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Anand Kulkarni
Victoria University

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Africa's Knowledge Economy and Links to India

Abstract

Competitive advantage for economies, both developed and developing, will be increasingly based on knowledge in all its forms, including science and technology, smart entrepreneurship, and new business and organizational development models. Due to COVID-19, the need for innovative solutions to health and economic disruptions has never been as keenly felt. This paper is structured in five parts. The first part examines the extent to which various countries in Sub-Saharan Africa participate in the global knowledge economy. Data is drawn from the UN Knowledge Index and canvases knowledge economy parameters such as research and development, value-added industrial production and knowledge-intensive services, advanced education, and entrepreneurship. The second part examines in more depth some of the critical drivers of the knowledge economy, drawing on our own framework. The third part critically examines the key policy documents and visions of select African nations to ascertain progress and performance in the knowledge economy from a policy point of view. The fourth section examines the relationship between Africa and India. India has long-standing links with Africa in economy, culture, and society. This paper examines recent developments in the relationship including trade and student mobility. The final section is the conclusion and provides some strategies and policies for Africa to engage further with the knowledge economy.

Keywords

knowledge, knowledge economy, innovation, economic development, capabilities, technology, research, papers, entrepreneurship

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Keywords: Knowledge; Knowledge Economy; Innovation; Economic Development; Capabilities; Technology; Research; Papers; Entrepreneurship

Introduction

It is increasingly the case that knowledge in all its manifestations is critical to economic prosperity, competitiveness, and wealth creation, and for addressing complex societal and environmental challenges. This is the case for both the developed and developing world. We use a broad concept of knowledge and innovation (used interchangeably) to include the development and diffusion of new and improved products and services, technologies and businesses, and organizational models for commercial gains and/or social purposes (Kulkarni 2019). A range of statistics and reports highlight the growth of research, patents, skilled labor, value added capabilities and new and improved technologies (Kulkarni 2019). The 4th industrial revolution (41R), which is driven by artificial intelligence, robotics, big data, blockchain, the internet of things, nano technology, biotechnology, and life sciences is radically changing industries, technologies and the nature of work (UNESCO 2021). The COVID-19 outbreak, which has had massive and disruptive implications in all corners of the globe and all sectors, has demonstrated the importance of innovation in finding vaccines, developing and deploying specialized equipment, and conducting research to explore the impacts of COVID-19 and the paths back to recovery.

The recent UNESCO report highlights the importance of global collaboration and open science in addressing the challenges of COVID-19. According to the report, the pandemic has heightened the importance of science and evidence; energized knowledge systems, including innovations in equipment, vaccine research and drug production; and promoted greater co-operation and collaboration in the pursuit of rapid response solutions. It also calls for open science and for new mechanisms and approaches, drawing on various COVID related examples, to align science with policy, based on robust evidence, and for communicating science to the community in an iterative fashion (UNESCO 2021).

More broadly, UNESCO outlines the growing importance of science, knowledge and innovation. Global research spending increased by 19.2% between 2014 and 2018, exceeding the growth in global GDP (14.8%), while the number of researchers grew by 13.7%, compared

to growth in global population of 4.6%. International collaboration in publications rose from 22% to 24% between 2015 and 2019. Total publications grew by 21% between the same period, with 30% growth in publications in key cross-cutting technologies (AI, robotics, biotechnology, energy, materials, nanoscience and nanotechnology and opto electronics). The report also notes surges in patents and internet usage as key drivers of the knowledge economy (UNESCO 2021).

However, these changes are masking several key factors. Firstly, China alone accounted for almost half of the growth in research investment in the world, 44%, between 2014 and 2018, followed by the US and Europe. Thus, the global innovation system is becoming more inequitable. 80% of countries still invest less than 1% of their GDP on R&D. The high-income country average of Gross Expenditure on Research and Development (GERD)/GDP is 2.4%, and high-income countries account for two-thirds of the share of global GDP. China alone accounts for more than one-fifth of global researchers. The G20 countries still account for nine-tenths of research expenditure, publications and patents (UNESCO 2021).

Structure

This paper is structured in five parts: The first part looks at overall innovation performance, as reflected in the UN Global Knowledge Index for 2020, canvassing the African nations of Botswana, Kenya, Rwanda, South Africa, Uganda, Nigeria, and two benchmark countries, India and the US. Note that Nigeria is not featured in the UN Global Knowledge Index but is included in other data that we draw on. These countries are chosen based on their development levels. India and the US are medium-income and high-income countries, respectively. The second part looks at a more detailed analysis of key selected data based on a framework that we have developed for identifying and understanding knowledge. The third section considers policies related to the knowledge economy and economy more broadly, for three countries: Uganda, Kenya and South Africa. The fourth section looks at key economic relationships between African nations and India, one of our benchmark countries. The final section is a brief conclusion that spells out our suggested priorities for African nations to enhance the knowledge economy.

Broad Knowledge Performance

Table 1 *UN Global Knowledge Index 2020 (138 countries): Rank and Score (in bracket)*

	Overall	Pre-University	Technical/ Vocational	Higher Ed	Research, Development, and Innovation	ICT	Economy	General Enabling
Botswana	91 (41.4)	103 (50.6)	22 (61.8)	99 (32.4)	91 (17.4)	104 (38.5)	92 (36)	72 (58.6)
India	75 (44.4)	105 (49.9)	38 (55.7)	70 (38.9)	44 (27.3)	76 (52.1)	75 (40.6)	113 (47.5)
Kenya	88 (42)	86 (56.2)	54 (52.3)	98 (32.6)	64 (21.3)	80 (50.9)	109 (32.5)	102 (51.4)
Rwanda	99 (39.9)	115 (45.4)	48 (53.2)	118 (29.2)	73 (20.2)	94 (44.8)	100 (34.5)	73 (58.3)
South Africa	71 (41.5)	98 (52.2)	83 (47.4)	58 (42.3)	52 (25)	68 (55.6)	67 (41.5)	86 (55.3)
Uganda	119 (33)	128 (32.3)	104 (44.2)	103 (31.7)	120 (13.1)	113 (34.4)	108 (32.7)	112 (47.6)
US	2 (71.1)	57 (63.2)	1 (92.3)	8 (57.8)	4 (64.3)	1 (86.5)	9 (61.1)	31 (73.5)

Source: UN Global Knowledge Index (UNDP) 2020

The UN Global Knowledge Index measures knowledge and innovation across the following pillars and examples of metrics (UNDP 2020):

- **Pre-University Education**: enrollment, completion, government expenditure, teaching qualifications and pupil-teacher ratios.
- **Technical and vocational education and training**: continuous training, expenditure and enrollment, work force ethic, ease of finding employees, and number of technicians.
- **Higher Education**: Government expenditure, enrollment, pupil-teacher ratios, researchers in higher education, undergraduate and postgraduates, labor force with advanced education and unemployment with advanced education, university-industry collaboration, ranked universities (and enrollment in globally ranked universities) and inbound student mobility.
- **Research, Development and Innovation***: R&D inputs* (GERD, STEM graduates, high technology inputs); *R&D outputs* (documents, citations, patents, quality of research institutions); *Innovation in production* (GERD performed and financed by business, researchers in business, Foreign Direct Investment (FDI) and technology transfer, intellectual property receipts, industrial design applications, production process sophistication and extent of marketing); *social innovation inputs and outputs* (ease of protecting minority investors, ICT goods imports and exports, computer software spending, trademark applications, feature films produced, printing and publishing manufactures)
- **ICT***: inputs* (infrastructure such as population covered by mobile subscriptions, international internet bandwidth, secure internet servers); *sector competitiveness* (price, competition, laws relating to ICT); *outputs* (mobile and fixed subscriptions, internet users, virtual social networks, business to consumer usage, firm level technology absorption, Government ICT promotion and online service).
- **Economy**: *economic infrastructure and competitiveness* (ease of starting a business and enforcing contracts, investment, competition); *competitiveness drivers* (FDI, entrepreneurship, venture capital, investment in telecom services); *economic openness* (creative goods and services exports*); trade*; *finance and value added (*taxes, banking and finance, manufacturing value added, high skilled employment).
- **General enabling environment:** *Political and Institutional* (political stability and Government effectiveness, judicial independence, regulatory quality and world press freedom index); *socioeconomic* (women to men in parliament and in the labor force, educational attainment); *empowerment* (literacy, mean years of schooling, unemployment, GDP per capita, youth not in employment or education and training); *Health and Environment* (mortality rate, life expectancy at birth, Co2 emissions, energy intensity and renewable energy consumption).

As can be seen from Table 1, the US is number 2 in the world, with an overall score greater than the world average (46.7). It is characterized by strengths across the board, which are necessary for a strong knowledge and innovation eco-system. There are areas for improvement, notably in pre-university. For other countries, South Africa performs better overall than its BRICS counterpart in India. There are some emergent strengths in African nations. These strengths are patchy when looked at in totality. The foundations in pre-university education are not strong universally. However, technical/vocational education shows promise. Results for research, development, and innovation are more mixed, with Kenya, Rwanda, and South Africa ranked above their overall ranking in this category, but Botswana on par and Uganda below its overall ranking. In broad terms, ICT, the general economy, and the enabling environment require attention. ICT is among the weakest performers for the African countries in question.

The following table highlights the key strengths and weaknesses at a more detailed level. Further details can be found in Table 1, Appendix 1.

Table 2 *Knowledge Strengths and Weaknesses*

	Reasonable Strengths	Weaknesses
Botswana	Govt. expenditure on secondary education, enrollment in vocational programs, new business density, creative services exports, mobile cellular subscriptions.	Labor force ethic, ICT laws, business-to-consumer internet use, women-to-men in parliament, manufacturing value added, social impact of ICT, Government online service index.
Kenya	Ease of protecting minority investors, printing and publishing manufactures, international internet bandwidth, internet and telephony level of competition, labor force female to male.	Pupil-teacher ratios in primary and secondary, fixed telephone subscriptions, trade, political stability/terrorism, energy intensity level of primary energy.
India	Expenditure on non- tertiary vocational education, enrollment in vocational post-secondary and non-tertiary, STEM graduates, citable documents, ranking of universities, internet and telephony level of competition, enrollment in tertiary ISCED 6.	Gender issues, trade, fixed telephone subscriptions, new business density, unemployment with advanced education, enrollment in secondary vocational, mean years of schooling, labor market freedom.
Rwanda	Gross enrollment primary, expenditure on non- tertiary vocational education, enrollment in vocational post-secondary non-tertiary, renewable energy consumption, government success in ICT promotion, GERD per researcher, internet and telephony level of competition, female labor force participation, pupil teacher ratio.	Mean years of schooling, press freedom, private sector credit, mobile cellular subscription, fixed telephone subscription, ICT prices, bandwidth for international internet, internet use, unemployment with advanced education, pupil teacher ratios, researchers, STEM graduates, documents, patents, highly skilled employees, Early Childhood Education gross enrollment, gross enrollment in upper secondary, low number of technicians.
South Africa	Teacher qualifications, enrollment in vocational post-secondary non tertiary, mobile cellular subscriptions, printing and publishing manufactures, women in parliament.	Unemployment, youth not in employment, education or training, CO2 emissions, energy intensity, fixed telephone subscriptions and fixed broadband, unemployment with advanced education, poor work ethic, pupil teacher ratio.
Uganda	Labor freedom, documents per researcher, citations-per-document, internet and telephony level of competition, unemployment, CO2 emissions, renewable energy.	Trade, credit to private sector, energy intensity, ICT metrics, pupil teacher ratios, Government expenditure on secondary education.
US	Universities, research, IP receipts, new business density, internet and telephony level of competition, ICT laws, ease of finding skilled employees, finance sector, technology absorption.	Co2 emissions, energy intensity, renewable energy, trade, investment in telecoms, gross fixed capital formation, work ethic, enrollment in tertiary ISCED 6.

Source: Adapted by author from UNDP 2020

This table reveals a mixed bag from which it is hard to draw definitive statements of commonality. If pressed, it would be reasonable to say that emergent strengths for African nations include enrollment in vocational education, competition in ICT markets and some broader ICT capabilities, printing, and publishing manufactures, and, to some extent, renewable energy. Common weaknesses are mostly in labor market-related areas, including unemployment, education capabilities, gender issues and trade matters.

Framework[1]

[1] In this part we draw on multiple data sources rather than necessarily any reports from which data emerges, as appropriate. The interpretation of the data is the author's, and all data compilation was completed in August 2021.

