National Research Outlook Report

Unlocking Uganda's Research Potential for Long-Term Development and Prosperity

June 2023

Uganda National Council
for Science and Technology

UNCST

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Abbreviations and Acronyms:

BERD	Business Expenditure on Research and Development
COVID-19	Corona Virus Disease 2019
CUUL	Consortium of Uganda University Libraries
EU	European Union
FTE	Full-time Equivalent
GERA	Gender Equity in Research Alliance
GERD	Gross Domestic Expenditure on Research and Development
GBAORD	Government budget allocations for R&D
GCI	Global Competitiveness Index
GCRI	Global Climate Risk Index
GDP	Gross Domestic Product
GII	Global Innovation Index
HEIs	Higher Education Institutions
HRST	Human Resources in Science and Technology
HDI	Human Development Index
HDR	Human Development Report
ICT	Information and Communication Technologies
INASP	International Network for Advancing Science and Policy
ITDTP	Innovation, Technology Development and Transfer Programme
MSMEs	Micro, Small and Medium-sized Enterprises
MTAs	Material Transfer Agreements
MOSTI	Ministry of Science, Technology and Innovation
NDP III	Third National Development Plan
NRC	National Research Council
NRI	Network Readiness Index
NRIMS	National Research Information Management System
NRRU	National Research Repository of Uganda
OOP	Office Of the President
ORTARCHI	Oliver Tambo Research Chairs Initiative
PDM	Parish Development Model
RECs	Research Ethics Committees
RIs	Research Infrastructures
R&D	Research and Development
RENU	Research and Education Networks Uganda
RCA	Relative Comparative Advantage
S&T	Science and Technology
SDGs	Sustainable Development Goals
SGCI	Science Granting Councils Initiative
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
STI-OP	Secretariat of STI, Office of the President
STISA	STI Strategy for Africa
NSTEI-SEP	National Science, Technology, Engineering and Innovation Skills Enhancement Project
TAI	Technology Achievement Index
TBP	Technology Balance of Payments
TISCs	Technology and Innovation Support Centers
TIBIC	Technology Innovation and Business Incubation Centre
TOT	Transfer of Technology
TRIDI	Tropical Institute of Development Innovations
TTOs	Technology Transfer Offices
TVET	Technical Vocational Education and Training
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNCST	Uganda National Council for Science and Technology
USPTO	United States Patents and Trademarks Office
WIPO	World Intellectual Property Organization

Key Words:

Artificial intelligence (AI):
Simulation of human intelligence processes by machines, in particular by computer systems. These processes include: learning (the acquisition of information and rules for using the information); reasoning (using rules to reach approximate or definite conclusions); and self-correction.

Big data:
Extremely large data sets, produced through the digitization of content, greater monitoring of human activities through digital technologies, and the spread of the internet of things.

Bibliometrics:
A set of methods to quantitatively analyse academic literature. It could be used to measure the number and quality of scientific and technical journal articles in an economy.

Blockchain:
A distributed register designed to store static records and dynamic transaction data without central coordination by using a consensus-based mechanism to monitor the validity of transactions.

Cloud computing:
The practice of using a network of remote servers hosted on the internet to store, manage and process data, rather than a local server or a personal computer.

Cobot:
Collaborative robot, intended to physically interact with humans in a shared workspace (in contrast to robots operating autonomously).

Cognitive technologies:
Products of the field of artificial intelligence which are able to perform tasks that only humans used to be able to do.

Digitalization:
The use of digital technologies and digitized data to influence how work gets done, transform how customers and companies engage and interact, and create new – digital – revenue streams.

Digital reality:
Wide spectrum of technologies and affordances that include the processes known as "augmented reality", "virtual reality" and "mixed reality" that simulate reality in various ways.

Doctoral students:
Students who attend "tertiary programs which lead to the award of an advanced research qualification [and which] are therefore devoted to advanced study and original research and are not based on course work only"

High-tech industries:
Industries that use the most advanced technologies available to manufacture goods or provide services

High-tech exports:
These are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments and electrical machinery.

Intellectual property:
An innovative work whose exclusive right to the inventor could be legally protected.

International Standard Classification of Education
Qualifications by education levels and fields.

Internet of things
Of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

Machine learning:
AI application that provides systems the ability to automatically learn and improve from experience without being explicitly programmed to do so.

Patent
The sole right granted by a government to an inventor to market an invention for a period of time. It is a form of intellectual property that encourages innovative efforts among entrepreneurs.

Prototype:
An original model constructed to include all the technical characteristics and performances of the new product.

Research and Development:
Comprises creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge

Researchers:
Professionals engaged in the conception or creation of new knowledge. They conduct research and improve or develop concepts, theories, models, techniques instrumentation, software or operational methods.

Royalty:
The percentage of income accruing to inventors from the sales of their inventions.

Technology absorption:
An economy or enterprise's capacity and readiness to use the most advanced technology available for productive purposes.

Utility Model:
An exclusive right granted by the government for an Innovation/invention, which is either a product or process that offers a new technical solution to a problem.

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Preface:

The Uganda National Council for Science and Technology (UNCST) was established by the UNCST Act (CAP 209) of the Laws of Uganda and commenced operations in 1990. UNCST was designed to be the apex policy formulating and advisory body on science and technology matters to the Government of Uganda. Under the new dispensation, the UNCST has been accorded the following STI functions; a) Regulating all aspects of Science, Technology and Innovation in Uganda; b) Translating STI policies into regulations and standards to guide the operations of the entire STI system; c) Monitoring and evaluation of STI activities and compliance to STI regulations; and, d) Homing of science professional institutions and continuing professional development.

This National Research Outlook Report provides an analytical snapshot of the different drivers of STI in the country. Specifically, this report places a sharp focus on the state of research, including investments, personnel and infrastructure in research. The report assesses Uganda's readiness to gainfully engage in a progressively competitive global knowledge ecosystem. This is critical for informing Uganda's future policy options around STI financing, research regulation, quality assurance and international research collaboration, particularly in light of the emerging challenges, like the COVID-19 pandemic.

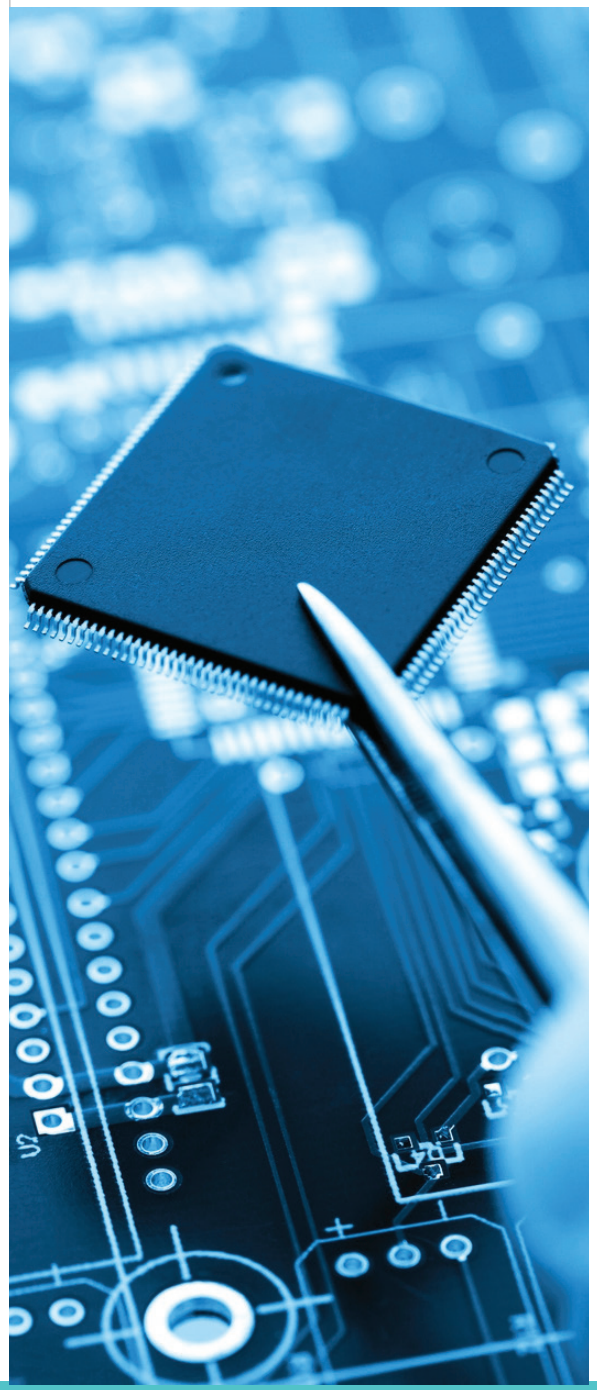
I am very thankful to the President of the Republic of Uganda who has been a consistent advocate of STI and its contribution to national transformation. The Minister for STI is also acknowledged for putting Uganda's STI system on a trajectory of science-led development through a new value-chain approach. I would also like to thank the management and staff of UNCST for undertaking this critical study which I believe will help us track progress towards the achievement of our national, regional and global targets.
I thank you.

……..
Theresa Ssengooba (PhD)
Chairperson, the Governing Council
Uganda National Council for Science and Technology

Acknowledgement:

The development of the 2022 National Research Outlook Report was a result of a series of stakeholder consultative and editorial committee meetings under the leadership of the Policy Coordination Division of the Uganda National Council for Science and Technology (UNCST). The Report provides useful insights into Uganda's Science, Technology, and Innovation landscape, especially on the centrality of STI to Uganda's transformative agenda.

The UNCST recognizes the important inputs of all the stakeholders who contributed their valuable time and ideas that led to the production of this edition of this Report. UNCST acknowledges and appreciates the roles played by the authors, contributors, and reviewers in the development of the chapters of this report. The Report was prepared under the general guidance of Dr. Martin Ongol, the Ag. Executive Secretary of UNCST. Specifically, Mr. Steven Sebbale is acknowledged for consolidating the report content. Special mention also goes to Ms. Noeline Komucunguzi for coordinating the data collection and literature review; and Mr. Jacob Komaketch for data mining and compiling. Mr. Patrick Mafabi is acknowledged for data analysis and statistical support. Mr. Ismail Barugahara and Ms. Immaculate Nakamya are also acknowledged for their excellent input, comments, and guidance at various stages of report writing and analysis. The team further acknowledges the rich comments provided by the peer reviewers and the insightful feedback from stakeholders across Uganda's growing research system.



Foreword:

Science, Technology, and Innovation (STI) are expected to play a critical role in Uganda's socioeconomic transformation, especially during this era of rapid global technological advancements alongside new and emerging challenges. With Uganda's vision to achieve middle-income status by 2030, the country has to accelerate technology-driven approaches to strengthen its import-substitution strategy and build a strong human capital base. This will ensure that Uganda gainfully engages in this Fourth (or Fifth) Industrial Revolution. The COVID-19 pandemic placed STI front and center of Uganda's recovery strategy and has been vital in building system-wide resilience. The pandemic also demonstrated STI's role as a key enabler in resolving the country's persistent challenges like youth unemployment and climate change.

One of the key mandates of the Uganda National Council for Science and Technology (UNCST) is to provide evidence for STI policy formulation to the Government of Uganda. The S&T data and information collected under this activity from state and non-state S&T institutions provide a strong knowledge resource for measuring the current S&T capacity and Uganda's progression towards a Knowledge-Based Economy (KBE). Therefore, this Research Outlook Report helps identify system deficits and gaps in S&T capacity necessary to build resilience to new and emerging challenges. While the Report provides comprehensive insights into the issues defining Uganda's current STI landscape, the criticality for policy reforms in specific areas should be the mainstay. Reforms in STI training, gender inclusivity, research funding options, the utilisation of research results by the private sector, and the harnessing of research collaboration, are among some of the critical enablers that should be fast-tracked to ensure that Uganda can achieve some of its most national, regional and global targets for STI-led development.

I want to thank the UNCST team for their hard work toward the successful production of this 2022 Research Outlook Report. I want to extend our gratitude to the stakeholders who provided comments, data, and insights during this process.

I am confident that this report will catalyze new conversations and spur fundamental reforms across our vast STI system to ensure that no Ugandan is left behind in our country's transformative journey.

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Martin P. Ongol (PhD)
Acting Executive Secretary
Uganda National Council for Science and Technology

Key Messages:

- Uganda's research eco-system is on an expansive path. Although research undertaken by business entities and small and medium-sized firms (SMEs) is yet to grow, the role and contribution of scientific research is increasingly becoming visible.

- International research collaboration cannot be overemphasized. Participation in research collaboration is inevitable owing to the growing list of challenges, including climate change, pandemics, migration, green energy options, etc. that no country can tackle on its own.

- Government investment in R&D has been increasing although not commiserate to global trends. Uganda's public funded research budgets still remains largely foreign-led. New direct and/or indirect models of research funding need to be explored to incentivize private-sector actors to invest in research.

