average. As shown in figure 2, the contribution of agriculture to GDP is becoming increasingly important, while manufacturing is declining. Therefore, the slight increase observed in the contribution of manufacturing to GDP in all LDCs is a result of growth in the non-African LDCs. On the other hand, the contribution of services to GDP for the African LDCs shows an upward trend, and is in tandem with the 'all LDCs' average. If the African LDCs do not invest more in manufacturing, there is a risk of early de-industrialisation where LDCs begin to experience not just the falling manufacturing shares in employment but also, falling manufacturing value added, as a share of GDP. This is a phenomenon that Rodrik (2015) highlighted in his empirical paper where he observed that some developing countries were running out of industrialization opportunities sooner and at much lower levels of income compared to the experience of early industrializers.[20]

Figure 2: Structure of African LDC economies, relative to all LDCs (1990 – 2015)



Source of data: World Development Indicators, World Bank

[20] See also UN-OHRLLS (2017a).

In relation to the impact of advanced technologies on manufacturing in Africa, it has been argued (The Economist, 2017) that the concern that advanced robotics and 3D printers are a threat to manufacturing jobs may not apply to most of the African countries where manufacturing has not taken off. Hence, robots will not kill many jobs but offer an opportunity to create new ones by helping African firms overcome bottlenecks in production and, by lowering barriers to making and selling things globally. Given that the impact of the emerging technologies is likely to vary among countries, it will be important to conduct detailed analysis in various LDCs on the impact of the new technologies on both productivity and jobs.

The very low STI base as evidenced by the various indicators reviewed above makes it necessary to work on many fronts. On the one hand substantial investments of time, effort and resources are required to build the capacity of indigenous STI and eventually harness that capacity into productive activities, higher paying jobs, increased resilience to shocks and disasters and better management of natural resources and the environment. On the other hand absorption and adaptation of existing technologies remains necessary, as it was for the "newly industrialized countries", which used technologies from abroad to grow their industrial base before being able to generate their own scientific and technical knowledge (Duller, 1992).

In all areas, African LDCs need support. Building the STI base requires long-term investments to foster quality human resources, build facilities, procure equipment, develop relationships with research, firms and markets abroad, and secure online connectivity so that researchers can interact with their peers, and access existing research (including trough online publications). It is against this background that the Technology Bank for the LDCs initiative was conceived.

3. The Technology Bank and its role in the global governance of knowledge

In order to help respond to some of the challenges highlighted above, the LDCs advocated for the establishment of a multilateral institution specifically geared to address their needs in the area of STI.[21] In the 2011 IPoA, the international community underscored the critical role played by STI as a vehicle for structural transformation and called for the establishment of a technology bank dedicated to LDCs. This LDCs priority was confirmed in

[21] In 2010, the United Nations Conference on Trade and Development (UNCTAD) Least Developed Countries Report put forward the notion of a "Technology Licensing Bank for LDCs" to address the increasing difficulties faced by the LDCs to incorporate adequate knowledge that is relevant to their development needs (due to wide-spread intellectual property protection strategically used by high-technology firms in developed countries), limited capacities to negotiate licenses and poor access to information on available technological options. See *The Least Developed Countries Report 2010: towards a new international development architecture for LDCs*. Geneva: UNCTAD, 2010. For a review of the international initiatives see Roffe P., "Comment I: Technology transfer on the international agenda", in Maskus, Reichman, 2005, pp. 257-264. See also the Feasibility Study for a United Nations Technology Bank for the Least Developed Countries (United Nations, 2014).

Sustainable Development Goal 17.[22] In December 2016 the UN General Assembly established a new institution with the stated aims to improve the LDCs' scientific research and innovation base, help the LDCs access and utilize critical and appropriate technologies, and promote collaborations among research institutions.[23]

The Technology Bank has the potential to be an important instrument to ensure that STI plays its full role in the sustainable development of the LDCs. It is intended to help LDCs strengthen their STI capacities, foster the development of national and regional innovation ecosystems, generate home grown research and innovation and take them to market. It also aims to assist LDCs in building their national and regional capacities in the areas of intellectual property rights and technology related policies, as well as facilitate the transfer of appropriate technologies and in the process, accelerate the LDCs integration into the knowledge-based economy.

According to the Charter of the Technology Bank (UN, 2016), the new entity has five specific objectives:

1. To strengthen STI capacity in LDCs, including the capacity to identify, absorb, develop, integrate and scale up the deployment of technologies and innovations, as well as the capacity to address and manage intellectual property rights issues;
2. To promote the development and implementation of national and regional STI initiatives;
3. To strengthen partnerships among STI-related public entities and with the private sector;
4. To promote cooperation among all stakeholders involved in STI, including within and between LDCs, as well as other countries; and
5. To promote and facilitate the identification and utilisation of and access to appropriate technologies by the LDCs, as well as their transfer to the LDCs.