With the backdrop of the UN Knowledge Index in mind, we develop a comparable framework, with various supporting metrics, to further assess progress towards a knowledge economy. These framework elements are knowledge resourcing, access and opportunity; knowledge capability; knowledge relationships; knowledge supports; and knowledge translation and transformation.[2]

Knowledge Resourcing, Access, and Opportunity

In knowledge resourcing, access and opportunity, we consider research expenditure (performed), gross enrollment ratios, and educational expenditure. These are all important elements in the overall resourcing and access to education and research.

Table 3 *Gross Expenditure Research and Development (GERD) 000's $PPP constant 2005 prices*

	2013	2014	2015	2016	2017	2018
Botswana	159,927.6					
Kenya						
Rwanda				120,409.2		
SA	4,282,637.7	4,640,158.9	4,861,833.5	5,005,723.9	5,159,134.7	
Uganda		67,725.1				
Nigeria						
India	39, 673, 216.3	42, 321, 459.5	45, 152, 571.8	47, 240, 178.6	50,256,014.5	52, 298, 735.0
US	390, 752, 685.8	401, 740, 360.2	413, 036, 237.7	426, 307, 669.6	444, 589, 642.1	460, 108, 210.8

Source: UNESCO Statistics

The patchy data (Table 3) suggests that GERD is growing across many countries, including South Africa, India, and the US. South Africa has been consistently higher than India, another of the BRIC countries. South Africa, India and the US outweigh the other nations considerably.

Overwhelmingly, in the US, research is concentrated in the business sector (Table 4). This reflects the economic drivers of research, and the fact that the business sector is comprised of leading edge, innovative firms. There tends to be a close correlation between the size of a country's research intensity and its innovation performance. In most countries with a high research intensity, the business sector contributes more than half of the research expenditure (UNESCO 2021). Furthermore, according to UNESCO, businesses are often unwilling to collaborate with public research bodies. Governments are developing new incentives to foster technology transfer, including laboratories where business "test before they invest" (UNESCO 2021, pg.31). The business sector in African nations (and in India) perform R&D far less in share terms than the US.

In the non-business domain, there are variations (Tables 5 and 6). For example, in Botswana, South Africa and Uganda, research performed is dominated by higher education, whereas in Rwanda and India, it is dominated by government. Unlocking the research in government and higher education towards more commercial orientation is a key challenge in African nations, as part of fully functioning, fully integrated business systems.

Aligned to this is the need to improve GERD/GDP (Table 7). The average GERD/GDP for wealthy countries is 2.4% (UNESCO 2021). 2% is generally an aspirational target. Many African nations fall well short of this level. As is to be expected, given its higher level of development, South Africa leads the field in GERD/GDP and has grown over time, but is well short of the US figure (which has also grown). Interestingly, and of concern, is that India's GERD/GDP has fallen over time, indicating that overall, India is expending less resources relative to its wealth on research.

Table 4 *GERD performed by business 000's $PP constant 2005 prices: Share of total GERD (in bracket)*

[2] Analogous to Kulkarni 2019

	2013	2014	2015	2016	2017	2018
Botswana	28,277.8 (17.7%)					
Kenya						
Rwanda				8,226.4 (6.8%)		
SA	1,966,505.95 (45.9%)	2,101,624.5 (45.3%)	2,077,090.4 (42.7%)	2,072,983.9 (41.4%)	2,112,860.9 (40.95%)	
Uganda		2,936.8 (4.36%)				
Nigeria						
India	15,255,581.7 (38.5%)	15,742,746.0 (37.2%)	14,999,561.1 (33.2%)	15,818,466.7 (33.5%)	16,280,379.2 (32.4%)	19,240,344.6 (36.8%)
US	277,093,907.4 (70.9%)	287,294,792.3 (71.5%)	296,846,593.0 (71.9%)	309,202,828.5 (72.5%)	324,018,114.2 (72.9%)	333,929,792.3 (72.6%)

Source: UNESCO Statistics

Table 5 *GERD performed by Govt 000's $PP constant 2005 prices: Share of GERD (in bracket)*

	2013	2014	2015	2016	2017	2018
Botswana	21,002.6 (13.1%)					
Kenya						
Rwanda				93,633.3 (77.8%)		
SA	1,001,658.7 (23.4%)	1,090,691.8 (3.5%)	1,165,804.9 (23.98%)	1,154,885.0 (23.1%)	1,150,971.4 (22.3%)	
Uganda		31,892.2 (47.1%)				
Nigeria						
India	22,412,848.6 (56.5%)	23,911,492.2 (56.5%)	25, 229, 500.5(55.9%)	26,157,033.4 (55.4%)	28,338,878.98 (56.4%)	29,343,536.5(56.1%)
US	44,994,425.7 (11.5%)	45,621,058.5 (11.4%)	45, 605, 559.7 (11.0%)	43,325,614.0 (10.2%)	43,835,062.9 (9.9%)	47,680,746.95 (10.4%)

Source: UNESCO Statistics

Table 6 *GERD performed by Higher Education 000's $PP constant 2005 prices: Share of GERD (in bracket)*

	2013	2014	2015	2016	2017	2018
Botswana	80,875.9 (50.6%)					
Kenya						
Rwanda				9,489.2 (7.9%)		

SA	1,217,145.4 (28.4%)	1,324,699.6 (28.5%)	1,484,954.5 (30.5%)	1,635,140.5 (32.7%)	1,733,257.9 (33.6%)	
Uganda		31,146.5 (45.98%)				
Nigeria						
India	2,004,786.1 (5.1%)	2,667,221.2 (6.3%)	2,883,247.96 (6.4%)	3,156,166.0 (6.7%)	3,436,936.5 (6.8%)	3,714,853.96 (7.1%)
US	52,876,955.6 (13.5%)	52,571,385.4 (13.1%)	53,912,268.8 (13.1%)	55,950,870.1 (13.1%)	57,701,966.9 (12.98%)	59,117,923.4 (12.8%)

Source UNESCO Statistics

Table 7 *GERD/GDP (%)*

	2013	2014	2015	2016	2017	2018
Botswana	0.54					
Kenya						
Nigeria						
Rwanda				0.65		
SA	0.72	0.77	0.80	0.82	0.83	
Uganda		0.14				
India	0.71	0.70	0.69	0.67	0.67	0.65
US	2.71	2.72	2.72	2.76	2.82	2.83

Source: UNESCO Statistics

Table 8 *GERD per researcher 000's PPP constant prices 2005*

	2013	2014	2015	2016	2017	2018
Botswana	418.66					
Kenya						
Nigeria						
Rwanda				744.46		
SA	183.44	196.85	185.85	181.00	174.80	
Uganda		65.89				
India			159.55			153.00
US	301.89	299.78	301.61	310.70	309.94	

Source: UNESCO Statistics

GERD per researcher (Table 8) reveals some interesting findings from a resourcing point of view. It shows considerable variation among African nations, with Uganda lagging behind. Other countries for which time series are available show declining performance, apart from the US. South Africa and India must make do with less resources per researcher. Expenditure has not kept pace with growth in the number of researchers.
Researchers per 1000 full-time equivalent (Table 9) show that the US is the standout, as is to be expected, and has improved slightly.

Except for South Africa, which is nearing parity, all other countries for which data is available show a significant male bias in the share of researchers. This is part of a bigger concern globally. The UNESCO report points out that globally, women comprised 33.3% of researchers in 2018. This has improved over time, from only 28% in 2013, but this improvement is subject to considerable country variation. Women represent only 22% of professional workers in AI and 19% of inventors. Men are more likely to be over-represented in the business sector and venture capital is harder to obtain for females. Women represent only 28% of total graduates in engineering and 40% in computer science. However, women have reached parity in life science graduations. Globally, women have been disproportionately impacted by automation and are more at risk of missing out on jobs on the future (UNESCO 2021).

Many countries reporting the lowest proportion of women researchers in engineering and technology are African. In a survey of 7,513 African scientists, the largest gap in gender mobility was in the field of engineering and applied technology. 85% of women but 63% of men had obtained a Ph.D. in Africa and only 23% of female respondents studied or worked abroad in the past 3 years. Mobile female researchers were more likely to undertake international collaboration than non-mobile ones and more likely to receive research funding (UNESCO 2021).

The data presented here pre-dates COVID-19. However, globally, COVID-19 has disproportionately affected women in science and engineering in terms of job security and prospects, funding for projects, and research time, even though women have been at the forefront in many cases of crisis responses to COVID-19.

Table 9 *Researcher per 1000 employment FTE*

	2013	2014	2015	2016	2017	2018	2019
Botswana	0.5						
India			0.6			0.7	
Kenya							
Nigeria							
Rwanda							
SA	1.5	1.5	1.6	1.7	1.8		
Uganda		0.1					
US	8.8	8.9	9.0	8.9	9.1		

Source: UNESCO Statistics

Enrollment

If we turn to Gross Enrollment Ratios (GER), which are vital for the Resourcing, Access and Opportunity pillar in our framework, gross enrollment ratios have generally increased in tertiary education (Table 10) but are well short of the levels of the US. While arguably, lower GER could be a sign that potential students are taking up employment or establishing their own businesses, there are serious questions on this, given youth unemployment challenges, and lagging labor force participation. There are also concerns though about the "drying up" of the pipeline of potential students. Upper secondary gross enrollment (Table 11), as the immediate entrée to higher education, also is lower for African countries (bar South Africa) when compared to India and the US. A whole-education approach, which examines the inter-relationships between the various tiers of student activity, is needed. Arguably, the high proportion of informal enterprises, social norms relating to female engagement, and participation and economic imperatives to address household finances could all be influencing the weaker gross enrollment in upper secondary.

For the most part, South Africa excepted, GER is higher for males than females, although GER is on the rise for females. Earlier, we drew on UNESCO data to outline that, globally, female researchers were underrepresented, compared to male researchers. Weaker gross enrollment ratios are one of several reasons for this.

Within tertiary secondary enrollment, we note that there is a sharp drop off in the African nations from enrollment in undergraduate to post graduate. Thus, there is potentially a constraint in the more specialized, research-oriented studies and capabilities that post-graduate courses and Ph.D.'s confer.

Table 10 *Gross Enrollment Ratio Tertiary both sexes (%)*

	2014	2015	2016	2017	2018	2019
Botswana	27.31	30.24	25.91	24.86		25.08
India	25.43	26.77	26.83	27.44	28.06	28.57
Kenya		9.23	11.43	11.46		
Nigeria						
Rwanda	7.39	7.61	7.67	7.37	6.73	6.24

SA	19.81		20.92	22.37	23.80	
Uganda	4.84					
US	88.63	88.89	88.84	88.17	86.30	

Source: UNESCO Statistics

Table 11 *Gross Enrollment Upper Secondary both sexes (%)*

	2014	2015	2016	2017	2018	2019
Botswana						
India	63.70	63.45	65.36	63.52	65.84	66.13
Kenya						
Nigeria	39.49	44.01	38.61			
Rwanda	32.34	32.03	30.48	30.19	30.58	31.76
SA		111.76	109.87	106.06	99.94	
Uganda						
US	93.99	94.74	95.67	95.67	96.53	

Source: UNESCO Statistics

Expenditure

We also consider government expenditure on education as a share of GDP (Table 12). Drawing on limited data, we observe that South Africa has a higher ratio than the US, as does Kenya. Uganda which lags considerably in this regard, and Rwanda lags to a lesser extent. However, as a share, more expenditure is going to tertiary education in the US compared to African nations, reflecting the greater level of development, its much stronger knowledge economy orientation, and the higher cost of tertiary education. African nations are still at the stage of spending on foundational elements. Of course, this data does not capture the significant privatization that is evident in the US, and increasingly in African nations.

Table 12 *Government expenditure on education/GDP (%)*

	2014	2015	2016	2017	2018	2019
Botswana						
India						
Kenya	5.28	5.27	5.36	5.37	5.31	
Nigeria						
Rwanda	4.18	3.63	3.42	3.11	3.07	
SA		5.96	5.94	6.11	6.16	6.51
Uganda	1.93	2.34	2.16	2.27	2.13	
US	4.96					

Source: UNESCO Statistics

Knowledge Capabilities

Graduates

Knowledge capabilities in our framework represent the core assets related to the knowledge economy which a country possesses. In this paper, we examine graduates from tertiary education, publications, researcher productivity and quality of tertiary institutions. First and foremost, as shown in Table 13, is the weakness in African nations of gross graduates from first degrees. This reflects the limited overall educational attainment of the population (not in tables), which constrains capabilities. Of concern is the weak share of graduates in health disciplines, agriculture, and ICT among African nations. COVID-19 has demonstrated the importance of health professionals while agriculture continues to be a vital sector. To promote innovation capabilities and its diffusion, a strong performance in ICT is required, and graduates are key to this.