- Rationalizing public research spending, establishing ties between public and private research actors and encouraging interdisciplinary research is ongoing. University-Industry collaboration remains a key challenge for translating research into commercializable products and processes. A strong intellectual property regime within academia can enhance these partnerships.

- Uganda's research talent is on the move. Human capital devoted to research is increasing as research activity becomes a priority among universities and research institutes. Ensuring the future supply of research talent and building a culture for innovation will be critical in building Uganda's research system.

- Improving research governance within research-performing institutions is critical. Stregthening policies and a strong attention to research monitoring and evaluation is critical for building a robust research eco-system.

- The sources of public research funding have also changed as a result of greater involvement by industry. Public-private partnerships (PPPs) offer opportunities for sharing risks. Private equity, although still small can play an increasingly important role in complementing public research.

- Efforts towards open science are still in nascence. Currently, no environment has been created or specific policy guidance given for open access and open data. Uganda is yet to embrace open science through infrastructure upgrades, revision of legislation and research funding mechanisms, that encourage open access and open data.

- Education policy has evolved to reflect the wider range of skills required to innovate. This includes increased budgets to boost science, technology, engineering and mathematics (STEM) education, initiatives to make STEM more attractive to young people, or revised curricula to develop generic skills, problem-solving capacity and entrepreneurial behavior.

- Through its eight STI value chains, Uganda is vigorously building a new "culture" of science and innovation that will help reinforce public participation in and support for science and entrepreneurship. Efforts to build capacity for the popularization of science, and to foster an entrepreneurial spirit are underway.

- Government is providing strong leadership in driving research and support to emerging technologies and linking these to its broader missions, like fostering household resilience, poverty eradication, tackling unemployment and buildin strong value chains. Renewing or reviewing STI policy frameworks and capabilities can help build resilience and enhance policy-learning across the ecosystem while investment in evidence to support policy is a pivot for such change.

- Uganda's research system is growing in resilience and adaptability, underpinning the inherent and latent capabilities of the system. The innovations around drug therapies and the roll out of digital technologies helped lessen the impact of the pandemic. Establishing robust early warning systems shaped by new research will best prepare the country to face future similar scenarios.

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Minister of Science, Technology and Innovations - Office of the President, Dr. Monica Musenero launching the National Research Bio-banking Guidelines, September, 2021

Executive Summary:

Insights About Uganda's Research Landscape:

- **192** – highly cited papers from Uganda between 2010-2020
- **0.23%** - the proportion of national expenditure on research and development
- **UGX12.1bn** – the research expenditure on different COVID-19 research innovations.
- **31%** - Increase of publications from Makerere University between 2019 and 2020
- **26** - R&D personnel per million Ugandans
- **48.3%** - Ugandan researchers employed in higher education. Uganda
- **48%** - percentage of lead researcher's / principle investigators with a PhD
- **23.4%** - percentage of female PhDs from public universities between 1970-2020
- **1,197** PhDs awarded in Uganda between 1970-2020
- **11%** - STEM PhDs awarded in private universities between 2001-2020
- **68.1%** - STEM PhDs awarded in public universities awarded over 20 years
- **119** – Uganda's ranking in the Global Innovation Index (out of 132 countries)
- **0.525** – Uganda's Human Development Index that her in the low human development category (out of 191 countries)
- **0.157** - Uganda's Technology Achievement Index – categorized among the technologically marginalized countries
- **3.5%** - the percentage increase in Government budget allocations towards R&D between FY 2015/16 and FY 2020/21
- **21.6%** - Budgets over $500,000 Ugandan- registered research
- **12** – Number of research journals in Uganda
- 16 – Uganda's active innovation hubs
- **31** – the number of Research Ethics Committees in Uganda
- **53** – number of private and public universities
- **3** – Ugandan universities ranked among Africa's top 200 universities
- **8** – the number of STI Value Chains that are shaping Uganda's STI agenda
- **135** – the number of students in higher education per PhD holder
- **7.8%** – Percentage of PhD programs in Higher Education

Scientific discovery occurs in an interconnected, international ecosystem that collectively leverages intellect, know-how, talent, financial resources, and infrastructure from around the world. Open and transparent communication and dissemination of scientific information and sharing of research materials are essential for the global science ecosystem to operate effectively.

There has been growing consensus that strengthening research capacity in Uganda is one of the prerequisites if development goals are to be met. Over the past 30 years, Uganda has rapidly transformed from an economy that is heavily dependent on primary commodities into one characterized by a vibrant and growing services sector. Specifically, Uganda has strengthened its research and development footprint with her research outputs becoming more visible in a highly competitive global knowledge system. This withstanding, Uganda's performance when calibrated against several global research indicators remains a challenge. Several barriers still prevent researchers from fulfilling their potential. Under-research investment in universities and research institutions, inadequate research infrastructure and limited prospects for researchers, are just some of the factors that are holding back research activity in Uganda. While International research collaboration has increased over the past decade, emigration of research talent has been increasing. Its estimated that 37% of researchers in Uganda will be leaving the country in the next five years (UNCST, 2020). Challenges relating to the retention of research personnel and funding remain typical of the landscape.

Within academia, research performance remains a criteria for staff promotion. However, translating research for socio-economic impact has remained lukewarm. The under-investment

in data systems and the inherent capabilities to formulate, analyze and monitor Science, Engineering and Technology Institutions (SETIs) policies and instruments continue to be a major handicap of Uganda's wider STI system. The Government of Uganda has been intentional in placing Science, Technology and Innovation (STI) at the center of its transformative agenda and has undertaken far-reaching structural reforms to integrate STI in some of its most recent development vehicles, including the Parish Development Model (PDM).

This Report provides a snapshot outlook of Uganda's research landscape by focusing on key aspects of the broader STI ecosystem. Specifically, the Report seeks to show the current state of play in Ugandan research across a continuum of issues ranging from the harnessing of research talent, research funding, international research collaboration, Uganda's place in the global research system, the nexus between research and commercialization, among others. An appraisal of these issues has highlighted key opportunities and identified new gaps and recommendations, critical to building a competitive and robust research system. These issues are expected to put a spotlight on the areas that can benefit from policy reform and institutional strengthening. Using documentary reviews, primary and administrative data analysis, the Report shows that Uganda's research system is indeed rapidly changing.

The emerging challenges, including the COVID-19 pandemic, have placed research at the center of the policy debate. Moreover, the new STI approach through Value Chains (e.g. the Pathogen Economy, Mobility, Industry 4.0+, Infrastructure Innovations, Aeronautics and Space, Productivity acceleration, Import Substitution and Export-Targeted STI) is providing fresh impetus for research and the criticality of building evidence to drive policy in these new and emerging areas.

The Report shows that while Uganda remains a net-importer of goods and services with limited product diversification and a high dependence on Foreign Direct Investment (FDI), the visibility of Uganda's research is improving, albeit mildly. Between 2012-2020, Uganda had 192 highly cited papers and hosts 53 R&D personnel per million inhabitants. The underlying gender challenges still persist with 24% of Ugandan PhD holders being female. PhD programs in higher education constitute 7.8% of the total programs while the ratio of PhD holders to students in higher education have marginally increased to 1:135.

The Report shows that over the past three years, Uganda performed better in innovation inputs than innovation outputs. Nevertheless, Uganda ranked 116th in innovation inputs and 120th in innovation outputs and a global innovation ranking of 119 out of 132 countries. Uganda's Technology Achievement Index increased marginally from 0.146 to 0.157 between 2015 and 2020 respectively. This TAI index places Uganda in what the index classifies as "marginalized". This withstanding, government budget allocations for R&D grew 3.5 times (in absolute terms) from 109 billion in FY 2015/16 to 384 billion in FY 2020/21.

This Report lays out five over-arching recommendations, each of which requires actions from a variety of actors: (a) It underscores the importance of scientific research and international collaboration as a key component of Uganda's research ecosystem; (b) the strengthening of Uganda's research quality assurance system as being critical for addressing the new and emerging challenges; (c) the criticality of working across sectors and institutions to develop more integrated and effective research policies is necessary to craft a research culture across the public and private sector; (d) the delineation and upsellling a national research agenda is vital to ensure alignment to national, regional and global development aspirations; and (e) building of a strong research human capacity base as a vehicle for scientific leap-frog. Policy reforms will be needed to strengthen research and productivity outcomes. Improving the business environment for innovation is especially important whilst encouraging actors within Uganda's nascent business sector can spur innovative activity. Grounding the idea-to-market approach can streamline support and funding towards research to spur techno-preneurship. More research-friendly regulation can foster the flow of technology and knowledge across borders; build resilience among communities through impact-led research. Reforms in the what, how, who, where and when research is conducted can inform evidence-led policy reform and ultimately draw greater benefits from Uganda's investment in innovation, technology and research.

1World Bank (2018a), "Uganda Agricultural Policy from a Jobs-Creation Perspective", background paper
2Measured as GDP (in USD of Purchasing Power Parity (PPP) in Constant prices) per job
3World Bank (2019a). Uganda Economic Update, 13th Edition: Economic Development and Human Capital in Uganda - A Case for Investing More in Education. Washington: World Bank. https://openknowledge. worldbank.org/handle/10986/31751.

1. Setting the Stage:

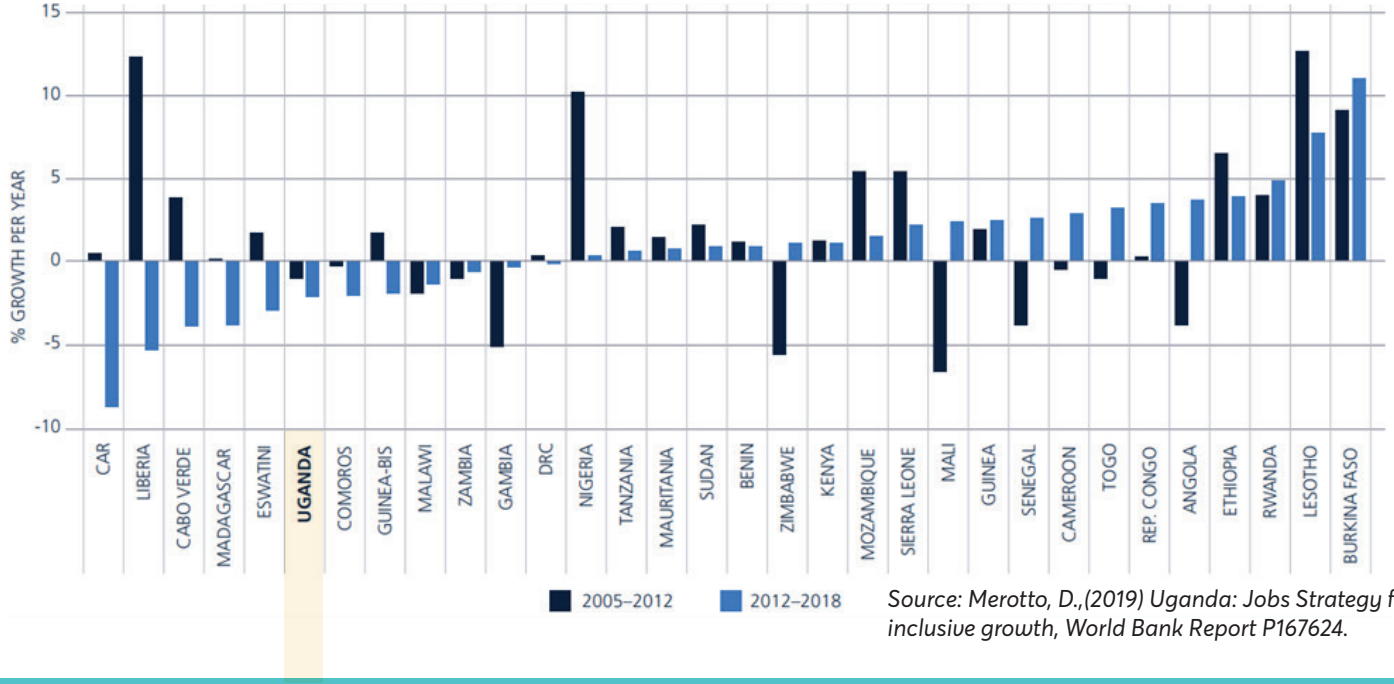
1.0 Context

Over the last three decades, Uganda has reported impressive rates of economic growth.