In light of its objectives the Technology Bank may be well-placed to play an important role in the provision of scientific and technical knowledge, a (quasi) public good whose current under-provision has momentous implications for the sustainable development both of the LDCs and at global level. Indeed, the LDCs' sustainable development depends in good measure on their ability to acquire scientific and technical knowledge and apply it to solve the many challenges they face.

[22] SDG target 17.8; "fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology".

[23] See UN Resolution 71/251, adopted on 23 December 2016 officially establishing the Technology Bank for the LDCs as a subsidiary organ of the General Assembly. The Technology Bank is to be financed by voluntary contributions from Member States and other stakeholders, including the private sector and foundations. The Technology Bank is guided by a Council composed of 13 independent experts, which will serve as its governing body. These experts are appointed by the Secretary General to serve for a period of three years and can be reappointed.

Knowledge exhibits some crucial elements of a public good in as far as it is not depleted by multiple use and it is generally difficult to exclude users from consumption. However, the non-excludability character of knowledge is not realized in the short to medium term in those areas where knowledge creators are able to resort either to secrecy or to intellectual property protection (Stiglitz, 1999). In addition its non-rivalrous character in consumption does not eliminate much competition in the generation and upgrade of knowledge, when such knowledge can be appropriated and sold.

As a result much controversy has taken place as to whether the existing intellectual property regimes provide efficient incentives for the creation and provision of knowledge (Maskus and Reichman, 2005). However, what appear certain is that LDCs access to both STI capabilities and technologies covered by intellectual property rights remains limited. Similarly limited remains their knowledge generative capacity. This means that LDCs are in large measure excluded from, or at best constrained in their use of existing knowledge for development. Knowledge as a public good is not yet a reality for them. And as the (potential) benefits of knowledge as a public good know no boundaries - since knowledge is by definition cumulative and incrementally contributes to solving problems, which similarly know no boundaries - the under-provision of knowledge in the LDCs calls for collective action by the international community.

The Technology Bank is poised to be, in light of its objectives, one of the actors in the global governance of knowledge.[24] An international actor set up to address some of the key constraints to the LDCs' access to knowledge. At its core the mandate of the Technology Bank lies in strengthening the STI base of the LDCs – or improving their technology absorptive and adaptive capacity. This indeed is one of the main constraints in realizing the potential of knowledge as a global public good. As Archibugi and Filippetti (2015, page 492-493) argue: "institutional (such as IPRs) or economic (such as industrial secrecy) are not the main obstacles to the use of knowledge. The main obstacle faced by developing countries is the lack of endogenous absorptive capabilities." Absorptive capacity at firms but also countries level refers to the ability to identify, assimilate and exploit information and knowledge apply it to commercial ends'' (Cohen and Levinthal, 1990; Fu, 2007).[25] It requires building human capital, physical infrastructure and research capacity, as well as putting in place the necessary institutional and policy frameworks. As such limited absorptive capacity is a potent structural bottleneck for the LDCs.

The 3-year strategic plan of the Technology Bank stresses this point when it states that: "[t]he main challenge for the Technology Bank is to help LDCs build the capacity to find, adapt and adopt appropriate technology." (UN-TBLDC, 2016, p. 1) This of course does not deny that in certain sectors intellectual property rights may prove to be a serious constraint due to the costs associated with identifying and licencing necessary technologies.

[24] We define "global governance" as the "existing collective arrangements to solve problems", see Weiss, T. and Thakur, R., *Global Governance and the UN*, 2010, p. 6.

[25] Absorptive capacity can be evidenced by looking at the technology gap between the foreign and the domestic firms, R&D intensities of the local firms, or human capital embodied in local firms (Fu, 2007).

However, both in these instances and even in sectors where intellectual property rights are not prevalent or for technologies no longer covered by IP, the absorptive capacity limitations remain a binding obstacle to the LDCs' access and use of knowledge for their development.

Beyond absorptive capacity the Technology Bank is also expected to concentrate on promoting LDCs' access to knowledge and the ensuing benefits by facilitating transfer of appropriate technologies, helping them manage IPRs, and promoting research collaborations and partnerships. These are all means to reduce the exclusion from knowledge that continue to constrain the potential of the LDCs and their people.[26] It is of note that among the first activities that the Bank decided to undertake at the outset of its operation in 2018 there is the promotion of "digital access to research." The Technology Bank is teaming up with Research4Life, a public private partnership that has been active in more than 100 lower income countries, including all the LDCs, since 2002. The partnership brings together UN agencies, 180 international publishers, universities and other organisations to provide researchers and others in the developing world with online access to high-quality international academic and professional journals, books, databases and other information resources.