If we further consider graduates from tertiary education by discipline, we find some interesting results. African nations are broadly comparable with the U.S. South Africa exceeds the US in the proportion of graduates in the STEM (Science, Technology, Engineering and

Mathematics) field, which is essential in our view for a knowledge economy (Table 14). India is also a leader in the proportion of STEM graduates out of total graduates. However, two cautionary points must be made. First, this data is not qualitative and therefore says little about the employability of graduates (which policy makers are turning their attention to), nor is it a raw quantum measure. Secondly, African nations are not represented significantly in arts and humanities. These fields are arguably important for a broad-based, multidisciplinary approach that captures the interdependencies and synergies across knowledge spaces. The "STEAM" (Science, Technology, Engineering, Arts and Mathematics) agenda appears to be missing in the case of Africa. Graduates from education and business, law and administration and social sciences are more pronounced than in sciences and engineering for African countries, and would, among other things, reflect the cost of degrees and specialist capabilities in their delivery. Interestingly, despite its strong performance globally in many segments of ICT, the share of graduates in ICT out of total graduates does not feature prominently in India.

Table 13 *Gross Graduation rate from Tertiary ISCED 6,7 First degree programs both sexes %*

	2014	2015	2016	2017	2018	2019
Botswana	7.49					
India	26.31	28.59	28.43	27.92	27.66	27.99
Kenya						
Nigeria						
Rwanda				8.44	7.43	5.86
SA	8.05	8.82	9.72	10.26	10.94	
Uganda						
US	15.76	17.37	17.92			

Source: UNESCO Statistics

Table 14 *% of STEM graduates out of total graduates (both sexes)*

	2014	2015	2016	2017	2018	2019
Botswana						
India	30.53	31.08	31.73	32.64	32.65	32.17
Kenya			16.48			
Nigeria						
Rwanda				13.75	16.27	12.96
SA	19.55	19.59	18.49	18.57	18.28	
Uganda						

Source: UNESCO Statistics

Papers

Consistent with the rising intensification of the knowledge economy is the growth over the last five years in papers produced by all countries (Table 15). The US is second now in number of papers produced, and India is fourth. African countries have seen papers grow very significantly, but from a low basis. Of importance is that African countries hold their own when considering the quality of papers, as represented by the proportion of papers produced in the top 1% most cited (Incites database but not shown in table). Therefore, the issue is not necessarily of *quality,* but of *volume*.

Table 15 *Papers**

	2015	2016	2017	2018	2019	2020	% Change 2015-2020
US	573,187	579,300	587,114	598,794	603,668	624,554	8.96%
India	132,961	142,993	142,731	165,270	182,018	191,590	44.1%
SA	18,618	20,520	21,958	23,534	26,200	28,365	52.4%
Nigeria	5,765	6,508	7,183	9,009	11,103	13,282	130.4%

	2015	2016	2017	2018	2019	2020	% Change 2015-2020
Kenya	2,387	2,572	2,812	3,040	3,401	4,110	72.2%
Botswana	378	561	557	679	709	800	111.6%
Rwanda	296	328	361	450	504	715	141.6%
Uganda	1,359	1,420	1,634	1,681	1,891	2,259	66.2%

** Citable documents, articles, reviews, conference papers*
Source: Sci Mago

Researcher productivity is an important demonstration of capability. Our calculations (Table 16) show that African countries perform well on researcher productivity relative to India and the US and have improved over time. The issue, therefore, for African nations is more about the small scale of papers and low number of researchers. The US has the lowest productivity of the countries that we note, and along with India has remained static.

Table 16 *Researcher productivity (papers per researcher)*

	2015 or nearest year	2018 or nearest year
Botswana	0.98	
India	0.47	0.48
Rwanda	1.76	2.78
SA	0.71	0.79
Uganda	1.32	
US	0.42	0.42

Source: Author calculation from Sci Mago and UNESCO Statistics

The following table (Table 17) shows the top 3 publication outputs by subject area in 2020. As is to be expected, medicine dominates the output by papers for the countries in question, except for India, in which engineering is pre-eminent. However, social sciences are second in African nations, except for Kenya. African countries are not necessarily focusing their publications on fields directly and explicitly linked to the knowledge economy, which is driven in large measure by STEM fields. This, in turn, is related to the distribution of graduates by field of discipline, discussed in the previous section.

Also related is the number of researchers by field. In Rwanda, where data is available from UNESCO Statistics, more than 20% (and upwards of 40% five years ago) of researchers were found to be in social sciences, as distinct from medical and health, which accounted for just 3.2% of researchers by discipline (down from 19.7%) a few years earlier.

Table 17 *Top 3 papers by subject 2020*

US	Medicine	Chemistry	Engineering
SA	Medicine	Social Sciences	Agricultural and Biological Sciences
Nigeria	Medicine	Social Sciences	Engineering
Kenya	Medicine	Agricultural and Biological Sciences	Social Sciences
Uganda	Medicine	Social Sciences	Agricultural and Biological Sciences
Rwanda	Medicine	Social Sciences	Environmental Science
Botswana	Medicine	Social Sciences	Environmental Science
India	Engineering	Chemistry	Medicine

Source: Sci Mago and Author assessment

University Rankings

University rankings, despite their flaws, are an indication of quality, through their focus on research and teaching, including reputation. From the available evidence (Table 18), we can see that, while there is some improvement, greater improvement in African countries is needed. South Africa has progressed the furthest, having 11 ranked institutions, with a best place of 155. Generally, any institution in the top 200 is considered a leading institution. South Africa has one ranked institution in the top 200, and the rest of the 11 ranked institutions broadly ranked across the remaining categories (i.e. 1 between 201-250, 1 between 251-300, 1 between 351-400, 1 in the 401-500 range, 1 in 501-600 category, and slightly more towards the back end with 3 between 601-800 and 2 from 1001+). The gulf in this domain, possibly South Africa excepted, is most pronounced given that the US led the world in 2021 with 181 ranked institutions, (followed by the UK 101 and China 91), the best being Stanford University at number 2. India too has made considerable strides, with growth in the number of ranked institutions from 49 in 2019 to 63 in 2021.

Table 18 *Times Higher Education Rankings (number of ranked institutions placed in bracket)*

	2021 (1526 globally ranked institutions)	2020 (1397)	2019 (1258)
Botswana	1 (10001+)		
India	63 (301-350)	56 (301-350)	49 (251-300)
Kenya	1 (601-800)	1 (801-1000)	1 (10001+)
Nigeria	6 (401-500)	4 (401-500)	3 (601-800)
Rwanda			
SA	11 (= 155)	10 (=136)	9(=156)
Uganda	1 (401-500)	1 (601-800)	1 (501-600)
US	181 (2)	172 (2)	172 (3)

Source: Times Higher Education World University Rankings

When considering the scores that underpin the rankings (Table 19) and average the scores for the top five universities, we find a mixed picture. Firstly, we may note the outstanding performance of US institutions across the criteria. We do find some positive messages for African nations, including citations and industry income. However, we find less positivity in research patterns, which are measured by research productivity, research income, and research reputation. International outlook, as measured by the proportion of international students and staff, is reasonably solid for African nations (and certainly stronger than India), possibly reflecting the growing mobility of students and staff within the African continent. It appears that, while ranked African institutions perform solidly in relation to several criteria once they meet thresholds to become ranked, there is a significant challenge in producing more ranked institutions. It should also be noted that for 2021, only one university in Botswana, Uganda and Kenya was ranked, and so these numbers were used, while Rwanda has zero ranked institutions.

Table 19 *Times Higher Education 2021 Top 5 average*

	Overall	Teaching	Research	Citations	Industry Income	International outlook
Botswana: Uni of Botswana (1001+)	10.3-25	16.0	10.8	13.7	33.6	66.0
Kenya: Uni of Nairobi (601-800)	30.2-36.3	13.4	8.3	68.7	33.4	46.6
Uganda: Makere Uni. (401-500)	39.8-43.5	18.3	24.7	68.7	100	54.7
India		38.5	26.2	59.0	51.8	18.9
Nigeria		18.4	11.3	67.3	36.4	30.1
Rwanda						

SA		26.9	32.5	83.4	67.1	60.3
US		91.1	96.8	99.0	80.9	80.6

Source: Author Calculations based on Times Higher Education World Rankings

Knowledge Relationships

Knowledge relationships refer to the collaboration and linkages that countries and agencies undertake in pursuit of joint discovery, to capitalize and leverage complementary capabilities and to defray costs and risks. In many ways, it is tied up with the notion of innovation systems.

Collaborative Papers

The growing interdependence of scientific endeavors around the word is captured in the increasing collaboration by papers, according to Sci Mago data (Table 20). Every country has increased collaboration. African countries are more likely to engage in international collaborative research than the US and India. African researchers might engage in collaboration more often to leverage the knowledge and capabilities of more advanced economies. In addition, it possibly reflects brain drain, to an extent, with researchers holding multiple affiliations across national boundaries.

Table 20 *International collaborations (% of papers)*

	2015	2016	2017	2018	2019	2020
US	31.41	32.89	34.66	36.16	37.83	39.64
India	15.65	16.07	17.92	18.04	18.46	21.08
SA	47.58	48.63	50.94	52.55	52.7	55.46
Nigeria	37.26	40.67	43.22	43.63	47.39	49.96
Kenya	75.1	75.61	76.55	76.68	78.5	78.28
Botswana	64.98	68.84	71.05	71.89	78.85	77.95
Rwanda	87.99	84.51	88.52	88.2	87.99	90.64
Uganda	79.97	79.32	80.37	81.93	80.96	82.43

Source: Sci Mago

The table below (Table 21) also shows that the percentage of industry collaboration is the highest in the US, reflecting the business orientation of the US. The African nations are generally better than India on this score. Industry collaborations are vital for bringing ideas to the market and commercializing know-how. Previously, we indicated that there is reluctance for business to collaborate with public sector agencies. This could be due to mismatched objectives, costs, and risks of collaboration.

Table 21 *Industry Collaboration (% of papers)*

	% Industry collaboration
Botswana	1.12%
SA	1.21%
Uganda	1.55%
Nigeria	0.66%
Kenya	1.76%
Rwanda	1.56%
USA	3.33%
India	0.77%

Source: Incites

There are also tentative signs of an emerging intra-African innovation sphere, with African countries increasingly collaborating with each other. South Africa is looming as a hub for collaboration with other countries. South Africa is the number one collaborator for

Botswana and is in the top 3 for Uganda, Rwanda and Kenya, based on Scopus data not shown in the table. However, to be sure, the UK, US, and to a lesser extent Germany and Australia continue to be key collaborators for African nations. There is some evidence that India is becoming a significant collaborative partner for African nations. India is in the top 10 partners for Botswana, Nigeria and South Africa, but below levels of collaboration on papers that Africa has with Europe and the US. There is evidence of collaboration between African nations and China. Four countries--Nigeria, South Africa, Rwanda and Kenya--have China in their top ten.

Knowledge Supports

ICT

Knowledge Supports relate to the fundamental enablers of a knowledge economy. These are the foundational aspects that support an economy and its agents to plan with certainty and invest, and include key infrastructure, as well as regulatory and institutional underpinnings. While several metrics could be canvassed, we focus on the Network Readiness Index (NRI) which canvasses investment in, and application of, ICT (Dutta and Lanvin 2020). ICT in all its domains of infrastructure, regulatory environment, access, content, skills and usage are key underpinnings of a knowledge economy. The NRI has the following elements:

- Technology (access, content and future technology)
- People (individual, business and government usage and skills)
- Governance (trust, regulation and inclusion)
- Impact (economy, quality of life and contribution to UN Sustainable Development Goals)

Table 22 *Network Readiness Index rankings 2020 (134 countries)*

	Overall	Technology	People	Governance	Impact
Botswana	99	91	102	99	105
Kenya	82	99	78	51	104
India	88	76	84	84	108
Rwanda	96	100	97	95	103
Nigeria	117	124	99	112	125
SA	76	64	83	52	109
Uganda	114	112	121	90	129
US	8	4	7	8	14

Source: Dutta and Lanvin 2020

Overall, as is to be expected, most of the African nations are at the rear end of the scale (Table 22). The US and South Africa lead the field, although there is a very significant gap between them. The weakest areas among the African countries are impacted i.e., the extent to which ICT has strengthened the economy, quality of life, and UN Sustainable Development Goals (SDG's). Conversely the Governance pillar shows tentative promise as African countries, especially Kenya and South Africa, have attempted to provide stable and supportive regulatory environments. Technology and people parameters, in terms of access, content, and future technologies, and the people pillar including individual, business and government usage, and skills and promotion, continue to require attention. South Africa, Uganda, India, Rwanda, Kenya and the US possess Knowledge Supports above what their level of development would imply, while Botswana and Nigeria are underachieving (Dutta and Lanvin 2020).