The Ugandan economy grew at 4.6% in 2022, faster than had been anticipated. Growth benefited from a gradual increase in investments in the oil sector and dividends from the government's promotion efforts in tourism, export diversification, and agro-industrialization. However, according to the World Bank, Uganda's growth model of debt-financed public spending is not sustainable. The Bank advises that the State should instead support the economy through investments in human capital, through regulations that facilitate investment and job-creation, and through measures that reduce inequality and strengthen resilience. The prospects for this shift to a private sector-led growth model will also rely on better support for the vulnerable groups and small enterprises whilst increasing the uptake of digital technologies. W0hereas agriculture now accounts for 24% of Uganda's GDP, it employs 64% of Ugandans, and 72% of young Ugandans. Labor productivity growth in Uganda is not keeping pace with comparable countries. The Ugandan labor force is growing fast, and since most people work because they cannot afford not to, disguised unemployment is also rising fast. Growth in value-added manufacturing is not accelerating. As a result, aggregate labor productivity growth (GDP per person employed) has fallen quite significantly. Average Total Factor Productivity (TFP) growth has been negative in agriculture for the last two decades.[1] For instance, national agricultural output has grown at only 2% annually over the last five years, compared to agricultural output growth of 3 to 5 percent in other EAC members, and 3.3 percent annual growth in Uganda's population over the same period (Figure 1). The concentration of jobs in the agricultural and informal sectors, as well as the small size of businesses, are obstacles to the country's economic development, and explain the relative stagnation of labor productivity[2] over the last decade (+5% between 2011 and 2019 as against +55% between 2000 and 2011). Uganda will need to create more than 600,000 jobs a year until 2030, and then 1 million jobs a year up to 2040, to enable the inclusion of youth in the labor market[3].

Uganda remains a net-importer of goods and services with limited product diversification and a high dependence on Foreign Direct Investment (FDI). Growth has been further decelerated by the ongoing effects of COVID-19 pandemic and disruptions in the global markets of the primary products in which Uganda deals in. A recent report has shown that in 2020, the economic downturn caused by the international health crisis resulted in a -2% recession that had serious

Fig 1: Agriculture value added per person employed, annual growth 2005-2012 and 2012-2-18



Source: Merotto, D.,(2019) Uganda: Jobs Strategy for inclusive growth, World Bank Report P167624.

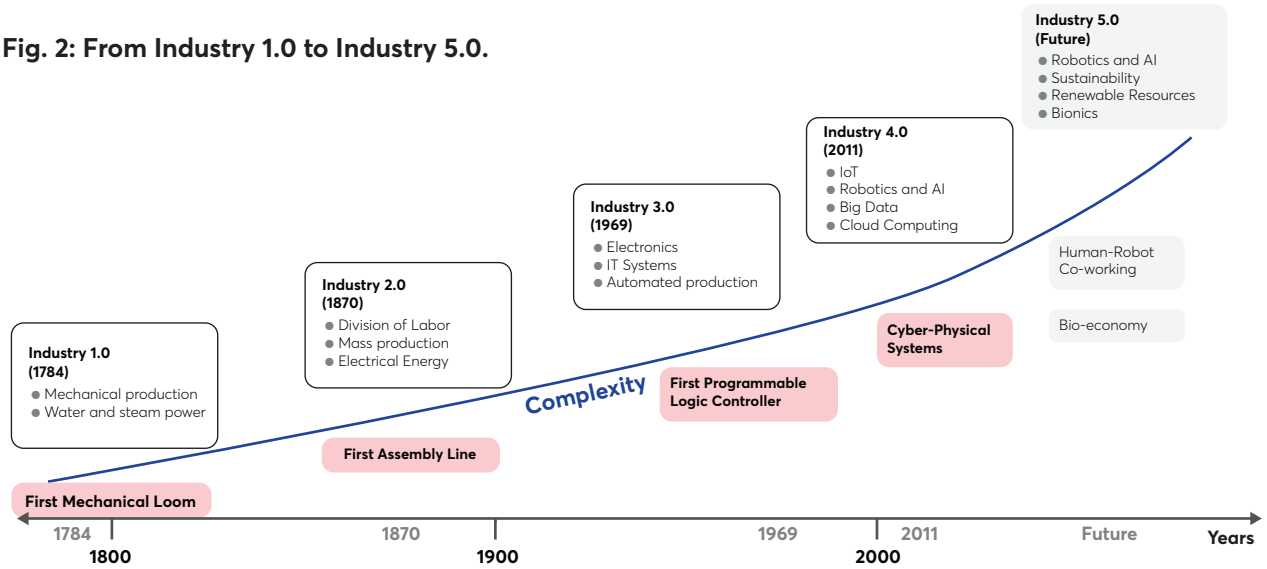
social consequences[4]. This economic reality has increasingly forced Uganda to embark on building internal resilience to such global shocks. The growing consensus of the criticality of Science, Technology and Innovation (STI) has been amplified by these new and emerging challenges that the country continues to face. Whereas Uganda's 2040 Vision seeks to transform the Ugandan society from a peasant to a modern and prosperous country within 30 years, the drive towards industrialization, manufacturing, skills development and agro-security should become a mainstay of the country's transformative agenda. Nations with mechanisms to leverage the globally available pool of knowledge and that produce new knowledge for a global market to innovate, have profited, while nations unable to do so have been increasingly left behind.

1.1 Contribution of STI to economic growth

Historical experience has shown that achieving a sustained improvement in living standards is based on the extent to which nations develop their science and technology capabilities and that continued prosperity depends on the degree to which they continue to do so.

Technical advances have changed the way humans do things. Over the last 300 years, the transition from the pre-industrial stage up to the most recent period where novel technologies like Industry 4.0+ are being adopted has been shaped by the pace and progress of research and the application of research results in the development of new products and services, the emergence of new institutions and the structural reforms with the local, regional and global knowledge eco-system. For developing economies like Uganda, the criticality of research and development (R&D) as a driver for sustained developed cannot be overemphasized. Specifically, creating a conducive environment for rapid increases in R&D expenditure will be a catalyst for driving more dramatic technological advances and narrowing the global north-south divide. The waves of technological change have not only widened disparities in access to products, social services and public goods – from education to health, from ICT infrastructure to electrification but have spurred many countries to try and catch-up through technological learning, imitation and innovation.

Fig. 2: From Industry 1.0 to Industry 5.0.



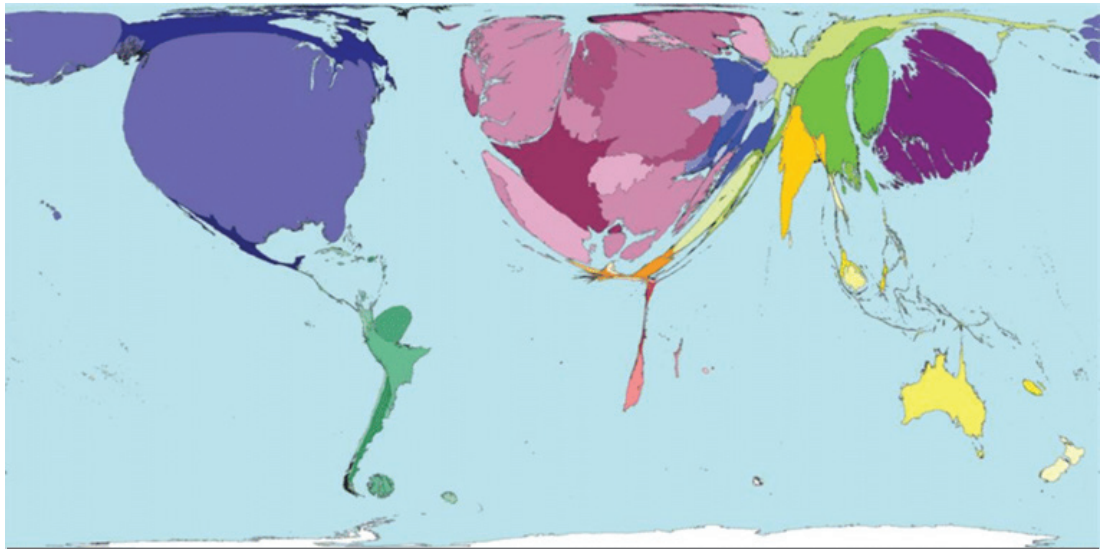
1.2 Perspectives from the Global Research System

The global research system is highly skewed towards the global north (See Figure 3).

Over the last five decades, the volume of scientific research production in the Global South has been incomparable to that from the Global North. This dramatic difference is reflective of several complexities related to, among others, the quality of institutions, the availability of human capacity, the access to technology a gaping digital divide,

4Puloc'h, M., (2021), Uganda: revising the growth model while preserving debt sustainability, in Macroeconomics and Development, MACRODEV

Fig.3: World map of Concentration in Scientific Production



the mindset towards innovation, and other structural challenges related to governance and policy. As a result, many Sub-Saharan Africa (SSA) countries get left behind in their response to new and emerging challenges like climate change, in building resilient food systems or in gainful engagement in the global knowledge economy. A search of Clarivate Analytics Essential Science Indicators for the period 2010–2019 shows that Africa produced 659,910 publications. Between 2001 and 2018, Africa contributed 508,102 scientific publications to the world total of 6,688,920 Publications. This represented a marginal increase from 1.7% in 2010 to 3% in 2018. Nevertheless, Africa produced 7.6% of all scientific research and about 30% of the world's research in tropical medicine. African research is on a positive trajectory. The top ten science categories reveal dominance of Engineering-Electrical and Engineering, well above the next category, Public Environmental and Occupational Health. However, when combined with the categories 'infectious diseases', 'pharmacology pharmacy' and 'tropical medicine', Uganda's research posture heavily leans towards the health sciences. Uganda's research performance has been increasing although this pales in comparison with other countries. As shown in Table 1, Uganda had about 192 highly cited research articles between 2012 and 2019 compared to 1,807 from South Africa over the same period.

Table 1: Research Performance in selected African Countries (2012-2019)

COUNTRY	Count	Citations	C/P	Highly Cited	CNCI
South Africa	114,795	1,357,226	11.82	1,807	1.19
Egypt	92,103	767,548	8.33	655	0.91
Kenya	15,940	251,260	15.76	341	1.51
Nigeria	25,362	191,924	7.57	225	0.84
Tanzania	8,551	122,336	14.31	135	1.38
Uganda	9,276	144,264	15.55	192	1.47
Ethiopia	11,309	107,285	9.49	128	1.19

Source: Clarivate Analytics

Linder A, Schick S, Hell W, et al. ADSEAT–Adaptive seat to reduce neck injuries for female and male occupants. Accid Anal Prev. 2013;60:334–43.

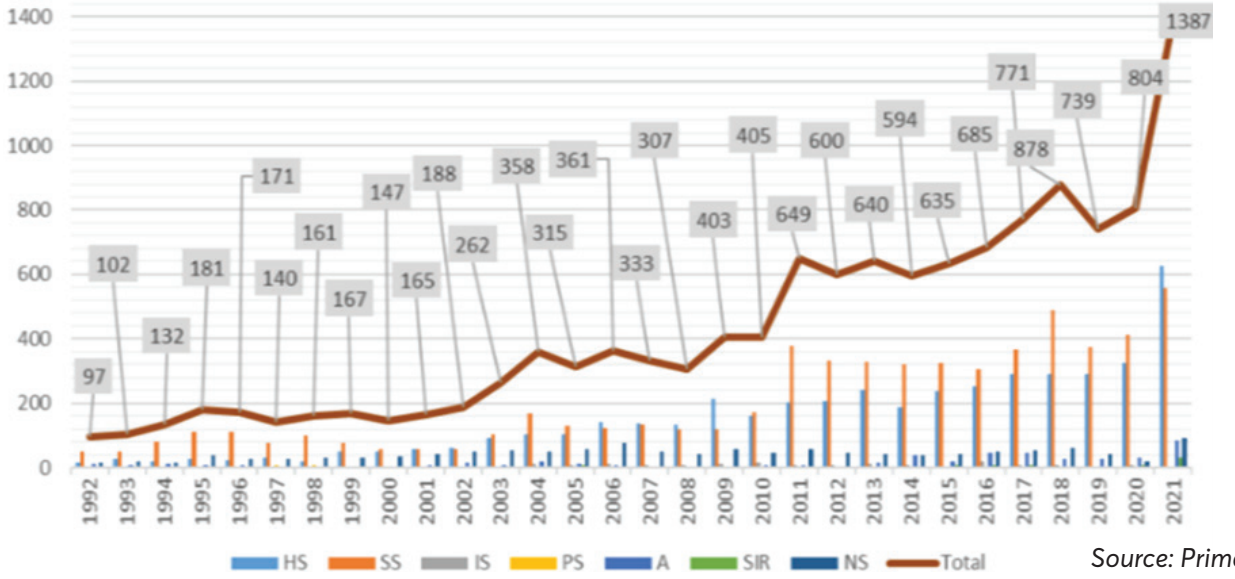
1.3 Research Performance in Uganda

Research performance in Uganda is on the rise.