Indeed, the Technology Bank as a new, small-scale UN entity will need to work collaboratively within the UN system and with other stakeholders. The Bank's strategic plan stresses that "[s]ynergies across existing initiatives and/or joint actions and approaches should be a guiding principle for planning. The Technology Bank should leverage the existing initiatives within the UN system at the regional and national level to implement its programme of work." (UN-TBLDC, 2016, p. 16) The mode of governance that the Bank is likely to adopt is thus that on an "orchestrator" (Abbott et al., 2015). Orchestration occurs when an international organization "enlist intermediary actors on a voluntary basis, by providing them with ideational and material support to address target actors in pursuit of the international organizations governance goal." (Abbott et al., 2015, p. 3) In particular when interfacing with regional organizations in Africa, with which it shares objectives, it is to be hoped that the Bank will forge strong links and provide strong support. This will allow the Bank to reap important governance advantages in terms of delivery of results through steering, empowering and cooperating closely with the relevant regional organizations.

4. Select African initiatives to enhance STI

There are various organizations and initiatives within Africa that respond to the STI challenges at the pan-African, sub-regional as well as national levels. While this paper attempts to highlight some of these key initiatives, the review is by no means exhaustive and the analysis will focus on select pan-African and regional initiatives.

[26] It is interesting to note that access to knowledge has not only a global governance dimension, but also a human right one as stipulated by article 15 of 1966 International Covenant on Economic, Social and Cultural Rights, which states "the right of everyone: … (b) To enjoy the benefits of scientific progress and its applications."

At the pan-African level, leaders have long been committing to enhancing STI in Africa (AU, ECA and AfDB, 2016 and ACBF, 2017; NEPAD, 2014). In 1979, African Leaders adopted the Monrovia Declaration, which committed to enhancing science and technology. This commitment was reiterated in the Lagos Plan of Action in 1980. The Lagos Plan of Action further called for Member States to formulate national policies on science and technology. However, and as argued by Africa's Science and Technology Consolidated Plan of Action (2005), many of the policies are focused on organizational aspects and not on programmatic issues.

Subsequently, the African Union adopted the Addis Ababa declaration on Science and Technology and Scientific Research for development in 2007, the year for championing STI in Africa. In the final Declaration on Science, Technology and Scientific Research for Development, the Heads of State and Government vowed to "increase funding for national, regional and continental programmes for science and technology (S&T) and support the establishment of national and regional centres of excellence in S&T." However, and as highlighted above, African LDCs are yet to attain the target of allocating 1 per cent of GDP to STI.

Since its endorsement by the African Union Summit of Heads of State and Government in 2006, NEPAD had been implementing the "AU/NEPAD Africa's Science and Technology Consolidated Plan of Action (CPA)". The CPA was developed by the Ministers of Science and Technology (AMCOST) in 2005, to ensure Africa's comparative advantage and leverage the continent's capacities to focus its research and development on responding to the continent's challenges and needs (Africa's Science and Technology Consolidated Plan of Action, 2005).[27] Significant achievements in the implementation of the CPA include: the establishment of Networks of Excellence and the African Union Competitive Research Grants.

Taking into account the findings of the CPA review, a High Level Panel developed the African Union STI Strategy, which became a successor of the CPA. Hence, against the backdrop of increased recognition by African leadership and the public of the critical role STI plays in economic growth and human development, the African Union Heads of State and Government Summit adopted a 10-year Science, Technology and Innovation Strategy for Africa (STISA-2024) in June 2014. STISA-2024 provides a focus on improving Africa's STI status in human capital, technical competence, infrastructure, the enabling environment, innovation, and entrepreneurial mind-sets (AUC 2014; ACBF, 2017).

In addition, one of the Calls for Action for the African Union's Agenda 2063, agreed in January 2015, is to "catalyse education and skills revolution and actively promote science, technology, research and innovation, to build knowledge, human capital, capabilities and skills to drive innovations and for the African century". Agenda 2063 also calls for building

[27] See also https://www.au.int/web/en/st-division

and expanding an African knowledge society through transformation and investments in universities, science, technology, research and innovation. Other relevant bodies under the African Union Commission include: the Pan-African University whose research programs will focus on addressing the key priorities identified in STISA-2024, and the pan-African Intellectual Property Organisation, which is in the process of being established.

Regional initiatives on STI also exist. These include: the Southern African Development Community (SADC) protocol on STI, which was established in 2008; the Economic Community of West African States (ECOWAS) Policy on Science and Technology; the commitment of the Member States of the Common Market for Eastern and Southern Africa (COMESA) to sharing knowledge on research developments and science and technology in various areas of cooperation, among others; the pledge contained in Article 80 of the Treaty establishing the East African Community (EAC) to "promote industrial research and the transfer of technology, acquisition, adaptation and development of modern technology" and "disseminate and exchange industrial and technological information."[28] In addition, the Pan African Institute of Science and Technology was recently established as a partnership between some academic and research institutions of Nigeria, Burkina Faso and Tanzania (ACBF, 2017). The African Regional Intellectual Property Office (ARIPO), an international organization established in 1976 with the aim to facilitate cooperation among member states in intellectual property matters and provides training on a diverse range of areas related to intellectual property legislation and technology transfer.[29]

STISA-2024 also highlights some institutions with a regional or international mandate to perform research, which are encouraged to align their priorities to the strategy. These include among others, Organisation Africaine de la Propriete Intellectuelle (OAPI), the Forum for Agricultural Research in Africa (FARA), Conseil Africain et Malgache pour l'Enseignement Superieur (CAMES), African Academy of Sciences (AAS) and the Association of African Universities.