The following is the author's assessment of the NRI data. South Africa has apparent strengths in the Future Technologies sub-pillar, legislation, and, to some extent, in the Business and Government sub-pillar. Trust and regulation are solid, as is gender equality. Key weaknesses are ICT skills, professionals in the workplace, quality of life metrics, and affordable and clean energy.

Uganda, reflecting its level of development, has a myriad of weaknesses across the board, most notably in the people pillar, access to technology, quality of life, and the UN SDGs. It has some very niche strengths, such as the ICT regulatory environment and the rural gap in the use of digital payments. Nigeria, like Uganda, is only strong in a few areas—notably, the medium

and high technology industry and 4e world on technicians. Nigeria and Uganda have core weakness across the spectrum, especially in access to technology, individual usage of ICT's and inclusion. Contribution to the UN's SDGs is also a concern. Botswana, by contrast, has strong performance in two SDGs, notably, gender equality and affordable and clean energy, as well as some ICT regulatory parameters and handset prices. Its main weakness appears to be in the quality of life and the economic impact of ICT. Rwanda's future technologies show promise, as does the government's promotion of ICT and online services. Its role as an emerging technology destination is evident in high technology exports, but weaker in the People pillar (internet users, mobile subscriptions, virtual social networks) and in the Technology Pillar, relating to access. Trust parameters are, to some extent, a weakness, as is a contribution to Gs on good health and well-being.

Kenya has a wider set of capabilities among the African countries, including international internet bandwidth, e-commerce legislation, gig economy, business use of digital tools and R&D expenditure by government and higher education. Its growing role as a finance hub is reflected in online access to financial accounts. Most of its weaknesses fall in the People pillar, namely in internet usage, use of virtual social networks, and active mobile broadband services. SDG contributions are mixed, similarly to several other countries.

India, which performs better than its overall development on Knowledge Supports, has capability in government online service delivery, e-participation by citizens, investment in emerging technologies, and freedom to make life choices. It is mixed overall, with areas of weakness incling SDGs on gender equality and good health and well being, online financial accounts, and individual usage of, and access to, ICT, as well as professional and associate professionals in the workplace.

Much like the UN Knowledge Index, the US has strengths across the board, notably in technology, especially future technology.

Knowledge Translation and Transformation

Knowledge translation and transformation refer to the taking of new and improved products and services and ways of doing things, to the marketplace, and for addressing complex societal challenges. It represents in this sense, the final link of the knowledge chain. In this section, we consider entrepreneurship, high technology exports, economic complexity, patents and social domain of UN SDG's.

Entrepreneurship

Entrepreneurship is vital for economic growth and bringing new and improved products and services to the market. According to the Global Entrepreneurship Monitor Survey (GEM 2020), some characteristics of African economies can be noted. Well above 50% of the population aged 18 to 64 indicate that they can perceive opportunities, and with numbers as high as 77% for Uganda. Similar results are noted for perceived capabilities, with Uganda leading our benchmark set at 84.9% (in 2014). It appears that Africans could be entrepreneurs, and entrepreneurs are a confident lot and have should have reasonable expectations for job creation in the next five years. For the most part, early-stage entrepreneurial activity[3] is dominated by males, except in Uganda, where the female-to-male ratio is 1.1. It is lowest in India, at 0.30. According to patchy data available from the Global Entrepreneurship Monitor, however, the percentage of those who indicated that their products or services are new to at least some customers or that few/no businesses offer the same products or services, is not high.

Fear of failure is much lower in Uganda and Botswana than in other countries, highlighting the confidence of the population. It should be noted that many entrepreneurs in Africa are likely to be necessary ones, often starting business due to a lack of alternatives, as distinct from opportunity entrepreneurs (GEM 2020). Fear of failure is higher in South Africa

[3] Total Early Stage Entrepreneurial activity is defined by the Global Entrepreneurship Monitor as the percentage of 18-64 who are either nascent or owner/managers of new businesses. Established businesses are the percentage of 18-64 who are owning and running a business that has paid salaries, wages or any payment to owners for more than 42 month, with early stage entrepreneurs having done so for less than 42 months.

and India than in Uganda and Botswana. In fact, it appears the higher the level of a country's development, the higher the country's fear of failure, for the most part. Total Early-Stage Entrepreneurial Activity exceeded the rate of established business ownership in African nations, except for Uganda, suggesting that business sustainability and longevity is an issue.

The table below (Table 23) indicates that new business density per 1000 people aged 15-64 has been growing in Botswana, Kenya, Rwanda and South Africa between 2012 and 2018, and to a minor extent in India, which has the lowest business density rate of our benchmark set. Thus, the potential to grow businesses is high in India. The Uganda case is important and interesting. Whereas the GEM data has buoyant numbers for Ugandan enterprises, this is not reflected in the World Bank data. Clearly, the form of business matters. The World Bank database refers to new limited liability enterprises. Other forms of enterprise, including informal ones, are significant in both Africa and India.

Table 23 *New Business Density per 1000 people*

	2012	2013	2014	2015	2016	2017	2018
Botswana	12.9	11.9	14.5	18.1	20.09		
India	0.13	0.11	0.08	0.09	0.11	0.12	0.14
Kenya						1.29	1.5
Nigeria	0.91	0.82	0.77	0.73	0.76	0.77	0.8
Rwanda	1.44	1.52	1.59	1.52	1.53	1.48	1.51
SA	6.37	6.79	6.57	8.68	10.2		
US							
Uganda	0.98	0.87	0.91	0.96	0.90	0.83	0.86

Source: World Bank Indicators

Surveys of formal registered businesses (greater than 5 employees) by a World Bank Enterprise Survey for manufacturing and services reveal the following:

- The proportion of total sales exported directly by firms is lower in Sub Saharan Africa (SSA) (4.1%) than globally (6.2%), with particularly low results obtained for Uganda (0.9%), Botswana (1.8%), South Africa (1.9%) and India (3.7%), suggesting that these countries lack an export focus among its firms, and that this is key to the future. The exceptions are Kenya (5.5%) and Nigeria (6.4%).
- As a further rough benchmark, in terms of global value chains, we look at the percentage of total imports that are of foreign origin. Globally, the figure is 37.3% and for SSA it is slightly lower at 35.9%. India is only at 2% and South Africa 5.2%, Kenya 36.1%, Nigeria 14.1%, Rwanda 21.1% and Uganda 12.5%, with Botswana well above the global and SSA averages, at 61.6%. Two broad interpretations can be made. Countries with higher imported input share are integrated into global value chains through specialization at least in a backward integration sense, or are lacking internal capability in these areas, mainly relying on imports. The fact that less-developed nations are having higher input usage from foreign sources lends itself to the latter explanation.
- Encouragingly, Rwanda (35.9%), Botswana (51.9%), Kenya (37.4%), Uganda (34.7%) and India (35.9%) and Nigeria (30.7%) all had percentages of firms offering training in excess of global (35.9%) and SSA averages (32.7%). South Africa lags badly on this measure (7.9%).
- All benchmark countries reported below the global average (20.5%) and SSA average (16.3%) for the levels of the workforce identifying as inadequate education as a major constraint (except for Botswana). Thus, most of our countries did not view lack of skilled personnel as a major issue, although we note that the survey only sampled registered or formal businesses, rather than the whole of the business sector.
- Across a range of obstacles that firms face, access to finance is the most pronounced. As high as 30% of Nigerian and Rwandan firms claimed that access to finance was a major obstacle. Yet for some countries, the percentage of firms that claimed this to be the case

was less than both the SSA and global average. It should be noted that the SSA average was higher than the global average.

- Related to this is that investment financed internally is higher in SSA than globally (although both are significant), but significantly less so than SSA levels for Nigeria, Kenya and Botswana. The overall level of having a bank account remains high across the board. Providing collateral, which is often difficult for firms, is still a key requirement to obtain loans from the banking sector. Many businesses still require loans to provide working capital. For the most part, working capital firms are reliant on banks, rather than suppliers or customers.
- Levels of competition from unregistered or informal firms are significant, as are those, with some variation, who claim that practices of competitors in the informal sector are a constraint.
- Except for South Africa, the percent of firms with top female managers is less than 30%, while the percentage of female full-time workers varies sharply from 14.7% in India to 41.2% in Botswana. The global average is 32.1% for female full-time workers, while the SSA average is 26.8%. All benchmark countries, except for India and Nigeria, are above the SSA average, and many are above the global average.
- However, nearly all the benchmark countries are either on the average for SSA (but below global) or below the SSA average for firms with majority female ownership and participation in ownership (Note that this survey does not provide US data).

Technology

Table 24 shows that, for the most part, high technology exports, as a share of manufactured exports, are at the lower end of the spectrum, compared to the US and India. Growth in high technology exports as a share of total exports has been mixed, with Botswana, India, Uganda, and Kenya growing, but declines noted in South Africa, Rwanda, Nigeria, and the US. Of interest, though, is that Rwanda has a share of high technology exports as a share of total exports exceeding India and has experienced rapid growth in this area since 2017 (although it is still declining from a high point in 2015). Rwanda's government has been increasingly driving policy towards a technology-oriented economy. Of course, there are various caveats. These shares are not absolute numbers and do not reflect the size and scale of total manufacturing exports.

Table 24 *High technology exports, as % of manufactured exports**

	2014	2015	2016	2017	2018	2019
Botswana	0.25	0.69	0.24	0.94	0.66	0.39
India	9.23	8.04	7.68	7.39	9.08	10.30
Kenya		4.37	7.59	3.35	3.61	4.59
Nigeria	2.27	12.26	2.35	2.33	1.93	1.48
Rwanda	11.86	15.33	13.53	2.66	2.57	10.55
SA	6.66	7.42	6.66	5.68	5.29	4.89
Uganda	2.68	2.29	2.05	2.05	3.53	
US	20.86	21.76	22.72	19.51	18.74	18.93

*Aerospace, computers, pharmaceuticals, scientific equipment and electrical machinery.
Source: World Bank Indicators

A further clue to the technology status of African industry is found in the Economic Complexity Index, which measures the diversity and ubiquity of exports, with a higher rank for countries that produce a more diverse set of exports, thus reflecting capabilities (Atlas of Economic Complexity). Except for South Africa, African countries are in the bottom third of the scale out of 133 countries, as shown in Table 25. Nigeria is last out of 133 countries, Botswana is 84th and Uganda 86th, with Kenya slightly better at 77th. The US leads the field at 11th, as is to be expected, and at 42nd place India is performing reasonably in line with its developmental stage. This data shows the magnitude of the change required for African nations.

Table 25 *Economic Complexity Index Rankings out of 133 countries*

	2014	2015	2016	2017	2018
Botswana	102	83	116	79	84
Kenya	79	91	84	89	77
India	48	48	51	47	42
Nigeria	133	133	132	133	133
Rwanda					
South Africa	51	57	60	61	63
Uganda	84	84	87	93	86
US	11	9	11	12	11

Source: Atlas of Economic Complexity

Part of the issue of manufacturing export constraints relates to the size of manufacturing itself. Most of the African countries in question have smaller manufacturing sectors than the US and India, although both these countries have declined in manufacturing abilities over the last five years, according to World Bank data. The exception in Africa is Uganda, which has a manufacturing sector exceeding all other countries. Nigeria has grown between 2015-2020, as has Rwanda, while the others have declined, indicating both smaller size and smaller reduction. Manufacturing is not the growth engine of these African nations. A concerted effort at lifting manufacturing is arguably critical, as this sector tends to be a large employer, has strategic links and knowledge spillovers to other sectors though upstream and downstream connections, and offers scope for innovation and productivity.