As shown in Figure 4, the number of research registered at the UNCST has continued to grow over the past thirty years. Part of this growth can be attributed to the establishment of robust research quality assurance systems with a global reputation for research excellence[5]. It is already government policy to create new centers of excellence in the form of science parks, international campuses and R&D centers. Uganda's expansive higher education sector has also increased the propensity for research across the system. The sector has gradually evolved from the establishment of its first public university in 1922 to fifty-three (53) universities at present.

Enrollment in Universities also grew from about 10,000 students in 1990 to more than 200,000 students in 2022. In addition, the establishment of globally acknowledged research quality assurance systems has made Uganda a destination of choice for high-grade international research. Increasingly, global research partnerships between Ugandan and foreign research consortia have also contributed to this trend. However, inspite of this growth, more needs to be done. Establishing robust research monitoring systems, supporting research institutions to maintain strong research ethical practice and enhancing access to top research infrastructure remain enduring challenges facing the system. The UNCST is establishing frameworks for supporting regulatory aspects of research whilst creating an environment for homing research talent within the system. Systems for research monitoring and evaluation are being established to ensure that research from Uganda can sustainably contribute to the national, regional and global challenges. The increasing visibility of Uganda's research and research institutions is a growing testament to this evolving change. As shown in Figure 5(a) and Figure 5(b), only two universities in Uganda are ranked with regard to research and innovation. These are: Makerere University and Mbarara University of Science and Technology (MUST). Their ranking of 23rd (Makerere) and 63rd (MUST) has been enhanced owing to the growing visibility of Ugandan research and innovation on the global stage.

Fig.4: Trend of Research registered at UNCST



Source: Primary Data

Fig. 5 (a): Global Ranking: Mbarara University of Science and Technology

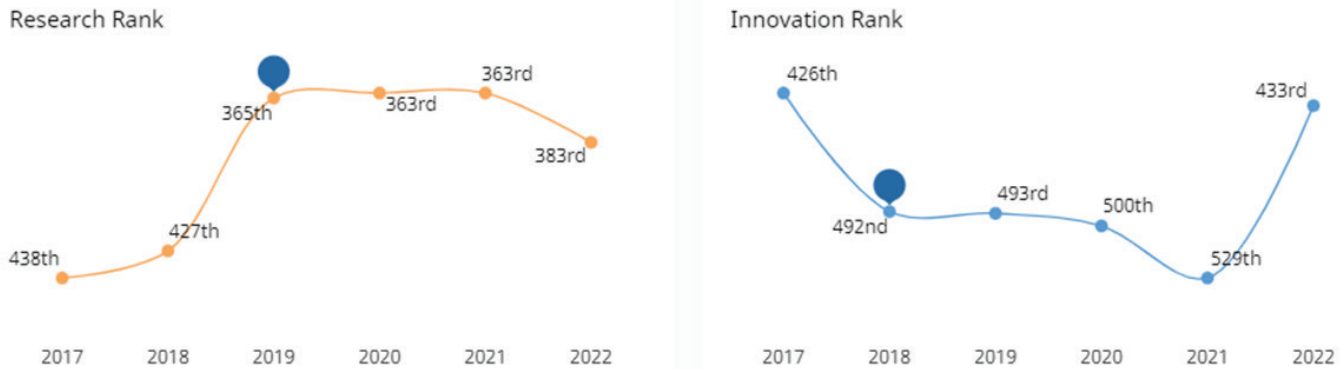


Fig. 5(b): Global Ranking: Makerere University

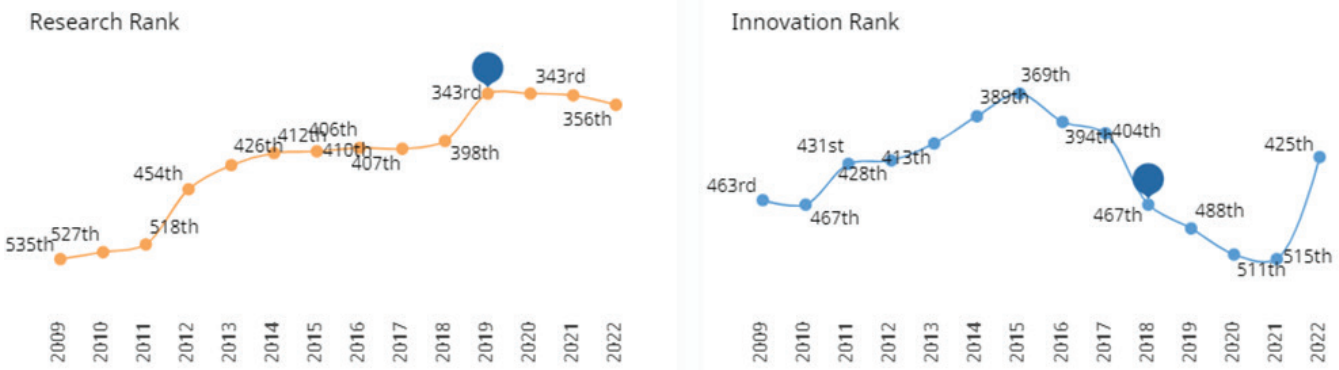


Table 2: Ranking of research Performance of Selected Ugandan Universities

No.	University	Ranking in Africa (Out of 1701 universities)	World Rank (Out of 30000 universities)
1	Makerere University	13th	1092nd
2	Kampala International University	58th	2275th
3	MUST	112nd	3116th
4	Kyambogo University	197th	4331st
5	Busitema University	237th	4871st
6	Gulu University	265th	5269th
7	Uganda Martyrs University	282nd	5548th
8	Makerere University Business School	372nd	7056th
9	Islamic University in Uganda	378th	7192nd
10	Mountains of the Moon	397th	7711st

As shown in Table 2, Uganda has only two universities among the top 100 universities in Africa.

Source: Webometrics rankings for Universities in Web content and Research performance as of January 2022.

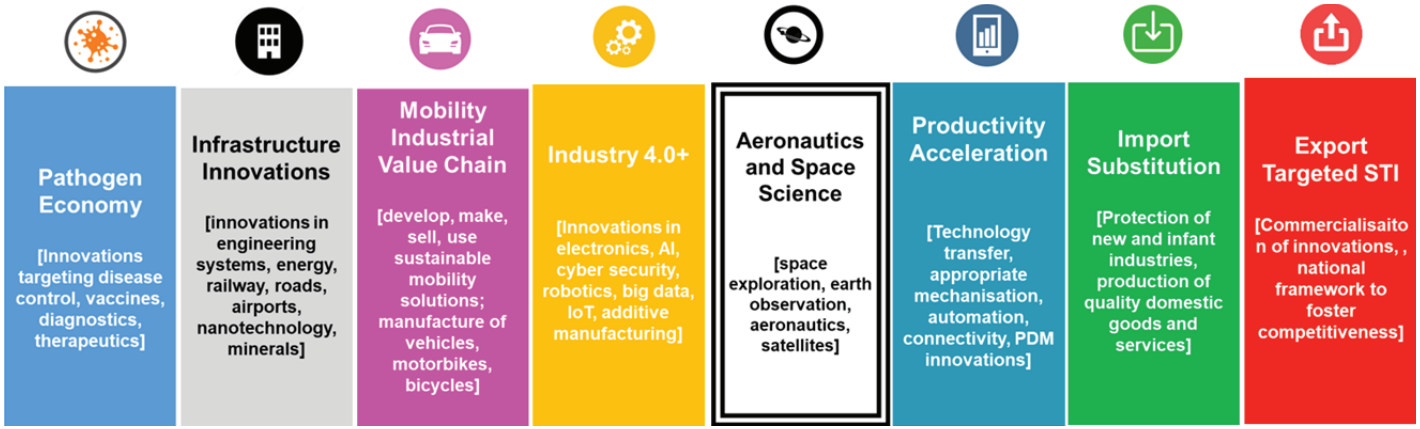
5https://assets.publishing.service.gov.uk/media/5ef4adad86650c129b9af059/NA_report_Uganda__Dec_2019_Heart_.pdf

1.3.1 Delineating a National Research Agenda

A National Research Agenda (NRA) offers an opportunity to focus research funding towards those strategic areas that can strengthen Uganda's resilience to engage in a globally competitive knowledge market place.

The NRA can generate more synergy in research as a whole and augment the consistency, efficiency and impact of Ugandan research. For several years, STI has been on the fringes of the policy debate in Uganda. However, this has changed. Among the fourteen (14) key issues mentioned in the NRM Manifesto (2021-2025)[6] is the investment in scientific research and development (R&D). The Manifesto acknowledges that low investment in scientific research and development (R&D) has been the bane of shaping a national innovation and policy. The government is intentionally pursuing a value-added approach with selected value chains being identified as providing the catalyst for economic transformation and leapfrog. Eight value chains have been identified to guide Uganda's strategic priorities over the next years (Figure 6).

Fig. 6: Uganda's Eight STI Value Chains

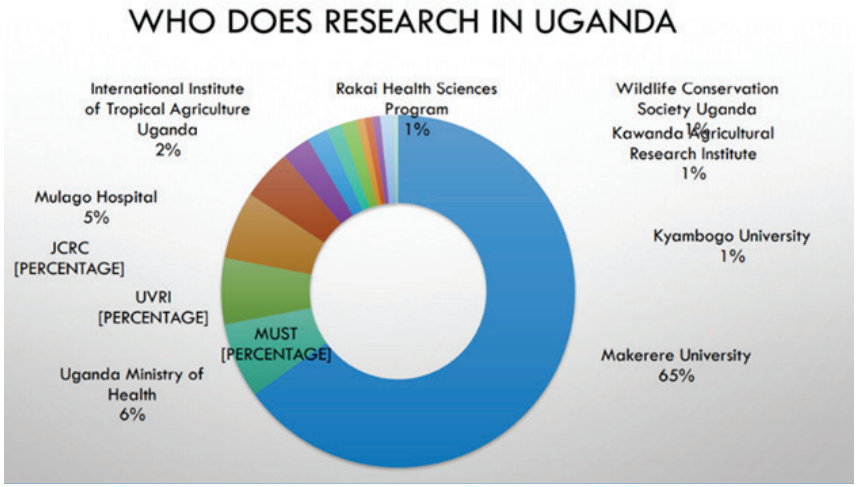


1.3.2 Who Does Research in Uganda

Research in Uganda is largely undertaken by public sector institutions, through international collaborations and sponsorship, and is primarily centered on agriculture, industry and engineering, natural sciences, social sciences, health and energy.

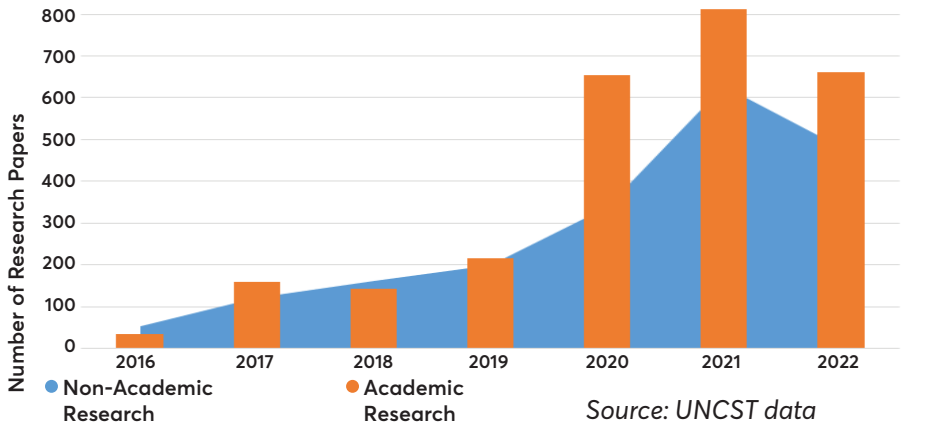
Research into sustainable agriculture and food security is predominantly undertaken by the National Agricultural Research Organization (NARO) and Makerere University's College of Agriculture and Environmental Sciences (CAES). The Joint Clinical Research Centre, Makerere University College of Health Sciences, and the Uganda Virus Research Institute have been instrumental in building research capacities in the medical and health sciences fields,

Fig. 7:



especially in HIV/AIDS, malaria and tuberculosis research. However, over the past decade, research in Uganda has been concentrated within the university system. In particular, Makerere University is responsible for almost two thirds of Uganda's total research output. This over-concentration of Uganda's research potential is largely due to historical and structural factors that have placed universities at the crux of Uganda's research eco-system. The limited participation of the private sector and business enterprises in research is mainly due to structural limitations and scattered collaborative efforts with academia. Over the last fifteen years however, there has been a growing interest by private universities and private research institutes to undertake research through collaborative partnerships and skills enhancement. The analysis of the type of research conducted in Uganda as registered and recorded by UNCST as either Degree and non-Degree research shows that most of the research conducted in Uganda is academic research at 57% in the period between 2016 and 2022 while the non-academic research stands at 43% for the same period (See Figure 8). It can be construed that the motive of conducting research in Uganda is majorly an end (to earn a degree). Also academic research is widely recognized as a source of competitive advantage and as such, an increasing number of universities are involved in it as a core strategy to enhance their competitiveness.