However, despite all these commitments and initiatives, STI is still playing a limited role in African economies, as shown in section 2.

5. How the Technology Bank can contribute to enhancing STI in Africa

Table II highlight the coherence and synergies between the broad objectives and areas of action that may be implemented once the Technology Bank is fully functioning and existing African initiatives that could benefit from interaction and collaboration with

[28] See also the AU, ECA and AfDB (2016).

[29] Membership to ARIPO is open to all African States members of the UN Economic Commission for Africa or the African Union. There are currently 19 States which are party to the Lusaka Agreement establishing ARIPO: Botswana, The Gambia, Ghana, Kenya, Lesotho, Malawi, Mozambique, Namibia, Sierra Leone, Liberia, Rwanda, São Tomé and Príncipe, Somalia, Sudan, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe (see http://www.aripo.org/about-aripo).

Technology Bank. The table is not intended to be exhaustive, but rather underscore coherence and synergies, using examples.

The table summarizes the main African initiatives, mandates and select activities. These are then matched with the priority areas and activities of the Technology Bank. The review is conducted under four broad categories: supporting home-grown innovation and research; building human capital and technical competence; developing R&D networks and promoting cooperation; and intellectual property capacity building. The first three are clearly geared towards improving the STI base and absorptive and adaptive capacity of the LDCs.

Under category 1 (supporting home-grown innovation and research), the Technology Bank can contribute to various African initiatives, including, STISA-2024 and various research initiatives. For example, some key objectives of STISA-2024 include: (a) enhancing the effectiveness of STI in addressing/implementing priority areas, (b) improving technical competencies and institutional capacity for STI development, and (c) promoting economic competitiveness through fostering innovation, value addition, industrial development and entrepreneurship in synergy with instruments, such as the Action Plan for Accelerated Industrial Development of Africa (AIDA) and Pharmaceutical Manufacturing Plan for Africa (PMPA). The Technology Bank can broadly contribute to these efforts by fostering the development of national and regional innovation ecosystems that can attract external technology, generate home-grown research and innovation and take them to market in line with its strategic plan (UN-TBLDC, 2016). Specific goals and activities under this area are detailed in Table II.

Regarding category 2 (building human capital and technical competence), as highlighted in section 3 above, African Heads of State and Government committed through Agenda 2063 to speed up actions to catalyse education and skills revolution and actively promote STI and research, build knowledge, human capital, capabilities and skills to drive innovations. Related initiatives to advance the cause include STISA-2024 and the African Virtual University (AVU). The Technology Bank can contribute to building human capital and technical competence in Africa through its STI Support and Enabling Mechanism (STIM). Once operationalised, STIM could offer training in entrepreneurship and marketing, since most technical researchers cannot be expected to innately display parallel business skills (UN-TBLDC, 2016).

Similarly, the Technology Bank can contribute to developing R&D networks and promoting cooperation in Africa (category 3 in Table II). Under international cooperation, STISA-2024 commits to promote mutually beneficial South-South and North-South cooperation to achieve its ambitious goals. Some regional efforts, for example, the Intergovernmental Authority on Development (IGAD)[30] in Eastern Africa aims to, inter alia, promote research, science and technology agendas for the benefit of the region. IGAD intends to achieve this goal by strengthening strategic alliances, linkages and partnerships between regional research institutions and other institutions in the developed countries. In

[30] Member states of IGAD are: Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan, South Sudan and Uganda.

this regard, the Technology Bank can help spearhead and enhance the continental and regional efforts by linking the local R&D institutes into an expanding network of North-South, South-South, intra-regional and inter-regional knowledge creation networks. It may also promote collaborative innovation networks to enable LDC scientists, technologists and relevant public institutions to connect and collaborate with their global STI peers.

Finally, on matters related to Intellectual Property (category 4 in Table II), several African initiatives are in place. These include, the efforts to establish the Pan African Intellectual Property Organization (PAIPO) and STISA-2024's aim of protecting knowledge production (including inventions and indigenous knowledge) by strengthening the Intellectual Property Rights and regulatory regimes at all levels. The Technology Bank, is expected to help build LDCs' national IP capacity and facilitate technology transfer on voluntary and mutually agreed terms and conditions and, in the process, accelerate LDCs' beneficial integration into the global IP system (UN-TBLDC, 2016). Specifically, the IP Bank could add considerable value by providing a one-stop shop for coordinated support to national IP capacity building, facilitating technology transfer, serving as a focal point to help LDCs effectively communicate and work with the outside world, and taking advantage of existing pathways for technology transfer as well as creating new opportunities for the dissemination of key technologies for the African LDCs.