Tables 6 and 27 show service trade, which incorporates many knowledge-intensive, advanced services. This data reveals growth in service exports and imports from African nations, as well as for the US and India. It shows again the downturn in 2020 in service trade. For the most part for African nations, service exports are outweighed by service imports, a feature that one would expect, given development levels. This is particularly pronounced for Nigeria. The gap is narrower for Uganda, South Africa, Rwanda, and Botswana, noting that South Africa's trade in services is significantly higher than the other countries. For a number of these countries, services tend to be non-traditional, domestically oriented. Kenya bucks the trend with exports of services consistently higher than imports, arguably reflecting its growing role in trade in financial and business services.

Table 26 *Service exports ($m US)*

	2014	2015	2016	2017	2018	2019	2020
World	5,240,588	5,000,516	5,085,257	5,530,183	6,089,802	6,228,674	4,985,329
Botswana	985	912	851	941	938	924	509
India	157,196	156,278	161,819	185,294	204,956	214,762	203,253
Kenya	5,024	4,638	4,165	4,648	5,477	5,620	3,659
Nigeria	1,991	3,160	3,744	5,030	4,818	4,949	3,993
Rwanda	605	767	790	863	914	1015	560
SA	16,829	15,050	14,361	15,773	15,969	14,727	7,528
Uganda	2,181	2,061	1,915	1,649	1,991	2,029	1,114
US	757,051	768,660	780,944	833,775	861,725	876,725	705,643

Source: World Trade Organization

Table 27 *Services imports ($m US)*

	2014	2015	2016	2017	2018	2019	2020
World	5,144,001	4,895,497	4,921,183	5,324,019	5,789,905	5,947,811	4,681,535
Botswana	1,230	1,119	1,019	1,103	1,206	1,113	726
India	128,362	123,567	133,532	154,595	176,059	179,430	153,925
Kenya	3,350	3,321	2,732	3,092	3,881	3,855	3,573
Nigeria	24,911	19,613	11,758	18,265	30,884	38,710	19,833
Rwanda	662	1020	1035	1056	1057	1032	597

SA	17,042	15,531	14,939	16,177	16,502	15,673	9,856
Uganda	2,675	2,378	2,026	2,056	2,546	2,687	3,042
US	491,086	498,213	512,617	547,172	563,926	591,121	460,301

Source: World Trade Organization

Patents

We use patents as a representation of knowledge translation and transformation. It considers the commercialization and, ultimately, dissemination of ideas and know-how. As is to be expected (Table 28), the number of patent applications are quite low for African countries, especially Botswana and Uganda. This is likely associated with the cost of patenting and skills and capabilities required, and the fact that many innovations do not lend themselves to patenting in developing countries. For all countries, including the US and India, resident patent applications are outweighed by non-resident applications, representing in large measure the patenting activity of multinational enterprises. Patents abroad by residents have generally increased, reflecting the growing internationalization. Internationalization numbers are negligible for African nations.

UN Sustainable Development Goals (SDG's)

Of course, commercial orientation is not the only thing that should be considered in the development and application of knowledge. The social agenda, allied with economic and environmental domains, is significant. Knowledge and its application are important drivers of the UN's SDGs, through the creation of innovative products and services, the ability to address complex problems, and the diffusion of capabilities and knowledge in countries. To that end, we examine the progress of countries towards the 2030 UN SDGs. As the Sustainable Development Report suggests, COVID-19 was a setback for sustainable development, with declines in average score driven by poverty and unemployment associated with the pandemic (Sachs et al). Given time lags, there are likely to be further impacts, as various data is not yet available for 2020. The pandemic has affected all three domains of economy, society and the environment. Countries are ranked by the overall score. The overall score measures a country's total progress against all 17 SDGs. The score can be interpreted as a percentage of SDG achievement, with 100% meaning they have achieved the SDG.

Table 29 *SDG Ranking Index 2021 (165 countries)*

	Rank	Score
Botswana	115	61.9
Kenya	118	60.6
Nigeria	160	48.9
India	120	60.1
Rwanda	130	57.6
Uganda	140	53.5
SA	107	63.7
US	3	76

Source: Sachs et al

As can be seen from Table 29, all the countries, except for the US, occupy ranks below 100 (out of 165 countries), with the "best" being South Africa at 107, and the weakest being Nigeria at 160. Basically, for African nations, the scores range from 48.9% to 63.7% achievement of the SDGs, when viewing scores as percentage achievements.

Digger deeper (Table 30), there is considerable work to be done to realize the SDGs. Most African countries have "major challenges" and "significant challenges" in realizing the goals, drawing on the UN Sustainable Development Report. Except for climate action, where SDGs are "achieved" by many African countries, given low emissions, very few countries are in the "achieved" or "challenges remain" classification for SDGs. It is interesting that lack of achievement is also the case in the US and India, although, surprisingly, the SDG for climate action is rated as "achieved" in India.

For the African nations, SDGs around responsible consumption and production show that "challenges remain" in several cases. This aligns with positive climate action, suggesting that African nations are viewing the environment in a responsible, pro-active manner. Having said that, affordable and clean energy remains a major challenge. The SDGs around poverty (inequality, decent work, and economic growth), empowerment, and accountability (peace, justice, and strong institutions) remain challenges either in a major or significant way.

Policies of Selected Countries

This section briefly canvasses the vision, medium-term priorities, challenges, and roles of government in 3 countries that we focus on: Uganda; South Africa and Kenya.

Table 31 demonstrates the key focus areas and assessments of the challenges facing each country and its policy makers. At the outset, there are several issues that are common among the countries. There is recognition of the need for diversification in economies with a knowledge focus to add value to natural resources to move into higher value-added industries, including manufacturing, and lift and diversify exports. However, the focus areas still seem to be loosely and broadly defined.

Countries recognize, and are developing approaches, to focus on innovation, incorporating firm-level capabilities rather than research. This is not to deny the importance of basic research in universities, among other things. Building infrastructure, including STI infrastructure, science parks, hubs, and the like are key, as are developing and promoting linkages across whole systems. Lifting gross expenditure on research and development is vital. Another area of priority is improving performance in education and training by enhancing connections with industry, reviving and revitalizing curricula, addressing the human resource capabilities in the education and training system, and fostering a stronger Vocational Education and Training (VET) system. Preparing economies and societies for the advent of the fourth industrial revolution is also a feature of the countries' plans. Building a culture of monitoring and evaluation of policy and governance and the general business environment e.g., input costs in the economy, are areas that countries are focusing on.

There are differences between the countries in focus, emphasis, and sentiment, reflecting different levels of development, national contexts, circumstances, and requirements. For example, South Africa is placing more weight on being a business process outsourcing destination, as part of its stronger service sector. Moreover, South Africa is building on its leadership position in COVID-related innovations and inventions of specialized equipment. It is also building on its stronger publication base in 4IR related fields, including artificial intelligence and robotics (UNESCO 2021). Addressing apartheid-era holdovers of uneven and inequitable spatial development is a key focus area for South Africa, as is addressing inequality and employment, especially for younger people. South Africa is also moving to incorporate grassroots innovation in its overall STI mix.

Uganda is attempting to strengthen its ICT capability across the board as a major priority and is aspirational in its approach, including its 4IR strategy (UNESCO 2021). Also of importance is the emphasis given to space technology, including overseas collaboration, as a means of driving innovation across multiple sectors. Building human resource capacity and capability through a comprehensive 5-year approach will be key. For Kenya, building on distinct capabilities in startups and financing its burgeoning entrepreneurial sector, including models for online banking, continue to be key points of distinctiveness and priority. Kenya is also attempting to develop its innovation hub culture and attributes, being regarded as an important player in this respect in Africa (UNESCO 2021).

Yet, in our view, there are things that need to be done further to improve knowledge economy capability in the countries. Greater use can be made of the vibrant diaspora as a means of building capability and fostering core linkages and connections for the vital flow of knowledge. Despite recognition, there could be a greater focus on building a stronger whole of innovation and knowledge systems, including linkages between science, industry, firms, and

public sector agencies. As part of this, ensuring that science, technology, innovation, and embedding of knowledge into the mainstream of economic and social life and policy development is key. Further work is also needed to continue embracing and integrating indigenous knowledge and grassroots capabilities into economic and social development, including IP management, and link grassroots knowledge to "mainstream" science, technology, and innovation. It will be vital to explicitly and firmly prioritize innovation in solving national and global challenges. The UN Sustainable Development Goals should also be a priority. Further, the sustainability agenda, in its broadest sense, and, more narrowly, green industries and jobs, warrants greater attention. The gender agenda in science, technology, and innovations should also be a greater priority.

India and Africa: Economic Relationships

Trade

This section examines merchandise trade between India and African nations[4], drawing on UNCTAD Statistics with author interpretation, including a focus on high value goods, as per the knowledge economy. The key point to first note is the drop in trade in 2020 compared to 2019 across the board (Tables 32 and 44), reflecting the impact of COVID-19, particularly in low skill and technology intensive and medium skill and technology intensive exports to India. This drop in trade across the board is part of a broader global trend.

The next point is that the total merchandise exports of the selected African countries collectively account for only 3.6% of India's total merchandise imports in 2016, rising to 3.9% in 2019, based on author calculations. Thus, trade between India and African nations has been increasing, and we use 2019 as one reference point since 2020 patterns are distorted by COVID-19. The African countries' manufacturing exports are only 0.3% of Indian imports of manufactured goods[5] in 2016, falling to 0.2% in 2019. The corresponding figures for other categories are: 0.3% in 2016 and 0.17% in 2019 for labor intensive and resource intensive skills exports; 0.5% in 2016 and 0.4% in 2019 for low skill and technology intensive manufactures; 0.4% in 2016 and 0.15% in 2019 for medium skill and technology intensive manufacturing exports; and 0.2% in 2016 and 0.19% in high skill and technology intensive manufacturing exports. These figures are calculated by comparing African exports by category with comparable Indian imports (Table 57).

Thus, in all categories of manufacturing, African countries' exports, as a share of India's imports, has been extremely low and dropped further in 2019. At the same time, Indian imports of total merchandise (in terms of India's import share) from Africa has risen, reflecting the fact that African nations have been strengthening their relationships with India *in primary products and natural resources*.

If we look at the growth exports from Africa to India (Tables 32, 34, 36, 38, 40, 42), we find that Rwanda, Nigeria and South Africa have experienced positive growth for total merchandise exports between 2016 and 2019 and the rest of the countries negative; Kenya, Nigeria, Uganda, and Rwanda experienced growth in manufactured exports, but exports were negative; for labor and resource-intensive goods, export growth is negative across the board bar Uganda; for low skill and technology-intensive manufacturing exports, all are positive, with the exception of Botswana; and for medium skill and technology-intensive exports, growth has been negative, except Kenya and Uganda. Thus, the pattern is mixed and reflects the specific relationships between individual African countries and India. On balance, negative growth is

[4] This section is drawn entirely from the UNCTAD trade data base with author interpretation in the analysis

[5] Labor intensive and resource intensive include leather, textiles, clothing, glass, paper and wood; low skill and technology intensive includes iron, steel, motor cycles, railway vehicles, office supplies; medium skill and technology intensive includes household type equipment, apparatus for electrical circuits, agricultural machinery, textile machines, motor vehicles; and high skill and technology and intensive includes chemicals and chemical products, pharmaceuticals, office machinery, telecommunications equipment, aircraft and equipment and automated data machines.

more prevalent than growth, which shows that, that in terms of exports of African nations to India, there is potential for further development.

An interesting feature is that for nearly all countries between 2016 and 2019, there has been some growth in exports to India of high skill and technology-intensive products, often from low bases. South Africa is the exception, recording negative growth, but in absolute terms its exports are higher than other countries. Although it is difficult to be definitive, these are tentative signs of growth in knowledge intensity and the rise of the knowledge economy, at least as far as exports to India are concerned.

For the exports to India by share of country exports (Tables 33, 35, 37, 39, 41, 43), Nigeria dominates for total merchandise exports. However, for the most part, it is South Africa that leads in market share. This is certainly the case for manufactured exports, low skill and technology-intensive products, medium skill and technology-intensive manufactures and high skill and technology-intensive products. Although South Africa's growth in exports of high skill industries to India has been declining, in share terms it comfortably leads. It is only in labor-intensive and resource-intensive industries and in total merchandise exports that Nigeria has a higher share of exports than South Africa, reflecting Nigeria's emphasis on the resource end of the production and export spectrum.