Fig. 8: Academic and non-Academic Research



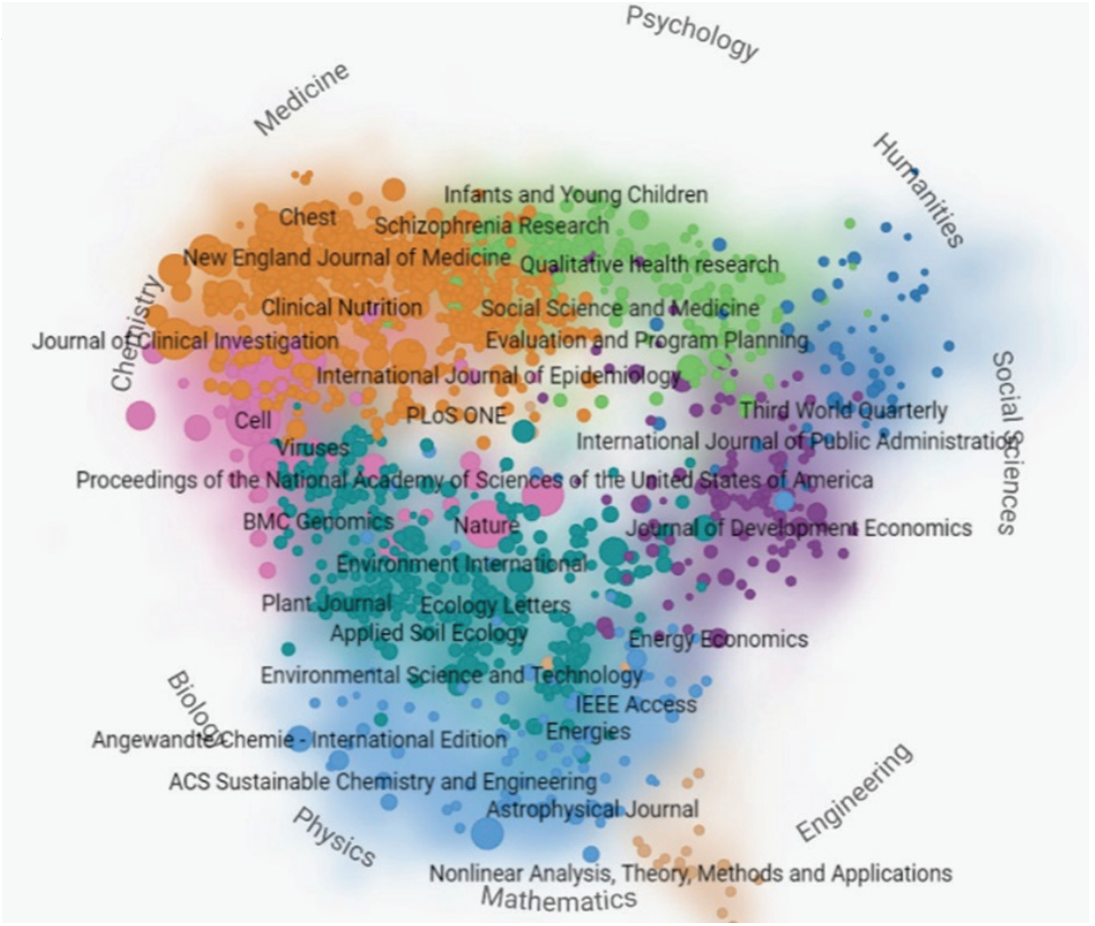
6NRM Manifesto (2021-2026), Securing Your Future. Available at www.nrm.ug

1.3.3 Research in the different scientific fields

According to Scientific Journal Ranking, research by authors from Uganda was published across 1,211 journals.

The graphic below (Source: SCImago, 2022) shows a research map that is generated from the relational matrix based on the citation, co-citation, and bibliographic coupling formed by the nearly 20,000 publications (journals and conference proceedings) registered in Scopus.

Fig.9: Concentration of Uganda's Research



The interface allows the publications' bibliometric indicators and the cluster structures that they form to be displayed based on their shared use by the authors of the documents. However, when compared globally, researchers from Uganda still publish in journals with a relatively low H-index (author-level metric that measures both the productivity and citation impact of the publications, initially used for an individual scientist or scholar. By field, most of the published research undertaken in Uganda remains largely in the medical fields. As shown in Table 2 below, Uganda produced almost half of what Kenya produced between 2010 and 2020 in terms of citable documents. A further comparison with South Africa shows that Uganda produced research of much less impact (low H-Index).

Table 3: Research Production and Visibility (2010-2020)

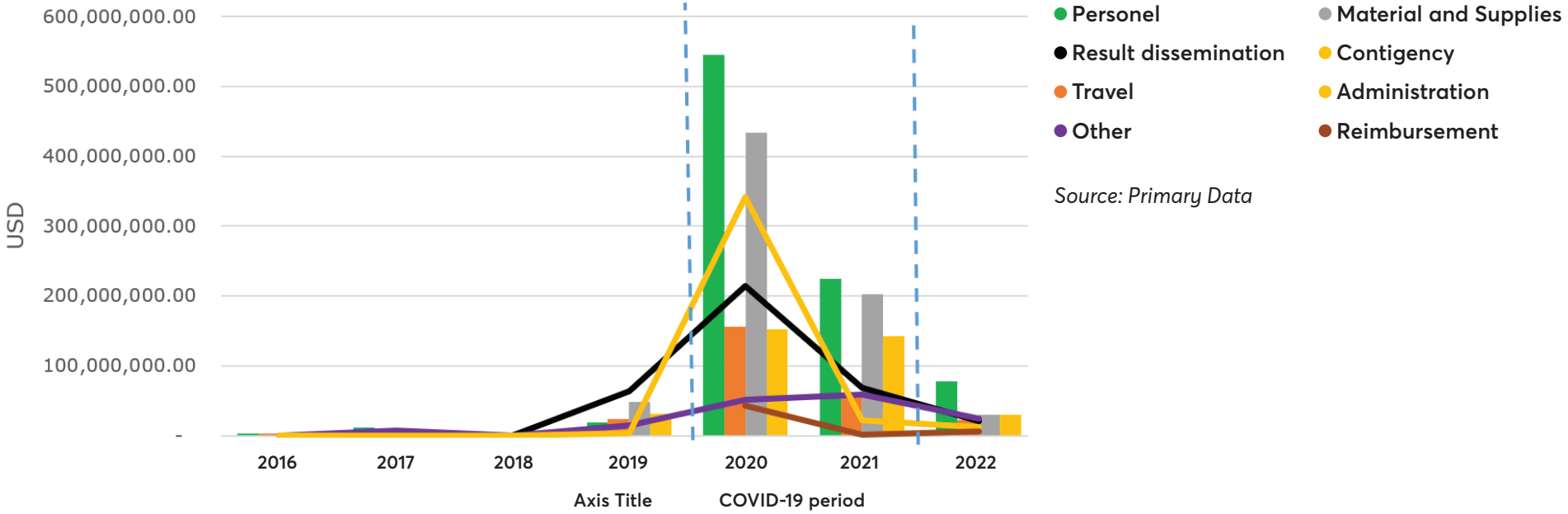
Country (Rank)	Documents	Citable documents	Citations	Self-citations	Citations per document	H-index	
Uganda (86)	25,278	22,955	541,244	74,784	21.41	209	
Kenya(66)	49,757	44,630	1128835	148,443	22.69	310	
Rwanda (127)	5,533	4,948	113,241	7,386	20.47	107	
Tanzania (88)	24,827	22,851	522,933	68,413	21.06	205	
South Africa (35)	372,646	336,951	626,845	1,247,517	16.82	567	
United States (1)	14,408,686	12,662,685	422,381,431	181,255,974	29.311	2711	*Source: SCIMAGO*

1.3.4 COVID-19 pandemic Research

Economies are slowly recovering from the most severe economic downturn occasioned by the COVID-19 pandemic.

To emerge from the downturn and put countries back on a path to sustainable growth, continuous innovation will be required. Specifically, response to the COVID-19 pandemic in Uganda was undertaken using research. For instance, research laboratories in the School of Biomedical Sciences made significant contributions to the national response to the COVID-19 pandemic. Research funding from government and international funders increased during this period with UGX12.1bn given to one research unit to contribute to a series of preventative and analytical COVID-19 studies. Similar funding led to the generation of the first full genomes of SARS-CoV-2 in Uganda and supported the procurement of diagnostic reagents for 10,000 preliminary tests. Several interventions were developed by researchers to mitigate the spread of COVID-19 across different universities. For instance, at Mbarara University of Science and Technology (MUST), a COVIDEX innovation was developed while COVILYCE-1, a recipe of eight different herbs was formulated at Gulu University. During the year 2020, research publications from universities and research institutes doubled due to research on COVID-19. Researchers in academia took advantage of the lull in face-to-face teaching to increase their research output. For instance, research publications from Makerere University rose by 31% from 992 papers in 2019 to 1,301 in 2020 respectively, while Kampala International University produced over 40 publications on COVID-19 in 2020 and 2021.

Fig 10: Uganda's Research Expenditure (2016-2022)



Source: Primary Data

1.3.5 Commercializing Research Products

There has been little progress in the commercialization of research outputs and technology transfer activities from research organizations to industry.

The varying nature of research, the typical research actors across the system and the landscape of research institutions and research infrastructure is highly complex. Several initiatives have been undertaken to accelerate the leapfrog from research to product commercialization. However, commercialization of research products from research requires an eco-system outlook for sustainable outcomes to be achieved. For instance, the success of the Makerere University Research and Innovations Fund (Mak-RIF) was guided by the Research and Innovations Policy (2008), and the Intellectual Property Management Policy (2008). At the National level, it is guided by the Industrial Property Act (2014) and the Copyright and Neighboring Rights Act (2006). The establishment of IP Management Offices at universities can support Commercialization Assessment (through conducting market research), Partnerships (assess opportunities with industry, entrepreneurs and investors) and ensure proper licensing of technologies. Providing last-mile support to research initiatives and their commercialization remains a critical component of completing the value chain and ensuring that the pathway to impact is fully achieved. BOX 1 shows some of the initiatives UNCST has been involved in under the SGCI.

BOX 1: RESEARCH COMMERCIALISATION UNDER THE SCIENCE GRANTING COUNCILS INITIATIVE (SGCI)

The Uganda National Council for Science and Technology (UNCST) is currently implementing the second Science Granting Councils Initiative [SGCI –II (2018-2023)] titled "Public – Private Partnerships in Research and Innovation in the Manufacturing Sector".

1. Through this funding, the College of Veterinary Medicine, Animal Resource and Bio-Security, Makerere University together with the Uganda National Beekeeping Development Organization (TUNADO) under the "Commercialization of propolis powder and infused tea bag for improved health and incomes in Ugandans (Proveno Boost)" have been able to attract more funding (UGX100,000,000) from Makerere University's Innovation fund;

2. The Department of Food Technology and Nutrition, Makerere University through the project titled "Identification of standards and gaps in the bakery and Confectionery Industries" has worked together with Uganda National Bureau of Standards (UNBS) and several private sector partners to train bakers on how to meet national food quality and safety standards for baked products.

3. The Natural Chemotherapeutics Research Laboratories is working on the "Fractionation of Ugandan Shea Butter into Commercial Shea Stearin and Shea Olein for Industrial Food and Cosmetic Application".

4. Uganda Christian University is working with PKM Reliable Enterprises Limited to fill the gap of lack of a commercial crickets feed on the Ugandan market to facilitate the commercial production of crickets for animal feed production as a protein source.

5. Department of Food and Nutrition has been supported to work with researchers in other East African Countries (Kenya and Tanzania) to Develop safe mass rearing tools and value addition for the Desert locust (Schistocerca gregaria Forskal) value chain in East Africa.

6. Researchers from the National Agricultural Research Organisation have been supported to Up-Scale the Uptake of Cocoa Innovative Technologies for Increased Value Through the Cocoa Primary Processing Value Chain.

1.4 Uganda's Research Eco-system

A research and innovation ecosystem is characterized by coherence and cooperation.