6. Concluding remarks

The analysis in this paper shows that despite the importance of STI, African LDCs are lagging far behind other countries in various STI indicators, including R&D, human resource capacity, patents and innovation. In order for African LDCs to catch-up, they will need to embrace the on-going Technological Revolution, while ensuring that the net effect on the labour market and productivity is positive. This would significantly contribute to eradicating poverty and fostering economic growth in the African LDCs.

The UN Technology Bank has the potential to catalyse the on-going initiatives on STI in Africa. In general, the analysis in Table II show a significant alignment of objectives. This means that the Technology Bank has the potential, once is fully operationalised, to significantly contribute to increasing the African LDCs' access to knowledge, especially if both acting in cooperation with the various African organizations and promoting synergies across them, and between multilateral and regional initiatives. Playing an orchestrating role by harnessing the various African initiatives may produce a useful rationalizing and ultimately a boosting effect on the ground. By doing so its efforts to increase the utilization of knowledge as global public good will be enhanced.

In order to ensure such cooperation, a feedback process between the multilateral level - the Technology Bank - and African STI initiatives should be established. This would entail dialogue across institutions to harness the potential that exists. This principle is also highlighted in STISA-2024 (p. 46) which states that "establishing a healthy, vibrant and

sustainable Innovation Ecosystem, requires clear communication and knowledge sharing between all innovation stakeholders. This serves to reduce duplication of effort, increase research and innovation excellence and properly utilise scientific and technological knowledge to address societal challenges through innovative products, services, processes, business models and policies".

In light of the difficult development cooperation landscape, multilateral institution-building (and its financing) remains challenging. Promoting complementarity of efforts between the new UN institution and African initiatives will certainly help achieve more effective results on the ground, thus showing the added value of the institutional development at the multilateral level in the STI area, which the LDCs have long pursued.

Table II: Coherence and Synergies between the Technology Bank and Select African Initiatives

Select African-specific initiatives that could benefit from the Technology Bank		Technology Bank contribution to enhancing STI in African LDCs, once fully operationalised
Category 1: Support home-grown innovation and research		
STISA-2024	▪ The mission of STISA-2024 is to accelerate Africa's transition to an innovation-led, knowledge-based Economy. This will be achieved by implementing specific policies and programs in STI that address societal needs in a holistic and sustainable way. ▪ Among its strategic objectives is to improve technical competencies and institutional capacity for STI development and promote economic competitiveness through fostering innovation, value addition, industrial development and entrepreneurship in synergy with instruments such as the Action Plan for Accelerated Industrial Development of Africa (AIDA) and Pharmaceutical Manufacturing Plan for Africa (PMPA). ▪ The AU Commission and NEPAD Agency shall mobilize and coordinate resources for technical support in developing and implementing national and regional plans and priority programmes.	▪ The Technology Bank will undertake activities to promote the substantial broadening of access for LDCs to global science and technology communities and the related research conducted worldwide. ▪ For countries without a critical mass of science and engineering R&D capacity, the Technology Bank will work on a multi-country/regional basis, helping countries to pool scientific resources and generate economies of scale in the use of scarce scientific capacity, thereby helping to broaden the array of technological solutions available to them. ▪ The Technology Bank intends to carry out baseline STI and Technology Needs Assessments (TNA) reviews to identify technological gaps and priority needs for each LDC, as a first step towards developing coherent and integrated strategies that are tailored to the specific situation of each LDC. ▪ By building on existing mechanisms such as Research4life, the Technology Bank aims to: ○ Foster knowledge networks and worldwide partnerships between researchers, innovators and entrepreneurs in LDCs and their global peers
Regional initiatives	▪ Shared goals of the regional economic commissions include: developing human resources for STI; encouraging free movement of science and technology personnel; increasing investment in R&D; and creating a culture of science and technology (NEPAD, 2014) ▪ In 2011, ECOWAS adopted a Policy on Science and Technology (ECOPOST). ECOPOST encourages countries to define their own research priorities, so that researchers are working on topics of national interest; develop small research and training units in key industrial fields; establish science and technology parks and business incubators; and, create networks between universities, research institutions and industry to promote collaboration.[31]	

[31] See http://www.esc.comm.ecowas.int/wp-content/uploads/2016/04/ECOWAS-Directive-on-STI-Eng.pdf and https://en.wikipedia.org/wiki/ECOWAS_Policy_on_Science_and_Technology_(ECOPOST).