On the score of imports from India, there has been mainly growth in all countries across all categories of merchandise and manufactured goods (Tables 44, 46, 48, 50, 52, 54). There are very few exceptions: Kenya, in imports of total merchandise products and medium skill and technology-intensive manufactures, and Botswana in total manufactured products and high skill and technology-intensive manufactures. For all merchandise products, total imports from India have been outweighed by total exports to India, reflecting India's dependence on Africa for natural resources and primary products, although this is masking considerable country variation. Imports outweigh exports for the African countries in question for total manufacturing, labor intensive and natural resource-intensive manufactures, low skill and technology intensive products, and both medium and high skills and technology-intensive products. The gap between imports and exports, in favour of imports, widens as goods embody higher values.

Nigeria and South Africa account for the bulk of imports from India in all categories, and in some cases Nigeria leads. Thus, the strength of the Nigeria-India trade relationship in both imports and exports is reflected in the data (Tables 45, 47, 49, 51, 53, 55).

For total merchandise, African imports from India collectively as a share of India's total exports was 3.1% in 2016 and 3.8% in 2019; for manufactured goods it was 3.5% in 2016 and 4.6% in 2019; for labor-intensive and resource-intensive manufactures it was 1.5% in 2016 rising to 2.04% in 2019; in low skill and technology-intensive manufactures it was 3.4% in 2016 and 4.5% in 2019; 5.3% in 2016 and 8.6% in 2019 for medium skill and technology-intensive manufactures; and were 3.9% and 3.7% in 2016 and 2019 respectively for high skill and technology-intensive manufactures. These numbers are calculated by comparing Africa's imports by category with comparable Indian exports (Table 56).

Although the above paragraph confirms that African imports as a share of India's exports have been growing between 2016 and 2019 in all categories, the numbers have been low, indicating that the trade relationships between Africa and India have a way to go. India's exports are still largely going elsewhere apart from the African nations that we consider. The highest share, as we have seen, has been in medium skills and technology manufactures.

Table 32 *Exports to India, all products (000's US dollars)*

	2016	2017	2018	2019	2020	Change 2016-2020	Change 2016-2019
Botswana	1,062,197	1,281,768	1,113,380	918,036	622,758	-41.37	-13.6

	2016	2017	2018	2019	2020	Change 2016-2020	Change 2016-2019
Kenya	121,546	63,980	107,148	69,814	53,278	-56.17	-42.6
Nigeria	7,992,074	9,886,255	13,643,500	13,575,305	7,161,239	-10.40	69.9
Rwanda	1256	5173	7614	6405	5648	349.68	409.95
SA	3,281,594	4,116,686	4,501,800	4,032,172	3,226,512	-1.68	22.9
Uganda	66,044	50,706	31,550	55,544	41,254	-37.54	-15.9
Total	12,524,711	15,404,568	19,404,992	18,657,276	11,110,689	-11.2	48.96

Source: UNCTADstat

Table 33 *Country share of total merchandise exports to India*

	2016	2017	2018	2019	2020
Botswana	8.5%	8.3%	5.7%	4.9%	5.6%
Kenya	1.0%	0.4%	0.6%	0.4%	0.5%
Nigeria	63.8%	64.2%	70.3%	72.8%	64.5%
Rwanda	0.01%	0.03%	0.04%	0.03%	0.1%
SA	26.2%	26.7%	23.2%	21.6%	29.0%
Uganda	0.5%	0.3%	0.2%	0.3%	0.4%

Source: UNCTADstat

Table 34 *Exports to India, all manufacturing (000's US dollars)*

	2016	2017	2018	2019	2020	%Change 2016-2020	%Change 2016-2019
Botswana	200	194	946	75	136	-32.00	-62.5
Kenya	29,376	27,843	47,660	31,494	25,021	-14.83	7.2
Nigeria	33,984	22,835	34,172	39,785	26,234	-22.80	17.1
Rwanda	131	14	180	324	334	154.96	147.3
SA	476,371	554,664	616,199	456,831	278,612	-41.51	-4.10
Uganda	5,683	5,388	5,662	7,816	3,573	-37.13	37.5
Total	545,745	610,938	704,819	536,325	333,910	-38.8	-1.7

Source: UNCTADStat

Table 35 *Country share of all manufactured exports to India*

	2016	2017	2018	2019	2020
Botswana	0.04%	0.03%	0.1%	0.01%	0.04%
Kenya	5.4%	4.6%	6.8%	5.9%	7.5%
Nigeria	6.2%	3.7%	4.8%	7.4%	7.9%
Rwanda	0.02%	0.002%	0.03%	0.06%	0.1%
SA	87.3%	90.8%	87.4%	85.2%	83.4%
Uganda	1.0%	0.9%	0.8%	1.5%	1.1%

Source: UNCTADStat

Table 36 *Exports to India, labour-intensive and resource-intensive (000's US dollars)*

	2016	2017	2018	2019	2020	% Change 2016-2020	%Change 2016-2019
Botswana	1	17	14	0	25	2400	0
Kenya	5,113	4,349	3,963	2,553	2,138	-58.19	-50.1
Nigeria	21,738	18,436	18,710	13,375	14,411	-33.71	-38.5
Rwanda	1	2	6	1	8	700	0
SA	20,241	16,935	24,537	11,585	10,547	-47.89	-42.8
Uganda	1,530	1,626	2,180	2,170	1,162	-24.05	41.8
Total	48,624	41,365	49,410	29,684	28,291	-41.8	-38.95

Source: UNCTADStat

Table 37 *Country share of labor intensive and resource-intensive exports to India*

	2016	2017	2018	2019	2020
Botswana	0.002%	0.04%	0.03%	0.0%	0.1%
Kenya	10.5%	10.5%	8.0%	8.6%	7.6%
Nigeria	44.7%	44.6%	37.9%	45.1%	50.9%
Rwanda	0.002%	0.005%	0.01%	0.003%	0.03%
SA	41.6%	40.9%	49.7%	39.0%	37.3%
Uganda	3.1%	3.9%	4.4%	7.3%	4.1%

Source: UNCTADStat

Table 38 *Exports to India, low skill and technology-intensive manufactures (000's US dollars)*

	2016	2017	2018	2019	2020	% Change 2016-2020	% Change 2016-2019
Botswana	3	76	0	2	36	1100.00	-33.3
Kenya	534	1,116	2,113	1,442	1,167	118.54	170
Nigeria	275	89	462	1794	601	118.55	552.4
Rwanda	45		0		0	-100.00	
SA	93,262	117,643	150,744	129,714	63,400	-32.02	39.1
Uganda	109	47	159	183	292	167.89	67.9
Total	94,228	118,971	153,478	133,135	65,496	-30.5	41.3

Source: UNCTADStat

Table 39 *Country share of low skill and technology-intensive manufactures to India*

	2016	2017	2018	2019	2020
Botswana	0.003%	0.1%	0.0%	0.0%	0.1%
Kenya	0.6%	0.9%	1.4%	1.1%	1.8%
Nigeria	0.3%	0.1%	0.3%	1.3%	0.9%
Rwanda	0.0%		0.0%		0.0%
SA	99.0%	98.9%	98.2%	97.4%	96.8%
Uganda	0.1%	0.0%	0.1%	0.1%	0.4%

Source: UNCTADStat

Table 40 *Exports to India, medium skill and technology-intensive manufactures (000's US dollars)*

	2016	2017	2018	2019	2020	% Change 2016-2020	% Change 2016-2019
Botswana	189	84	925	17	33	-82.54	-38.1
Kenya	1,039	431	1,516	2,137	1,279	23.10	105.7
Nigeria	948	253	11264	393	3128	229.96	-58.5
Rwanda	5	1	48	3	73	1360.00	-40.0
SA	178,585	187,146	173,888	142,583	71,427	-60.00	-20.2
Uganda	266	3,608	3,290	5,164	2,082	682.7	1841.4
Total	181,032	191,523	190,931	150,297	78,022	-56.9	-16.97

Source: UNCTADStat

Table 41 *Country share of exports of medium skill and technology-intensive manufacturing to India*

	2016	2017	2018	2019	2020
Botswana	0.1%	0.04%	0.5%	0.01%	0.03%
Kenya	0.6%	0.2%	0.8%	1.4%	1.3%
Nigeria	0.5%	0.1%	5.9%	0.3%	3.3%
Rwanda	0.003%	0.005%	0.03%	0.002%	0.1%
SA	98.6%	97.7%	91.1%	94.9%	74.2%
Uganda	0.1%	1.9%	1.7%	3.4%	21.1%

Source: UNCTADStat

T**able 42** *Exports to India, high skill and technology-intensive manufactures (000's US dollars)*

	2016	2017	2018	2019	2020	%Change 2016-2020	%Change 2016-2019
Botswana	7	16	7	56	41	485.71	700
Kenya	22,690	21,948	40,068	25,362	20,438	-9.93	11.8
Nigeria	11,023	4,057	3,737	24,223	8,095	-26.56	119.7
Rwanda	80	10	126	320	252	215.00	300
SA	184,283	232,939	267,030	172,949	133,238	-27.70	-6.1
Uganda	3,778	3,608	3,290	5,164	2,082	-44.89	36.7
Total	221,861	262,578	314,258	228,074	164,146	-26.0	2.8

Source: UNCTADStat

Table 43 *Country share of high skill and technology intensive exports to India*

	2016	2017	2018	2019	2020
Botswana	.003%	.006%	.002%	.02%	.02%
Kenya	10%	8%	13%	11%	12%
Nigeria	5%	2%	1%	11%	5%
Rwanda	.04%	.004%	.04%	.14%	.15%
SA	83%	89%	85%	76%	81%
Uganda	2%	1%	1%	2%	1%

Source: UNCTADStat

Table 44 *Imports from India, total merchandise (000's US dollars)*

	2016	2017	2018	2019	2020	% Change 2016-2020	% Change 2016-2019
Botswana	120,192	137,700	168,515	227,152	176,010	46.44	88.99
Kenya	2,007,058	1,663,101	1,865,609	1,745,934	1,534,424	-23.55	-13.0
Nigeria	1,832,871	1,585,843	2,502,586	4,704,870	3,057,195	66.80	156.7
Rwanda	154,209	160,740	201,687	224,459	263,855	71.10	45.6
SA	3,120,457	3,916,788	3,842,924	4,323,032	3,581,872	14.79	38.5
Uganda	777,599	727,505	849,724	936,710	961,503	23.65	20.5
Total	8,012,386	8,191,677	9,431,045	12,162,157	9,574,859	19.5	51.8

Source: UNCTADStat

Table 45 *Country share of total merchandise imports from India*

	2016	2017	2018	2019	2020
Botswana	1.5%	1.7%	1.8%	1.9%	1.8%
Kenya	25.0%	20.3%	19.8%	14.4%	16.0%
Nigeria	22.9%	19.4%	26.5%	38.7%	31.9%
Rwanda	1.9%	2.0%	2.1%	1.8%	2.8%
SA	38.9%	47.8%	40.7%	35.5%	37.4%
Uganda	9.7%	8.9%	9.0%	7.7%	10.0%

Source: UNCTADStat

Table 46 *Imports from India, all manufactured products (000's US dollars)*

	2016	2017	2018	2019	2020	% Change 2016-2020	% Change 2016-2019
Botswana	95,842	77,708	57,099	78,081	48,935	-48.94	-18.5
Kenya	1,164,178	1,088,864	1,298,823	1,185,351	1,126,727	-3.22	1.8
Nigeria	1,682,448	1,439,390	2,309,934	4,288,492	2,846,901	69.21	154.9
Rwanda	104,064	121,922	153,765	187,744	207,119	99.0	80.4
SA	2,031,393	2,596,138	2,980,157	3,067,612	2,605,564	28.26	51.0
Uganda	584,692	597,851	720,248	745,643	793,338	35.68	27.5
Total	5,662,617	5,921,873	7,520,026	9,552,923	7,628,584	34.7	68.7

Source: UNCTADStat

Table 47 *Country share of imports of manufactured goods from India*

	2016	2017	2018	2019	2020
Botswana	1.7%	1.3%	0.8%	0.8%	0.5%
Kenya	20.6%	18.4%	17.3%	12.4%	11.9%
Nigeria	29.7%	24.3%	30.7%	44.9%	30.2%
Rwanda	1.8%	2.1%	2.0%	2.0%	21.4%
SA	35.9%	43.8%	39.6%	32.1%	27.6%
Uganda	10.3%	10.1%	9.6%	7.8%	8.4%

Source: UNCTADStat

Table 48 *Imports from India, labour-intensive and resource-intensive (000's US dollars)*