Such a system can enable innovation and the development of new products and solutions, and enhance workforce skills. These advances in turn contribute to adaptability and increased productivity. To maximize the impact of R&D spending, Uganda is fostering an enabling research ecosystem that will allow research actors to be more effective producers of innovation and address Uganda's socioeconomic challenges. Specifically, Uganda's aspiration to transform into a "Prototype Nation" is one that aims at fostering new capabilities to engage in industrial production, design, and engineering. The pathway to this change calls for building a system that can lead to Uganda-originated approaches that for instance reduce fossil-fuel

Fig.11: Components of a research and innovation ecosystem

dependence, strengthen resilience in food-security, combat water stress; better management of healthcare using indigenous resources within a proactive pathogen economy; awaken and integrate into new strategic areas including rare earth mineral supply chains, among others. As shown in Figure 11, considerations across the Research eco-system are critical. How research is administered, the number of personnel devoted to full-time research, the available research infrastructure, the researcher-production capacity of the education system, among others. These input, throughput and output factors dictate the level of competitiveness of the research system.

Uganda is yet to put research at the fulcrum of its public-sector agenda whilst nurturing and empowering local researchers. Moreover, university–industry linkages with commercialization enablers, and a robust and effective IP legal framework are still in their nascence. This withstanding, efforts are underway to build and strengthen Uganda's research system. As shown, the component parts of such a system are being put in place as the role and contribution of research is increasingly being highlighted in policy debates. The plethora of research actors within Uganda's growing eco-system are being galvanized through different local and international initiatives that will shape national research outcomes in the coming years.

1.5 About the Research Outlook Report

The Research Outlook Report is one of Uganda National Council for Science and Technology's (UNCST) flagship studies whose overarching aim is to present insights based on relevant data on Uganda's research landscape – on how to increase the utility of research and how research can become a driver for Uganda's knowledge-led growth aspirations. The goal of Uganda's STI system is to *"Make Uganda the Best"* in all areas of STI. This ambition has placed a sharp focus on the urgency to establish systems and frameworks in Uganda's research system that can ensure that the country becomes a leader in research management, research performance and research quality assurance.

The objective of this research outlook report is to examine the impact of research on the economic, societal, and environmental outcomes for Uganda by reviewing and evaluating the current progress towards Uganda's aspirations across local and international development frameworks. This evidence-based independent review on key trends in Uganda's research system provides a functional yardstick for tracking and a comparability framework that assesses Uganda's progress and performance. It is anticipated that the research outlook report can provide a much-needed pulse that prepares Uganda face emerging challenges, including youth unemployment, productivity enhancement and on building resilience to new threats like climate change, pandemics and food security.

1.6 Structure of the Report

This Research Outlook Report aims at putting a spotlight on the major gaps within Uganda's fast-evolving research system with a view of identifying opportunities that can transform livelihoods of Ugandans. This report comprises the present introduction, that is relevant to the full publication, and three parts, each of which includes a table of contents and list of references. This report is divided into the following ten sections: Section 1 sets the stage and provides the context on the contribution of research in Uganda, its contribution to economic growth and research performance in the different fields of science. Section 2 provides a summary of the approach and methodology that guided this outlook report. Section 3 presents issues around human resources in research and the potential contribution of research personnel. Section 4 provides insights into Uganda's research global performance as calibrated across different global research indicators. Section 5 presents a summary of research funding and especially integrating financing collaborative research.

Section 6 underlines the state of research collaboration and partnerships. Section 7 presents the outputs from research, including research and innovation products while Section 8 presents a snapshot of research infrastructure and the necessary infrastructure critical to driving research in Uganda. Section 9 provides a summary of key imperatives around research governance, including research registration and ethical practice. Section 10 presents some key insights in new and emerging challenges, especially taking cognizance of Uganda's value chains in Science, Technology and Innovation. Section 11 wraps up with some recommendations on key issues that are likely to shape current and future capabilities in the research and innovation ecosystem. ■

Biosafety level II laboratory at Mweya in Queen Elizabeth National Park

2. Approach and Methodology:

2.1 Introduction

Uganda's research landscape has undergone unprecedented changes over the past thirty years powered by the forces of globalization, regionalization, structural recalibration and digitization.

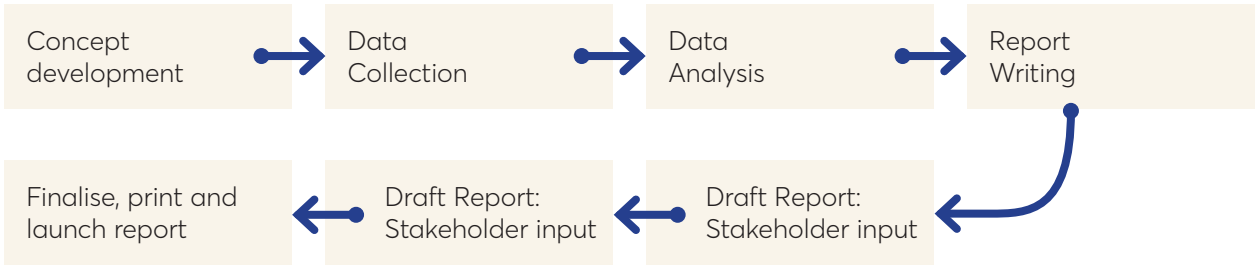
Rapid STI developments and convergence of technology platforms are integrating multiple countries, sectors of the economy, as well as society and stakeholders to create complex flows of information and knowledge networks. This Research Outlook Report is based on an extensive review of literature, and the identification of a set of STI indicators that are applicable to Uganda. Development of the Report employed a mixed methods approach. The Report's methodology sought to provide evidence of the dynamics of research and the impact of research activities. The process included review of the current status and the outlook through desk research, stocktaking exercises to study key trends and challenges in STI, data gathering, stakeholder engagements and international peer reviews. The mixed methods research entailed using both– qualitative and quantitative research approaches – to draw a comprehensive understanding of the industry, public and the perspectives of Uganda's key STI stakeholders.

2.2 Data Collection and Analysis

The report is informed by the collective perspectives from interactions and discussions with key stakeholders, primary data collected from across Uganda's research eco-system and other data collected from secondary sources and databases.

Statistical databases of United Nations agencies including United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Development Program (UNDP), United Nations Conference on Trade and Development (UNCTAD), United Nations Industrial Development Organization (UNIDO), and the Food and Agriculture Organization of the United Nations (FAO), were further sources of secondary data. ICT statistics were obtained from the International Telecommunication Union (ITU) and the World Intellectual Property Organization (WIPO). The World Bank's World Development Indicators was the source of statistics on general economic performance and data on social indicators. Other data types were sourced from different universities, education regulators (e.g. UNEB) and other reports from ministries, departments and agencies. The analysis relied entirely on an extensive document and literature review. This involved a critical review of key national, regional and global STI policy documents for Uganda (both current and past). These include: Vision 2040; the outgoing Second National Development Plan (NDPII) 2015/16 – 2019/20 and current NDP III 2020/21 – 2024/25; the STISA 2024, National STI Policy 2009, the National STI Policy Review Report of 2019, the NRM Manifesto, Africa Agenda 2063; the national budgets; UNCST Strategic Plan 2020/21– 2024/25; and other relevant STI policy documents. The data collection exercise commenced on 6th March 2022 and was completed on 20th July 2022.

Fig 12: Road Map for Developing the Research Outlook Report



2.3 Scope

Primary data was collected from Universities and research institutes, while secondary data was collected from some Ministries, Departments and Agencies as well as some private sector organizations.

The reference period for the data required for the Research Outlook Report was 2016-2022. The data included; STI enrollments, and graduates, Research products/ outputs, research funding, international research collaboration, university – private sector partnerships, research infrastructure, research regulation and governance and the national research road-map, and gender in research.

2.4 Data collection Instrument

The data collection instrument was self-administered and was forwarded to respondents in advance by email and adequate follow-up was done.

An online version of the tool was also developed and sent to stakeholders In order to determine the strengths and weaknesses of the questionnaire in terms of format, wording and sequence among others, both the hard and soft copies of the questionnaire were administered to a very small sample of 10 respondents, taking into consideration the variations in the sample population. This helped testing question ambiguity, flow, consistency, redundancy, sensitivity and reliability, time required to administer the questionnaire among others. After this pre-test, interviewers shared their experiences for improvement of the questionnaire for onward commencement of the data collection activity.

2.5 Data processing and analysis

a) Data entry
Double data entry was done using CSPro 7.6. The data entry applications were developed and tested before embarking on the data capture. Appropriate editing was undertaken before data entry. Regular data back-ups were undertaken and stored by the selected data managers and a master file containing original clean data records was maintained.

b) Exploratory data analysis
Data processing and analysis was undertaken in tandem with the questionnaire design and there was effective collaboration at all levels between the data analysists and the UNCST selected technical team. Data analysis involved using appropriate weights and adjustments to the initial weight to cater for non-response. Then data was processed and entered using the Statistical Package for Social Sciences (SPSS 25) summarizing them using frequency tables to identity errors and editing them to remove errors. The data was analyzed using descriptive and inferential statistics. Descriptive statistics involved the means while inferential statistics included Pearson Linear correlation and regression analysis.

2.6 Quality assurance

The UNCST data collection team ensured collection and production of quality data/ information.

The team ensured collection, processing and dissemination of relevant, accurate, interpretable, comparable and reliable statistics for this report. The UNCST statistical committee ensured quality in the generation, analysis, dissemination and use of these statistics. All information collected was deemed to be confidential. As such, data was used only in aggregated statistical form for analysis.

2.7 Conceptual Framework

This report draws its analytical framework that is shaped and informed by the critical issues shaping Uganda's research performance at local and international level.

Understanding the complex set of relationships among actors producing, distributing and applying various kinds of research allows for better appreciation of the flexibility and adaptability of how research in sectoral, national and regional contexts can be harnessed for social and economic transformation. The conceptual framework is shaped and characterized by enablers that should drive research capacity. Uganda's research eco-system is largely in nascence as the critical building blocks are still being put in place. The economy is still import-driven, with a low manufacturing base and a generally foreign-led research funding posture. In order to achieve the goals of becoming a middle-income status by 2030, Uganda urgently needs to move away from low-cost production mode towards knowledge driven, innovation based economy outlined in the different national and regional development strategies. This requires specific reforms in six critical areas:

- **Research Infrastructure –** quality of the research infrastructure such as laboratories, research facilities and equipment ensure effective, coherent and smooth research production.

- **Digital Infrastructure and Info-structure –** is the digital communication network that connects researchers internally or to the wider global knowledge eco-system. These include telecommunication infrastructure and relevant software systems that fosters ICT connectivity, use of big data, and seamless integration of multiple digital and data analytic systems.

- **Research Talent and human reservoir for research leadership –** the skill sets and entrepreneurial acumen for a knowledge society which include general and specialized knowledge, as well as technical, entrepreneurial, and research leadership skills

- **Research Governance and Ethics –** governance systems that manage resources efficiently and raise the contribution and participation of researchers within a robust accountability framework. These include policies, regulatory architecture, legislative framework, global best practices and standards that ensure rules of research engagement are effectively developed, managed, implemented and outcome-tracked.

- **Research Funding and Incentives–** These include grants, subsidies, tax incentives, cash transfers and other direct and indirect support to research undertaking in Uganda. Non-fiscal incentives include access to R&D, testing centers and specialist facilities, mentorships and other support schemes to encourage the adoption of new technology, innovation and knowledge systems.

- **Research Partnerships, Cooperation, Networking and Interaction –** quality and depth of cooperation, inter-institutional collaboration and knowledge sharing between research stakeholders to create network externalities and the required infrastructure to do that

- **Internationalization, Global Best Practices and Standards –** participation in the development, formulation and adherence to international laws, treaties, regulations and engagements that ensure sustainable management of the country's STI ecosystem. These include the depth and breadth of engagement with global knowledge networks, institutions of governance. The Figure below shows the conceptual framework shaping this research outlook report.