Research Institutions	▪ The Biosciences eastern and central Africa - International Livestock Research Institute (BecA - ILRI) Hub, a shared agricultural research and biosciences platform aims to increase access to affordable, world-class research facilities for African scientists conducting research on African agricultural challenges.[32] ▪ NEPAD Water Centres of Excellence (WCoE) has a mandate from the African Ministers responsible for Science and Technology and Water in 2006 to assist governments in establishing sound scientific researched policy.[33]	○ Work with the few National Research and Educations Networks (NRENs) which currently exists in African LDCs and coordinate the support for the creation of NRENs where they do not exist (NRENs are high speed data communications networks that are independent of the commercial internet and are dedicated to meeting the needs of academic and research communities). ○ Promote connectivity between institutions, campuses and scientists from LDCs and development partners and facilitate onward connectivity.
Other continental initiatives	▪ The African Union Research Grant programme aims to provide a framework for the African Union Commission to deploy and to improve science and technology research for poverty reduction, economic growth and social development efforts.[34]	
	▪ The African Innovation Summit (AIS) aims to mobilize the people and, especially those with the 'power to act', including investors, the people with the ideas, the policy makers, the researchers and academics, the business community, the youth, as well as innovators and thinkers into a coalition for collective action to promote and build an enabling environment for innovation in Africa. The goal is to engage as many people as possible in order to build a broad constituency in support of innovation in Africa. The summits promote dialogue, facilitate exchange of best practices among stakeholders and African countries, showcase what is happening on the continent, and share lessons of experience. The African Innovation Exhibit which is also part of the AIS provides a stage to showcase homegrown innovations and innovators on the continent.[35]	

[32] See http://hub.africabiosciences.org/
[33] See http://www.nepad.org/programme/nepad-water-centres-excellence
[34] See https://www.au.int/web/en/st-division
[35] See http://www.africainnovationsummit.com/

Select African-specific initiatives that could benefit from the Technology Bank		Technology Bank contribution to enhancing STI in African LDCs, once fully operationalised
Category 2: Build Human Capital and Technical Competence		
Agenda 2063	▪ A call to action to: … Catalyse education and skills revolution and actively promote science, technology, research and innovation, to build knowledge, human capital, capabilities and skills to drive innovations and for the African century.	▪ The Technology Bank intends to support local actors to absorb and integrate appropriate technologies into their daily operations, encourage closer linkages between science and engineering faculties and students on the one hand and business faculties and students on the other, and promote a culture of innovation and entrepreneurship at all levels, starting at the level of secondary school students.
Research Institutions	▪ The African Virtual University (AVU) has established the largest distance and eLearning network in over 27 countries in Sub-Saharan Africa, and produced more than 40,000 graduates. It hosts 219 open educational modules ranging from mathematics and science, teacher education, and ICT skills –available free of charge in English, French and Portuguese. The African Development Bank (AfDB) has been an active partner.[36]	
STISA-2024	▪ To accelerate Africa's transition to an Innovation-led, Knowledge-based Economy, Human Resources in Africa must be empowered with the necessary skills and, greater emphasis must be placed on innovation and on appropriate adaptation of technology and existing research results (Priority 6).	

[36] See https://www.afdb.org/en/news-and-events/african-virtual-university-transforming-africa-into-a-global-knowledge-hub-12187/

Select African-specific initiatives that could benefit from the Technology Bank			Technology Bank contribution to enhancing STI in African LDCs, once fully operationalised
Category 3: Develop R&D networks and promote cooperation			
STISA-2024	▪ STISA-2024 will promote mutually beneficial South - South and North – South cooperation to achieve its ambitious goals. ▪ The private sector will work closely with public, education and research, societal, funding and national and international development agencies to facilitate technology transfer, collaborate in commercializing and exploiting research and innovation and support building the necessary capacities and technical competencies required to achieve the objectives of the Strategy.		The Technology Bank intends to: ▪ Link the local R&D institutes into an expanding network of North-South, South-South, intra-regional and inter-regional knowledge creation networks. ▪ Establish collaborative innovation networks to enable LDC scientists, technologists and relevant public institutions to connect and collaborate with their global STI peers. ▪ Promote cooperation among all stakeholders involved in science, technology and innovation, including researchers, research institutions and public and private sector entities, within and between LDCs, as well as with their counterparts in other countries.
Regional initiatives	▪ The overall objective of Intergovernmental Authority on Development (IGAD) Regional Strategy is to promote research, science and technology agendas by strengthening strategic alliances, linkages and partnerships between regional research institutions and other institutions in the developed countries. IGAD's Research, Science and Technology Programme Area aims at assisting the Member States in their efforts to improve the management and application of research, science and technology for economic development, peace and security and knowledge management.[37]		
Research Institutions	▪ African Union Network of Sciences (AUNS) is a platform where African Scientists, Engineers, Innovators, Inventors and Technology Developers will be able to interact, cooperate, exchange information/knowledge and complement one another in research and academic work.[38]		
	▪ African Scientific Research and Innovation Council (ASRIC) is a pan-African institution aimed at serving as a voice for the African research community in the international arena. It will support knowledge production across various fields of science by formulating research projects and programs that will promote collaborative work among researchers. ASRIC will bring together the scientific community, funding agencies, the private sector, Civil Society and other stakeholders. It will work on the mobilization of resources and harnessing of scientific research and technology as a means to achieving the AU's development plans, objectives, and aspirations. It will also play an instrumental role in the implementation of STISA-2024.[39]		