	2016	2017	2018	2019	2020	% Change 2016-2020	% Change 2016-2019
Botswana	3,156	3,775	2,873	3,573	3,171	0.48	13.2
Kenya	143,435	159,622	190,451	176,102	182,676	27.36	22.8
Nigeria	208,314	206,978	280,995	365,680	346,003	66.10	75.5
Rwanda	5,838	7,727	10,931	19,601	23,008	294.11	235.7
SA	260,681	285,748	322,721	341,873	253,567	-2.73	31.1
Uganda	63,046	54,659	64,675	71,801	49,312	-21.78	13.9
Total	684,470	718,509	872,646	978,630	857,737	25.3	42.98

Source: UNCTADStat

Table 49 *Country share of imports of labor-intensive and resource-intensive from India*

	2016	2017	2018	2019	2020
Botswana	0.5%	0.5%	0.3%	0.4%	0.4%
Kenya	21.0%	22.2%	21.8%	18.0%	21.3%
Nigeria	30.4%	28.8%	32.2%	37.4%	40.3%
Rwanda	0.9%	1.1%	1.3%	2.0%	2.7%
SA	38.1%	39.8%	37.0%	34.9%	29.6%
Uganda	9.2%	7.6%	7.4%	7.3%	5.7%

Source: UNCTADStat

Table 50 *Imports from India low skill and technology-intensive (000's US dollars)*

	2016	2017	2018	2019	2020	% Change 2016-2020	% Change 2016-2019
Botswana	11,278	4,237	9,787	18,597	4,304	-61.84	64.9
Kenya	188,721	194,174	211,191	192,800	192,656	2.09	2.2
Nigeria	278,873	259,236	569,964	827,882	607,977	118.01	196.9
Rwanda	24,379	27,603	29,734	29,613	36,197	48.48	21.5
SA	143,125	185,973	199,617	177,161	140,463	-1.86	23.8
Uganda	82,965	88,403	112,770	111,822	127,192	53.31	34.8
Total	729,341	759,626	1,133,063	1,357,875	1,108,789	52.0	86.2

Source: UNCTADStat

Table 51 *Country share of low skill and technology-intensive manufactures from India*

	2016	2017	2018	2019	2020
Botswana	1.5%	0.6%	0.9%	1.4%	0.4%
Kenya	25.9%	25.6%	18.6%	14.2%	17.4%
Nigeria	38.2%	34.1%	50.3%	61.0%	54.8%
Rwanda	3.3%	3.6%	2.6%	2.2%	3.3%
SA	19.6%	24.5%	17.6%	13.0%	12.7%
Uganda	11.4%	11.6%	10.0%	8.2%	11.5%

Source: UNCTADStat

Table 52 *Imports from India, medium skill and technology-intensive (000's US dollars)*

	2016	2017	2018	2019	2020	%Change 2016-2020	%Change 2016-2019
Botswana	8,438	7,591	10,966	14,700	10,035	18.93	74.2
Kenya	360,827	324,989	388,067	342,085	326,390	-9.54	-5.2
Nigeria	566,066	416,728	697,339	2,320,174	1,172,682	107.16	309.9
Rwanda	21,876	25,282	61,495	73,091	65,490	199.37	234.1
SA	868,934	1,181,012	1,253,171	1,387,717	984,543	13.30	59.7
Uganda	141,816	151,152	191,634	189,492	222,301	56.75	33.6
Total	1,967,957	2,106,754	2,602,672	4,327,259	2,781,441	41.3	119.9

Source: UNCTADStat

Table 53 *Country share of medium skill and technology-intensive manufactures from India*

	2016	**2017**	**2018**	**2019**	**2020**
Botswana	0.4%	0.4%	0.4%	0.3%	0.4%
Kenya	18.3%	15.4%	14.9%	7.9%	11.7%
Nigeria	28.8%	19.8%	26.8%	53.6%	42.2%
Rwanda	1.1%	1.2%	2.4%	1.7%	2.4%
SA	44.2%	56.1%	48.1%	32.1%	35.4%
Uganda	7.2%	7.2%	7.4%	4.4%	8.0%

Table 54 *Imports from India, high skill and technology-intensive (000's US dollars)*

	2016	2017	2018	2019	2020	%Change 2016-2020	%Change 2016-2019
Botswana	72,970	62,105	33,473	41,211	31,426	-56.93	-43.5
Kenya	471,195	410,078	509,114	474,364	425,005	-9.80	0.7
Nigeria	629,196	556,448	761,636	774,756	720,240	14.47	23.1
Rwanda	51,971	61,309	51,605	65,439	82,423	58.59	25.9
SA	758,653	943,404	1,194,647	1,160,861	1,226,991	61.73	53.0
Uganda	296,865	303,636	351,169	372,528	394,534	32.90	25.5
Total	2,280,850	2,336,980	2,901,644	2,889,159	2,880,619	26.3	26.7

Source: UNCTADStat

Table 55 *Country share of high skill and technology-intensive imports from India*

	2016	2017	2018	2019	2020
Botswana	3.2%	2.7%	1.2%	1.4%	1.1%
Kenya	20.7%	17.5%	17.5%	16.4%	14.8%
Nigeria	27.6%	23.8%	26.2%	26.8%	25.0%
Rwanda	2.3%	2.6%	1.8%	2.3%	2.9%
SA	33.3%	40.4%	41.2%	40.2%	42.6%
Uganda	13.0%	13.0%	12.1%	12.9%	13.7%

Source: UNCTADStat

Table 56 *India's total exports by categories (000's US dollars)*

	2016	2017	2018	2019	2020
Total Merchandise Exports	260,326,912.3	294,364,490.2	322,492,099.9	323,250,726.4	275,488,744.9
Total Manufactured Exports	161,604,701.6	179,650,755.2	197,076,972.1	206,853,883.4	179,606,641.7
Labor and Resource Intensive Exports	45,061,390.03	46,760,748	47,688,188.4	47,919,138.82	39,750,304.59
Low Skill and Technology Intensive exports	21,334,647.32	29,408,113.64	27,770,167.3	30,138,521.2	27,586,438.83
Medium Skill and technology Intensive exports	36,894,728.27	41,557,698.82	49,660,133.3	50,374,525	41,655,887.27
High Skill and Technology Intensive exports	58,313,935.95	61,924,194.75	71,958,483.1	78,421,698.4	70,614,010.96

Source: UNCTADStat

Table 57 *India's total imports by categories (000's US dollars)*

	2016	2017	2018	2019	2020
Total Merchandise Imports	356,704,792.1	444,052,353.8	507,615,733	478,883,729.1	367,980,363.5
Manufacturing Imports	173,371,867.4	202,780,541	229,947,467.8	224,826,032.1	180,491,535.3
Labor and Resource Intensive Imports	14,247,399.63	15,979,404.1	17,302,323.7	17,235,127.71	11,928,908.68
Low skill and technology intensive imports	18,310,357.46	19,328,509.82	23,875,924.84	22,641,939.1	17,177,200.16
Medium Skill and Technology Intensive imports	48,459,828.43	53,491,924.96	63,893,399.88	62,794,900.28	47,460,198.12
High Skill and Technology Intensive Imports	92,354,281.84	113,980,702.1	124,875,819.4	122,154,065	103,925,228.3

Source: UNCTADStat

Student mobility from Africa to India

Beyond trade in goods between African nations in India, briefly we touch upon inbound student mobility as another dimension of the relationship. As can be seen, total international students in India grew between 2016-2017 from 47,575 to 49,348, reflecting India's increasing prominence as a destination for international students as India itself builds on its knowledge capabilities. However, there are a few things to note. First these numbers do not tell the full story of the COVID-19 impact on student mobility. Second, students from African nations have declined to India, even as the total number of international students has grown in India, and, in any case, make up only a small proportion of the total. India relies very heavily on international students from South Asia. The other point to note is (not in table) that African students in India are overwhelmingly in undergraduate studies, with only a small proportion in post-graduate courses and doctoral Studies. Further, students from Africa are largely male. Thus, there is scope for broadening and deepening the relationship in student mobility, including via online means, in the context of COVID, by attracting more students generally, particularly females and postgraduates. In this, there is a considerable potential two-way benefit in terms of knowledge flow, vibrant alumni, and opportunities for collaboration and export revenue for India.

Table 58 *International students in India*

	2019/2020	2016/2017
Botswana	45	34
Nigeria	1525	2091
Kenya	413	531
Uganda	326	311
SA	161	292
Rwanda	130	339
Total	49,348	47,575

Source: Indian Government Ministry for Human Resources and Development

Conclusion and Policy Agenda

This paper has examined the performance of selected African countries in terms of their progress towards a knowledge economy, using UN and other data. It is apparent that while there is some progress and pockets of strength, there is a considerable way to go in terms of fully effective knowledge economy performance in resourcing, access and opportunity, capability development, strength of relationships and investment in key support infrastructure, notably ICT, as in translation and transformation. Particular attention is needed by the African countries towards STEM enrollments, patents, high technology exports, volume of papers, and overall knowledge competitiveness, including in ICT infrastructure.

There is some evidence of a growing trade relationship between India and Africa, but this is from a low base, and driven by primary products and resources. Further deepening and widening of the relationship is recommended.

However, we consider that, notwithstanding the policy initiatives underway and planned, further measures should be considered by African nations. These are:

- Promote collaboration in research and innovation, based on identified competitive advantages, both across Africa and globally as a means of promoting joint knowledge discovery, and leveraging complementary capabilities
- Identify core weaknesses and gaps in national, regional and sector innovation systems and address gaps through investment including public/private partnerships, where appropriate
- Tap into diaspora networks for the purpose of research and innovation, beyond monetary remittances--the idea of knowledge remittances

- Prioritize research and innovation to more explicitly address complex national and global challenges, through national and pan-African hubs for problem solving, including COVID-19-related research
- Identify and invest in high quality flagship universities, to produce high quality graduates and basic research
- Leverage traditional knowledge and integrate with other forms of knowledge and embed both into curriculum and research, and more broadly align the education and training system alignment with industry needs
- Establish institutions and mechanisms to assist firms with technology absorption and provide access to financial capital for small-medium sized enterprises that are opportunity-entrepreneurship oriented and address whole-of-firm life cycle issues
- Promote firm-level export capability in advanced and integrated manufacturing and services, including participating in regional and global supply chains in a planned and orderly manner, recognizing the disruptive potential of the pandemic and other events on global supply chains
- Ensure that sustainability in all its dimensions is a core plank of medium-longer term policies and planning
- Develop specific Indian knowledge economy-focused plans to enhance trade and investment in knowledge economy sectors, including student mobility, building on complementarities.