Figure 13: Intersectionality of the issues shaping Uganda's Research Ecosystem

The conceptual framework postulates that Uganda's research system can have a significant impact on the dynamic capabilities of firms, organizations and lives. More specifically, the contribution of research to national programs, including the vehicles that deliver these programs (e.g. the Parish Development Modell - PDM) can only be appreciated by analyzing the role and contribution of both local and global research agents and how their dynamic capabilities and competitiveness are enhanced within an environment of global challenges like pandemics, climate change, protracted wars and rapid digital transformation. As such, a conversation of Uganda's research system can only be framed within this contextual lens in order to appreciate the inherent opportunities, threats and contradictions that are likely to shape the medium to long term aspirations necessary to enjoin in a rapidly evolving global knowledge landscape. ■

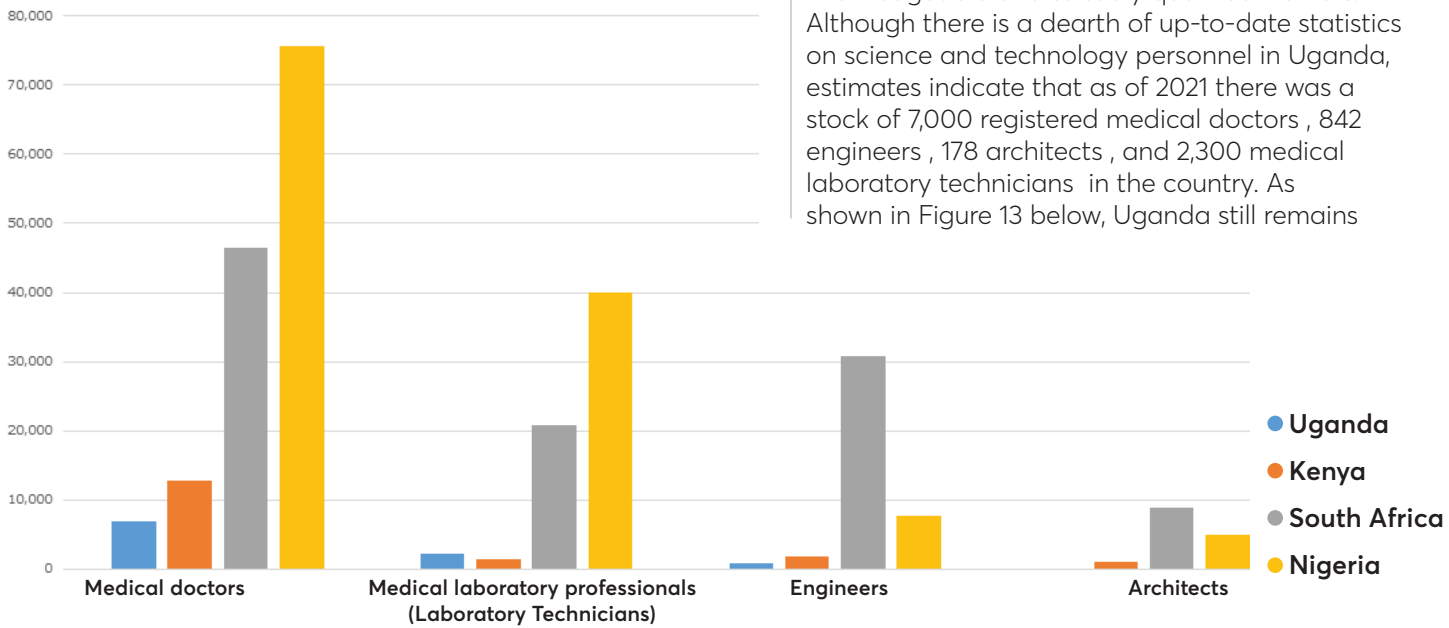
3. Human Resources in Research:

3.1 Introduction

The level and standard of education and research activity in a country are prime determinants of the innovation capacity of that country and its survival in a highly competitive global economy.

Human resources in S&T (HRST) are the major factor that enable a country to generate and master new technology. A large HRST base is a sine qua non condition for Uganda to continue to innovate, as it embodies the knowledge stock of the country. The goal of the National Human National Human Resource Development Plan (2020/21 - 2024/25) is to "Position Uganda's Human Resources to take a centre stage in the industrialization agenda for inclusive growth, employment and wealth creation." Over three-quarters of the population are below the age of 35 years, of which 45% are below 14 years, and 31% are between the ages of 15 -30 years. This youthful population implies that Uganda has the potential to benefit from the demographic dividend. Higher education, and universities in particular, are regarded as key to delivering these knowledge capabilities for development, based on their traditional role of producing, applying and disseminating knowledge, as well as preparing the next generation of knowledgeable and suitably qualified workers. Although there is a dearth of up-to-date statistics on science and technology personnel in Uganda, estimates indicate that as of 2021 there was a stock of 7,000 registered medical doctors , 842 engineers , 178 architects , and 2,300 medical laboratory technicians in the country. As shown in Figure 13 below, Uganda still remains comparatively behind with regard to the production of key human capital necessary in driving STI-led growth.

Fig.14: Stock of key STEM Personnel in selected countries



Higher education, and universities in particular, are regarded as key to delivering these knowledge capabilities for development, based on their traditional role of producing, applying and disseminating knowledge, as well as preparing the next generation of knowledgeable and suitably qualified workers. Although there is a dearth of up-to-date statistics on science and technology personnel in Uganda, estimates indicate that as of 2021 there was a stock of 7,000 registered medical doctors7 , 842 engineers8 , 178 architects9 , and 2,300 medical laboratory technicians10 in the country. As shown in Figure 14 below, Uganda still remains comparatively behind with regard to the production of key human capital necessary in driving STI-led growth.

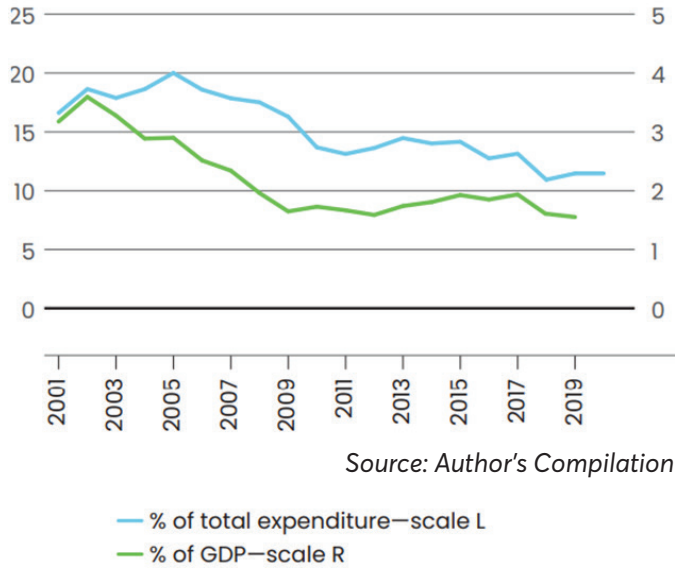
Universities are well-placed to leverage their research and education capacities to foster more innovative and dynamic economic growth. Even though Uganda has had an expansive higher education system over the past decade, the pace of research activity has not equally grown. However, an appreciation of Uganda's research potential is incomplete without having an understanding of the upstream realities in Uganda's education pipeline.

3.2 Uganda's Science Education and training system: A Leaking Pipeline

Public spending for education in Uganda, as a share of GDP compared with countries with similar GDP per capita, is slightly above expectations for primary education, but well below expectations for secondary education.

Education expenditures as a share of national budget has decreased from 15% to 11% over the last few years despite the introduction of the Universal Secondary Education (USE) policy in 2007 . Uganda's Human Capital Index , which is comparable to the average for SSA and low-income countries (LICs), puts Uganda in 137th place out of 157 countries. A Ugandan child can expect to complete 7 years of schooling, but this is, on average, only equivalent to 4.5 years of quality schooling. As shown below, spending on education has actually been on the decline since the 2000s, whether relative to total central-government spending—10% in 2019–2020, as against 18% on average in the 2000s)—or to gross national income (GNI): 2% since 2014, as against 3.4% on average between 2002 and 2008.

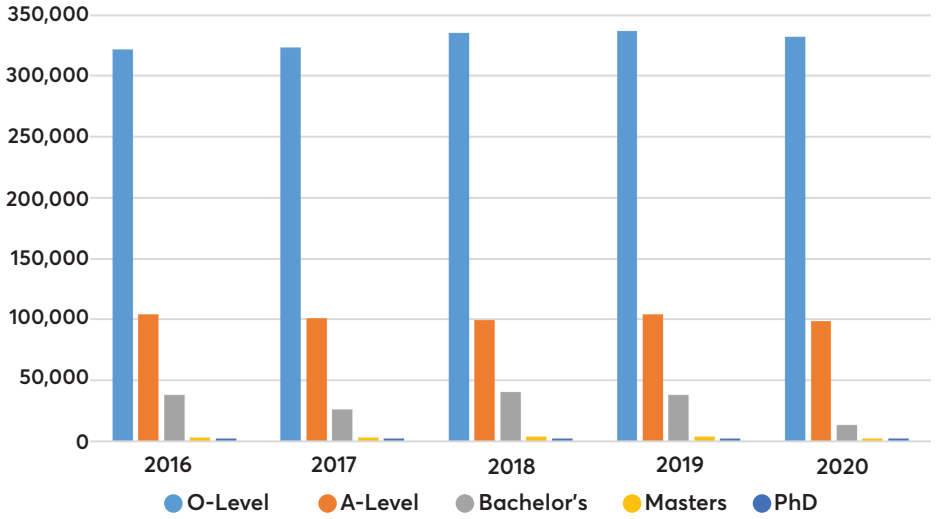
Figure 15: Declining central-government spending on education



Source: Author's Compilation

Inspite of increased access to schooling, the average level of education of the work force remains low and does not meet labor market requirements. Uganda will need needed to absorb an additional 600,000 new entrants to the labor market each year between 2014-2020. In order to sustainably increase welfare, these entrants must find productive employment.9 Estimates from the 2016 National Household Survey (UNHS) show that only entrants with postsecondary education can escape informal sector work. With regard to STEM, the Ministry of Education and Sports (MOES) has set up a number of initiatives to improve STEM education delivery. In 2005, the Government made science subjects compulsory for secondary school students at the 'O' level while preferential funding of university students taking science courses was introduced and science subjects were made compulsory at secondary school level. However, the transition from lower secondary to PhD level is very narrow. Only 0.0003 students who enrolled in ordinary level will attain a PhD. The pathway to becoming a researcher is very narrow (See Figure 16) However, performance at both Ordinary and Advanced levels in key STEM disciplines remain poor. For instance, the number of failed students between 2016-2020 has increased, albeit marginally. In 2005, the Government introduced the science education policy which

Fig 16: Transition from Secondary to PhD (2016-2020) *Source: Primary Data*



7Uganda Medical Association; Available at https://www.uma.ug/
8Uganda Engineers Registration Board; Available at https://www.erb.go.ug/registered-engineers-in-uganda/
9Architects Registration Board; Available at https://ugandafact.com/how-to-become-a- registered-architect-in-uganda/
10Kiwanuka, H.N., Damme, J.V., Van Den Noortgate, W., Anumendem, D.N., & Namusisi, S. (2015). Factors affecting Mathematics achievement of first-year secondary school students in Central Uganda. South African Journal of Education, 35(3), Art. # 1106, 16 pages, DOI: 10.15700/saje. v35n3a1106.
11World Bank (2018), Uganda Secondary Education Expansion Project. Available at https://documents1.worldbank.org/curated/en/521301533884327735/pdf/Concept-Project-Information-Document-Integrated-Safeguards-Data-Sheet-Uganda-Secondary-Education-Expansion-Project-P166570.pdf
12The World Bank's Human Capital Index measures the contributions that health and education make to the productivity of the next generation

made it mandatory to offer STEM subjects at the lower secondary level. Nonetheless, this was not backed up by a proportionate increase in recruited science teacher, science infrastructure including laboratories among others. These have compromised the teaching and learning of science leading to perpetually poor science outcomes at the lower secondary schools. This has significant ramifications on human resource development given that the government's strategy is to focus education towards producing scientists and innovators. At Advanced Level, the number of students studying Physics fell by 21% between 2016 and 2020. This trend is also apparent in other core STEM fields at other levels

However, performance at both Ordinary and Advanced levels in key STEM disciplines remain poor. For instance, the number of failed students between 2016-2020 has increased, albeit marginally. In 2005, the Government introduced the science education policy which made it mandatory to offer STEM subjects at the lower secondary level. Nonetheless, this was not backed up by a proportionate increase in recruited science teacher, science infrastructure including laboratories among others. These have compromised the teaching and learning of science leading to perpetually poor science outcomes at the lower secondary schools. This has significant ramifications on human resource development given that the government's strategy is to focus education towards producing scientists and innovators. At Advanced Level, the number of students studying Physics fell by 21% between 2016 and 2020. This trend is also apparent in other core STEM fields at other levels. The advent of Fourth Industrial Revolution means that Uganda's talent must be adaptable to change, have a high degree of preparedness for life-long learning, good interpersonal and collaborative skills, and is trained in multi-sectoral thinking. Preparation for technological disruption is possible through training and education; Re-skilling and up-skilling must be the norm for Ugandan talent to stay relevant to the job market.