[37] See https://igad.int/documents/8-igad-rs-framework-final-v11/file
[38] See https://www.au.int/web/en/st-division
[39] See https://www.au.int/web/en/st-division

Select African-specific initiatives that could benefit from the Technology Bank			Technology Bank contribution to enhancing STI in African LDCs, once fully operationalised
Category 4: Intellectual Property			
STISA-2024	▪ One of its strategic objectives is to protect knowledge production (including inventions, and indigenous knowledge) by strengthening IPR and regulatory regimes at all levels.		The Technology Bank intends to: ▪ assist the LDCs in building their national and regional capacities in the areas of International Property Rights (IPRs) and technology related regulations. ▪ facilitate technology transfer on voluntary and mutually agreed terms and conditions and, in the process, help accelerate LDC beneficial integration into the global IP system and technology markets. ▪ act as a conduit between IP holders and relevant actors in the LDCs to facilitate access and use of appropriate IPRs covering desired technologies. ▪ help LDC stakeholders identify, access and use appropriate technologies no longer protected by IPRs.
African Union	▪ The Pan African Intellectual Property Organization (PAIPO) is in the process of being established to implement AU policy in the field of Intellectual property. It will ensure dissemination of patent information, provide technical and financial support to invention and innovation and promote protection and exploitation of research results. ▪ African Union High level Panel on Emerging Technologies will advise the AU and its Member States on harnessing emerging technologies for economic development, make recommendations on the nature of regional institutional arrangements that are required to promote and sustain common regulatory approaches to the application and use of, and propose a strategy and policy on emerging technologies.[40]		

[40] See http://www.nepad.org/nepad-on-the-continent?nid=all&tid=2068&cdp=6361

References

Abbott, Kenneth W., Genschel, Philipp, Snidal, Duncan and Zangl, Bernhard, eds. (2015). International Organizations as Orchestrators, Cambridge University Press.

Africa's Science and Technology Consolidated Plan of Action (2005). Available at: http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/sc_plan_action_en.pdf

African Union (2014). Science, Technology and Innovation Strategy for Africa (STISA-2024). Available at: https://au.int/sites/default/files/newsevents/workingdocuments/33178-wd-stisa-english_-_final.pdf

ACBF (2017). African Capacity Building Foundation. African Capacity Report 2017. Building Capacity in Science, Technology and Innovation for Africa's Transformation.

African Union, Economic Commission for Africa and African Development Bank (2016). Assessing Regional Integration in Africa VII: Innovation, Competitiveness and Regional Integration. Available at http://www.uneca.org/publications/assessing-regional-integration-africa-vii

Archibugi, Daniele and Filippetti, Andrea (2015). "Knowledge a Global Public Good", in The Handbook of Global Science, Technology, and Innovation, Wiley, pp. 479-503.

Blanco, Luisa, Prieger, James and Gu, Ji, (2013). "The Impact of Research and Development on Economic Growth and Productivity in the US States", Pepperdine University, School of Public Policy Working Papers. Paper 48.
Available at http://digitalcommons.pepperdine.edu/sppworkingpapers/48.

Bordoff E. Jason, Deich, Michael, Kahane, Rebecca and Orszag R. Peter (2006). Promoting Opportunity and Growth through Science, Technology and Innovation. Strategy Paper. The Hamilton Project.

Cohen, Wesley M. and Levinthal, Daniel A. (1990). "Absorptive capacity: A new perspective on learning and innovation", Administrative Science Quarterly, Volume 35, Issue 1, pg. 128-152.

Cirera, Xavier, and William F. Maloney (2017). The Innovation Paradox: Developing-Country Capabilities and the Unrealized Promise of Technological Catch-Up. Washington, DC: World Bank.

Cornell University, INSEAD and WIPO (2017). The Global Innovation Index 2017: Innovation Feeding the World. Ithaca, Fontainebleau, and Geneva.

Davis, Nicholas (2017). "What Is the Fourth Industrial Revolution?" World Economic Forum. https://www.weforum.org/agenda/2016/01/what-is-the-fourth-industrial-revolution/

Duller, Hans (1992). “Role of Technology in the Emergence of Newly Industrializing Countries”, ASEAN Economic Bulletin, Vol. 9, No. 1, pp. 45-54

Fu, Xiaolan (2008). Foreign Direct Investment, Absorptive Capacity and Regional Innovation Capabilities: Evidence from China, Oxford Development Studies, 36:1, 89-110

Hjort, Jonas and Poulsen, Jonas (2016). The Arrival of Fast Internet and Skilled Job Creation in Africa. Columbia University and Harvard University.