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Appendix 1 Table 28 *Patent applications*

	2015			2016			2017			2018			2019		
	Res.*	Non-R*	Abroad	Res.	Non-R	Abroad	Res.	Non-R	Abroad	Res.	Non-R	Abroad	Res.	Non-R	Abroad
Botswana	3	5	3	1	6	2	3	4	3		3	1	2		1
India	12,579	33,079	11,411	13,199	31,858	12,654	14,961	31,621	13,048	16,289	33,766	13,746	19,454	34,173	14,561
Kenya	137	56	42	144	59	57	135	43	60	244	42	49	302	41	70
NIgeria				85	150	13	100	180	16	120	218	33	1	1	13
Rwanda	5	1		3	3	2	4	2	1	6	1				1
SA	889	6,608	1,188	704	6,506	1,314	728	6,816	1,461	657	6,258	1,204	567	6,347	947
Uganda	9		2	16		1				6		4			9
US	288,335	301,075	242,324	295,317	310,244	226,737	293,904	313,052	231,563	285,095	312,046	230,114	285,113	336,340	236,032

**Res.: Resident; Non-R.: Non-resident*

Source: World International Property Organization

Table 30 *Achievement towards SDG's*

	Botswana	India	Kenya	Nigeria	Rwanda	South Africa	Uganda	US
SDG 1 No poverty	Major Challenges (MC)	Significant Challenges (SC)	MC	MC	MC	MC	MC	SC
SDG 2 Zero Hunger	MC	MC	MC	MC	MC	MC	MC	MC
SDG 3 Good Health and Well Being	MC	MC	MC	MC	MC	MC	MC	SC
SDG 4 Quality Education	Challenges Remain (CR)	CR	SC	MC	SC	SC	SC	CR

	Botswana	India	Kenya	Nigeria	Rwanda	South Africa	Uganda	US
SDG 5 Gender Equality	SC	MC	SC	MC	SC	CR	MC	SC
SDG 6 Clean Water and Sanitation	SC	MC	MC	MC	MC	SC	MC	CR
SDG 7 Affordable and clean energy	MC	SC	MC	MC	MC	SC	MC	SC
SDG 8 Decent Work and Economic Growth	MC	SC	SC	MC	SC	MC	MC	SC
SDG 9 Industry, Innovation and Infrastructure	MC	MC	MC	MC	MC	SC	MC	CR
SDG 10 Reduced Inequalities	MC	MC	MC	MC	MC	MC	MC	MC
SDG 11 Sustainable Cities and Communities	SC	MC	MC	MC	MC	SC	MC	CR
SDG 12 Responsible Consumption and Production	MC	CR	CR	Achieved	SC	CR	CR	MC
SDG 13 Climate Action	SC	Achieved	Achieved	Achieved	Achieved	SC	Achieved	MC
SDG 14 Life Below Water	Unavailable	MC	MC	MC	Unavailable	MC	Unavailable	SC
SDG 15 Life on Land	MC	MC	MC	SC	MC	MC	MC	MC
SDG 16 Peace, Justice and Strong Institutions	MC	MC	MC	MC	MC	MC	MC	MC
SDG 17 Partnership for the Goals	CR	MC	SC	SC	SC	CR	MC	MC

Source: Sachs et al

Table 31 *Policy approaches*

	Vision	**Medium term priorities**	**Challenges**
Uganda	Vision 2040 "A transformed Ugandan society from a peasant to a modern and prosperous country within 30 years". Opportunities in oil and gas; tourism; minerals; ICT business; abundant labor force; geographic location and trade;	ICT; local start up's plan; 4IR Strategy; Satellite and space technology collaboration; agro-industrialization; extraction-based industries; knowledge sectors (e.g. pharmaceuticals, automotive); Industry parks and zones; COVID-19 opportunities and specialized	Policy and other silos; cost and availability of capital, including for innovation; lacking STI system including formal transfer of technology, STI Infrastructure and incubators; Not implemented National Science Plan 2012/2013-2017/2018; lack of

	Vision	**Medium term priorities**	**Challenges**
	water resources; industrialization and agriculture. Achieving transformational goals will depend on capacity to strengthen fundamentals, including infrastructure, Science, Technology, Engineering and Innovation; land use management; urbanization; human resources; and peace, security and defense.	equipment; clean energy; STI system including innovation and technology transfer; Regional Development; Human Resource Development.	absorptive innovative capacity in firms; innovation by purchasing off shelf technology and R&D rather than inhouse capability; innovation not focused on firms but more so based on research at institutional level; disconnect between education, training and industry; teacher shortages; Value added in manufacturing low; ICT Infrastructure and digital literacy needing improvement.
South Africa	National Development Plan 2030: Economy that will create more jobs; improving Infrastructure; Transition to a low carbon economy; Reversing the spatial effect of apartheid; improving the quality of education, training and innovation; quality health care for all; social protection; building safer communities; reform the public service; and fight corruption.	7 focus areas (capable, ethical development State; economic transformation and job creation; education, skills and health; consolidating social wages through reliable and quality basic services; spatial integration, human settlements and local Government; Social cohesion and safe communities; A better Africa and the World. Other core priorities: cyber security; grass roots innovation program; co-funding R&D in strategic sectors; sectoral innovation fund; science engagement framework; STI Infrastructure; SME fund; focus on innovation not just research; open science; innovation compact for policy co-ordination; COVID 19 science initiatives; 3D printing program; 4IR architecture. 7 sectoral priorities of manufacturing and services including business process outsourcing, 5 growth engines (industrialization, investment and infrastructure, innovation, integration and inclusion) and 4 spatial interventions (Special economic zones, Industrial Parks, township and village enterprises, Smart	Policy coherence, including independencies between policies. Business environment for innovation including more industrial competition; collaboration between science and industry; inequality; employment generation; export diversification, product and market; apartheid era spatial development; Higher education not aligned to societal needs; lack of qualified university staff; brain drain; quality assurance in education, and differentiated education and training to meet complex needs; supply of technicians; Governance of STI institutions; more participation in STI including from civil society; increased investment in STI including basic research; skills for 4IR and general skills shortage; need for greater diffusion of technology.

	Vision	Medium term priorities	Challenges
		youth centers). Active labor market policies; and transition plans for high carbon emitting sectors.	
Kenya	Kenya Vision 2030 "Globally competitive and prosperous country with a high quality of life by 2030" and aims at transforming Kenya into a "newly industrializing middle-income country providing a high quality of life to all its citizens in a clean and secure environment". Three pillars Economic, Social and Governance anchored on foundations of macro stability, continuity in governance reforms, enhanced equity and wealth creation opportunities for the poor, infrastructure, energy, Science, Technology and Innovation, land reform, human resource development and public sector reform. Flagship projects and sectors include agriculture, education, health, water, environment, housing, tourism, manufacturing, advanced services, gender, youth and vulnerable groups and rule of law.	STI Act 2013 provided establishment, recognition and funding for STI agencies. Geothermal leadership; technology incubators and accelerators; start up's; constituent (local) innovation hubs; STEM capabilities, including commercialization and co-ordination of technology and innovation; mainstream R&D into planning; strengthen legal and institutional framework for STI's; academic R&D and basic research in Universities; ICT training and affordability of ICT; Some emphasis on Internet of Things, nano technology; IP management and technology diffusion. More food and nutrition security; universal health coverage; revive curriculum and strengthen links between education and training and industry; affordable housing. Eight priority sectors in Medium Plan in agriculture and livestock, manufacturing and extractive industries and services including blue economy; Six social pillars: health; population, urbanization and housing; education and training; environment, water and sanitation; gender; sports and culture; 2 political pillars (devolution and governance).	Sustainable Development; succession planning in research; absence of strong national research agenda and research infrastructure; lack of publications in emerging fields including AI and robotics; need stronger links to SDG's; budget constraint for STI; demand for STI not high; limited IP awareness, lack of Centers of Excellence, STI not mainstreamed into economy; lack of inhouse capabilities in firms; poor STEM outputs; STI influenced overly by donors; priority for teaching rather than research in Universities; Missing knowledge embedded in education curriculum; Cybercrimes; youth unemployment; outdated curriculum; poor perception of VET; weak links between industry and training and research; university faculty lack Ph.D.'s. Lack of framework for green jobs; ease of doing business; public sector capacity; SME finance.

Source: Author assessment, based on UNESCO 2021 and policy documents

APPENDIX 2 TABLE 1: *UN KNOWLEDGE INDEX: DETAILS*

	Main Strengths	Main Weaknesses
Botswana	Survival to last grade of secondary education (8th); Govt expenditure secondary education (4); enrollment in vocational programs (1), GERD per researcher (4), New Business Density (1), Mobile cellular subscriptions (6), Creative services exports (3), World Press Freedom (33), Energy intensity level of primary energy (33), labor force participation (female to male 38)	Poor ethic in labor force (134); internet level of telephony competition (129); unemployment rate (133); life expectancy at birth (110); laws relating to ICT (107); Business to consumer internet use (121); Govt online service index (119), women to men in parliament (125). Manufacturing Value Added (125), Ease of starting a business (120), FDI Inflows (110), Gross Enrollment Early Childhood (107), Enrollment in tertiary (115), production process sophistication (114), ICT imports goods (112), Social impact of ICT (116)
Kenya	Gross Graduation Primary (8); intellectual property receipts (25); ease of protecting minority investors (1); printing and publishing manufactures (1); international internet bandwidth (5), internet telephony level of competition (1); Govt success in ICT promotion (23); labor force female to male (1); unemployment rate (26), Co2 emissions per capita (18)	Pupil teacher ratio primary (109); labor force with advanced education (116); average documents per researcher (103); pupil teacher ratio primary (107); ICT price basket (116); population covered by mobile cellular (109); fixed telephone subscription (132); fixed broadband subscription (132); Active mobile broadband subscriptions (114); Internet use (115), gross fixed capital formation (123); Trade (132); political stability and absence of violence/terrorism (122); GDP per capita (113); under 5 mortality rate (111); energy intensity level of primary energy (118)
India	Expenditure on non-tertiary vocational education (16); Expenditure on vocational programs non secondary non tertiary (1); enrollment in tertiary education ISECD 6 (19); Globally Ranked Universities (8); Graduates from STEM tertiary (12); Citable Documents H Index (21); Best Scientific Journal (14); Protecting Minority Investors (13); Internet and telephony level of competition (1); creative goods export (8)	Labor force participation female to male (132); women to men in parliament (115); Trade (125); ease of enforcing contracts (124); fixed telephone subscription (111); mobile cellular subscription (115); new business density (113); unemployed with advanced education (117); citations per document (121); enrollment in vocational programs secondary (119); Gross Enrollment primary (115); labor freedom (113); inbound student mobility rate (113); internet users (122); Mean years of schooling (108); under 5 mortality rate (105)
Uganda	Labor freedom (10); average documents per researcher (12); citations per document (33); inbound mobility rate (19); internet telephony level of competition (1); women to men in Parliament (31) labor force participation (15); unemployment rate (12); Co2 emissions per capita (10); Renewable Energy Consumption (5)	Trade (118); domestic credit to private sector (125); bank deposit to GDP (127); GDP per capita (128); under 5 mortality (115); life expectancy at birth (121); energy intensity of primary energy (127); secure internet servers (120); ICT price basket (129); mobile cellular subscription (130); fixed broadband subscription (124); fixed telephone subscription (123); Customer internet usage (122); ease o starting business (127); international internet bandwidth (124); computer software spending (117); labor force with advanced education (128); Govt expenditure secondary (119), pupil teacher ratio primary (123); patent applications (113); Govt expenditure tertiary (117)

	Main Strengths	Main Weaknesses
South Africa	Government expenditure primary (9); teachers with minimum required qualifications (1); enrollment in vocational post-secondary non tertiary (1); ease of protecting minority investors (18); new business density (12); printing and publishing manufacturing (10); mobile cellular subscription (8); unlicensed software installation (20); domestic credit to private sector (12), women in parliament (5)	Unemployment (138); youth not in employment, education or training (106); under 5 mortality rate (107); life expectancy at birth (118); Co2 emissions per capita (115); energy intensity (124), international internet bandwidth (119); internet and level of telephony competition (119); fixed telephone subscription (106); fixed broadband subscription (102); Govt success in ICT promotion (105); investment in telecom services (111); ease of starting a business (109); Gross fixed capital formation (117); pupil teacher primary (105); pupil teacher secondary (110); unemployment with advanced education (112); poor work ethic in labor force (116); Gross Enrollment primary education (105)
Rwanda	Gross Enrollment primary (4); Expenditure on non- tertiary vocational education (9); enrollment in vocational post- secondary non tertiary (1); GERD per researcher (3); internet and telephony level of competition (1); Govt success in ICT promotion (9); labor force participation female to male (1); unemployment (7), Co2 per capita (4); Renewable Energy Consumption (7)	GDP per capita (124), mean years of schooling (116); world press freedom index (124); bank deposits to GDP (126); creative goods exports (119); domestic credit to private sector (115); fixed telephone subscriptions (134); mobile cellular subscriptions (122); fixed broadband subscriptions (129); active mobile broadband subscriptions (111); ICT price basket (128); international internet bandwidth (122); internet users (118); virtual social network users (112); patent applications (121); unemployment with advanced education (122); enrollment in tertiary education (120); pupil teacher primary (134); Gross Enrollment Early Childhood Education (114); Gross Enrollment upper Secondary (120); mean years of schooling (116), Technicians per 1000 labor force (109); researchers per 1000 labor force (117); STEM graduates (105); citable documents H Index (112); patents (121); creative services exports (113); Trade (107); Highly Skilled Employees (115)
US	Enrollment in vocational post-secondary non tertiary (1); ease of finding skilled employees (1) Globally Ranked Universities (1); Citable documents H Index (1); Best Ranked journal (1); IP property receipts (1); extent of marketing (1), New Business Density (1); Internet and level of competition (1); laws related to ICT (1); firm technology absorption (1); unlicensed software (1); venture capital (1)	Co2 emissions per capita (129); energy level intensity (91); renewable energy consumption (108); Trade (137); Investment in telecommunications services (110); gross fixed capital formation (91); STEM graduates (87); poor work ethic in labor force (93) enrollment in tertiary ISCED 6 (119), trademarks (89)

Source: Drawn from UNDP 2020