Lee, Keun, and Byung-Yeon Kim (2009). Both institutions and policies matter but differently at different income groups of countries: determinants of long-run economic growth revisited. World Development, vol. 37, No. 3 (March), pp. 533-549.

Lee, Keun, and Mathews, John (2013). Science, technology and innovation for sustainable development. CDP Background Paper No. 16. ST/ESA/2013/CDP/16.

Lucas, Robert E., Jr. (1988). “On the Mechanics of Economic Development.” Journal of Monetary Economics. 22 (1): 3-42.

Manyika, James, Chui, Michael, Miremadi, Mehdi, Bughin, Jacques, George, Katy, Willmott, Paul and Dewhurst, Martin (2017). A Future that Works: Automation, Employment, and Productivity. McKinsey Global Institute. McKinsey and Company.

Maskus, Keith E. and Reichman, Jerome H., editors (2005). International public goods and transfer of technology under a globalized intellectual property regime. Cambridge (UK): Cambridge University Press.

Nelson, Richard R. and Phelps Edmund. (1966). “Investment in Humans, technological diffusion and economic growth”, American Economic Review, papers and proceedings, 61.

NEPAD (2014). African Innovation Outlook II, available at: http://www.nepad.org/sites/default/files/documents/files/2014_African_Innovation_Outlook.pdf

OECD (2000). Science, Technology and Innovation in the New Economy. Policy Brief, OECD Observer.

Romer, Paul M. (1990). “Endogenous Technological Change.” Journal of Political Economy. 98: 71- 102.

Rodrik, Dani (2015). Premature Deindustrialization, available at: https://www.sss.ias.edu/files/papers/econpaper107.pdf

Ross, Alec (2016). The Industries of the Future. Simon and Schuster Paperbacks.

Schwab, Klaus (2016). The Fourth Industrial Revolution: what it means, how to respond. World Economic Forum. Available at:

https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

Stiglitz, Joseph E. (1999). 'Knowledge as a Global Public Good', in Inge Kaul, Isabelle Grunberg, and Marc Stern (eds.), Global Public Goods: International Cooperation in the 21st Century, Oxford University Press.

The Economist (11 November 2017). Endangered: America's Future as a Global Power.

United Nations (2014). United Nations Secretary-General's High-Level Panel on the Technology Bank for the Least Developed Countries, Feasibility Study for a United Nations Technology Bank for the Least Developed Countries. Available at: http://unohrlls.org/custom-content/uploads/2015/10/Feasibility-Study-of-Technology-Bank.pdf

United Nations (2016). Charter of the Technology Bank. General Assembly resolution 71/363. Available at http://unohrlls.org/custom-content/uploads/2016/09/A_71_363-English-.pdf

UNCTAD (2010). Science, technology and innovation indicators for policymaking in developing countries. Available at http://unctad.org/en/Docs/ciimem1crp1_en.pdf

UNDP (2001) Human Development Report 2001, Making New Technologies Work for Human Development. Oxford University Press: New York.

UNESCO (2010). Science Report 2010: the current status of science around the world. Paris: UNESCO.

UN-OHRLLS (2017a). State of the Least Development Countries 2017: Follow up of the Istanbul Programme of Action for the Least Developed Countries. Available online at http://unohrlls.org/custom-content/uploads/2017/07/State-of-the-LDCs_2017.pdf

UN-OHRLLS (2017b). Leveraging Investments in Broadband for National Development: The case of Rwanda and Senegal. Available online at http://unohrlls.org/custom-content/uploads/2017/07/Leveraging-Investments-in-Broadband-for-National-Development-2017.pdf

UN-OHRLLS and ITU (2018*).* ICTs, LDCs and the SDGs: Achieving universal and affordable Internet in the least developed countries. Available at http://unohrlls.org/custom-content/uploads/2018/02/ICT-LDCs-and-SDGs.pdf

UN-TBLDC (2016). Supporting the operationalization of the Technology Bank for the Least Developed Countries: A 3-year Strategic Plan, 2016, page 1, available at: http://unohrlls.org/custom-content/uploads/2017/01/Strategic-Plan-of-the-Technology-Bank-for-the-LDCs-8-August.pdf

World Bank (1998). World Development Report 1998/1999: Knowledge for Development. New York: Oxford University Press.

The 47 Least Developed Countries (LDCs) are: Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Comoros, Dem. Rep of the Congo, Djibouti, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Haiti, Kiribati, Lao People's Dem. Republic, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Solomon Islands, Somalia, South Sudan, Sudan, Timor-Leste, Togo, Tuvalu, Uganda, United Republic of Tanzania, Vanuatu, Yemen and Zambia.

The United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and the Small Island Developing States (UN-OHRLLS) was established by the United Nations General Assembly in 2001. The Office advocates in favour of the LDCs and mobilizes international support for the implementation of the Programme of Action for the Decade 2011-2020 for the LDCs.