Table 4: O-Level performance in the core sciences

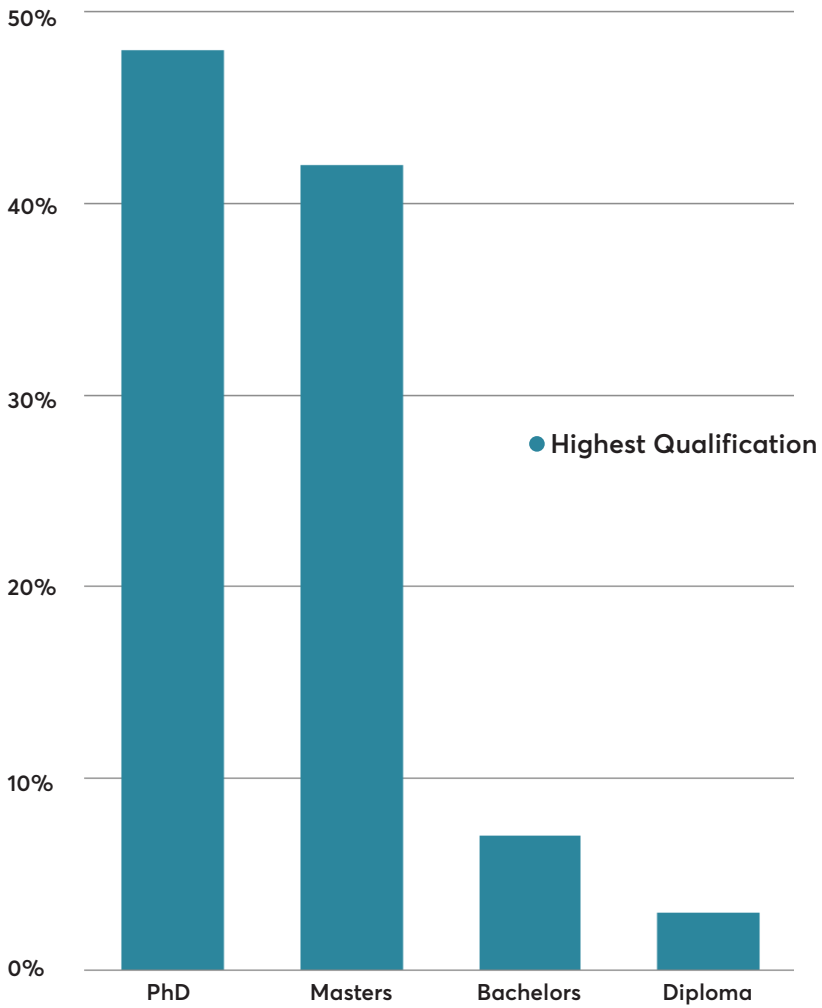
Subject	2015	2016	2017	2019	Average
Physics	58.3%	68.1%	59.6%	48,3%	58.6%
Chemistry	57.2%	59.9%	40.9%	53.5%	52.9%
Biology	59.3%	54.9%	44.5%	46.5%	51.3%

3.3 Research Personnel in Uganda

There is a growing need in Uganda for highly qualified research and development staff.

Most recent estimates shown that Uganda has about 0.04 full time equivalents (FTEs) or people working in full time research. According to UNESCO, Uganda has a low number of researchers relative to its population. The country hosts 26 R&D personnel per million inhabitants. The proportion of researchers (29.8 per million) is also significantly lower compared to the average reported for Africa (95.1 researchers per million). In 2018, UNESCO data reported that 48.3% of Ugandan researchers were employed in higher education (rising from 46% in 2014) and a further 47.1% of researchers were employed by government ministries, departments and agencies. The remaining 6% of researchers were employed in the business and nonprofit sectors. A significant proportion of GERD in Uganda is spent by the Government (47%) and higher education (46%) while the non-profit sector and business enterprise contributes only 3% and 4% respectively. In terms of gender, only 29.8% of Ugandan researchers are female – below the African average of 31%. A recent UNCST study showed that between 2015 and 2019, more than 85% of the PIs in Uganda had at least a postgraduate degree. Almost half (48%) of the PIs held a PhD while 42% (researchers reported a master's degree as the highest qualification as shown.

Fig.17: Highest Qualification of Researchers (2015-2019)



Source: Primary data

3.3.1 The sector-wide spread of researchers

Research in Uganda is largely undertaken by public sector institutions, through international collaborations and sponsorship, and is primarily centered on agriculture, health & medical sciences, industry and engineering, natural sciences, social sciences, health and energy.

The majority of Uganda's researchers are found in universities, in contrast to the high performing economies whose researchers are mostly found in business enterprises. Because 75% of employment in Uganda is in primary sectors, where little value addition is done, this reality is reflected in the exhibited limited propensity to undertake research. Whereas Industry-led R&D is key to technological innovations that drive the nation's economic expansion, Ugandan industries are not actively engaged in R&D-driven innovation as is the case in top economies, making the country vulnerable to technological seismic shifts that affect the global markets. The innovation ecosystem should be reshaped to encourage business enterprises to conduct more experimental development and facilitate migration of researchers from universities into industry. Remedial funds can be introduced as a financial enabler to support researchers in the development of prototypes, hence reducing the risks involved in commercializing technology. .

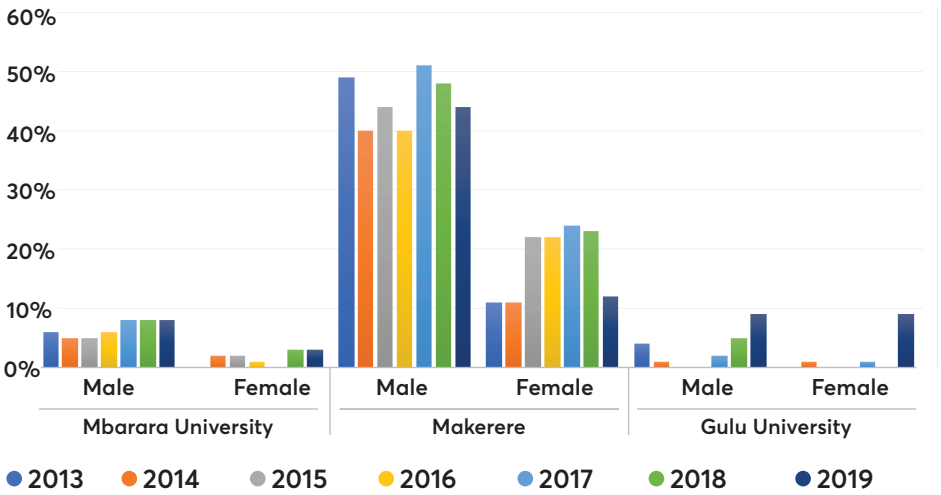
13LinkedIn. 2021b.The fastest-growing jobs in the world. https://business.linkedin.com/talent-solutions/emerging-jobs-report#all.

3.3.2 Production of Research Talent: PhD Researchers in Uganda

The contributions that doctoral graduates make to the economy and the demand for their skills is a critical measure for knowledge-led growth and development.

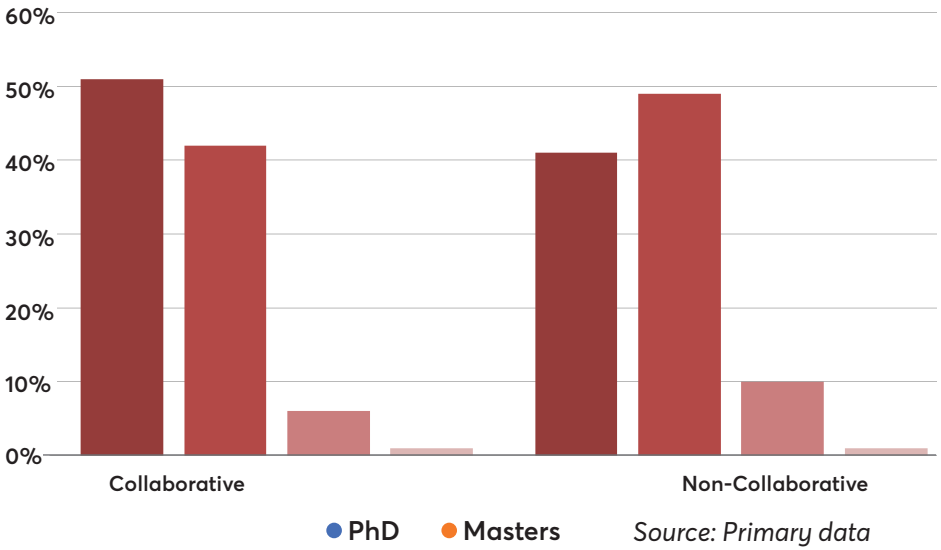
Doctorate holders are also a catalyst for engaging in international collaborative research. Currently, there is a great shortage of PhD holders with estimates of about 2,000 PhD holders in both higher education and outside of it. In a population of 45.8 million people, the ratio is 1 PhD holder to 22,000 people. Nevertheless, there has been an increasing trend in the number of PhDs being produced or trained although doctoral education and training in Uganda remains male dominated. Of the 1, 025 PhDs awarded by public universities between 1970-2020, only 240 (23.4%) were female and 68.1% were in STEM fields. In addition, of the 172 PhDs awarded by private universities between 2001-2020, only 42 (24.4%) were females and only 11% were in STEM fields . A UNCST

Fig.18: PhD Graduates in selected public universities (2013-2019)



Source: Author's Compilation

Fig.19: Highest Qualification Level and Collaborative Status



Source: Primary data

Study showed that about half of the collaborative research is led by PhD-holding Principle Investigators. In non-collaborative research, researchers with the master's degree as their highest qualification represent 49% of research conducted between 2015 and 2019. This confirms findings by Otieno et al. (2008) who found that universities use international collaborations for institutional capacity development and strengthening research capacity. At a time when research collaboration is a vital ingredient of any research agenda, PhD training is not adequately multi- or trans- disciplinary. Whereas policies underline a commitment that PhD programs are embedded in open research environments and culture in order to appropriately align doctoral programs to national development goals through cross-disciplinary interactions, this is hardly reflected. Apart from a few STEM fields, cross-disciplinary research practices are not widely spread, and not institutionalized.

Determinants of international research collaboration in Uganda; A case study of research registered at Uganda National Coyuncil for Science and Technology, 2015-2019.

3.3.3 Vocational Training as a reservoir for Research

Vocational education in Uganda has not been a major policy priority in the drive towards knowledge-led growth.

Whereas there have been stellar examples from around the world on the role and contribution of vocational education as a driver of innovation and growth, this has not been the case in Uganda. Namukasa et al (2010) seem to shed some light on this impasse when they found out that Uganda's science education is largely not influenced by recent international reforms, but purely essentialist with much focus on the gifted students. Similarly, as Jehopio and Wesonga (2017) warn from their findings, the use, practicability, depth, rigor, modernity, relevancy, and usefulness of the taught sciences were all statistically different from the desired vocational skills for the industry. However, there is an emerging interest in vocation education due to the new opportunities that this type of education can seemingly provide. Between 2016-2019 for instance, 4,479 male students registered for physical and biological science diploma more than the females who were 1,825 students. As shown in BOX 2, the UNCST has also embarked on skilling program aimed at amplifying the contribution of targeted skilling of youths in new value chains for employment and sustainable development. Quality human capital or talent is needed to promote Uganda's growth and position its excellence in the global marketplace. Talent is also unconditional not only in the pursuit of STI targets but also to sustain STI development towards building an efficiency-driven economy. Science, Technology, Engineering and Mathematics (STEM) talent in the country has been enhanced through the intensification of postgraduate programs at Higher Education Institutions (HEIs), which help promote R&D initiatives and provide a skilled workforce. Besides the mainstream education system, the private sector has also positively contributed to the STEM education ecosystem of the country by increasing the number of STEM programs being provided.

BOX 2: SKILLING THROUGH THE NSTEI-SEP PROJECT IN UGANDA

The National Science, Technology, Engineering and Innovation Skills Enhancement Project (NSTEI-SEP) program is a strategic effort to enhance the technological and skill base of Ugandans to participate in national infrastructural projects and manufacturing industries. NSTEI-SEP responds to the need to create more jobs especially for the youth, improve on the competitiveness of Uganda's products and firms, promote a culture of creativity and innovation, and improve the livelihoods of Ugandans.

(a) The National Science, Technology and Engineering Skills Enhancement Centre (NSTESEC) will enhance the technological and skill base of Ugandan graduates, craftsmen, technicians and engineers as well as instructors through the Flexible Factory Learning & Infrastructure Model covering the technology areas of construction engineering (including construction machinery technology & civil engineering technology), automotive technology, agricultural mechanization, industrial technology, metallurgy (especially. precision welding), and electronic & electrical R&D;

(b) Technology Innovation and Business Incubation Centre (TIBIC) will act as a platform and Tool room for technology development via the Process Industry Learning Factory Model covering the technology areas of leather & textile processing as well as a modern foundry to enhance the contract manufacturing agenda and business competitiveness.

Gender participation in Research

Women in research and higher education institutions in Uganda have been increasing over the last fifteen years. According to the latest report, only 28% of Ugandan researchers were women. This percentage tends to be even lower in typically male-dominated fields, like engineering and technology. Between 2010 and 2020, less than a quarter (24%) of Ugandan PhD holders were female. Nevertheless, it is worth highlighting the progress achieved during the last 10 years. More recently, it could also be noticed that the number of women researchers grew faster than the number of men. A similar trend is noted for the number of women scientists and engineers. Doctoral education and training in Uganda is male dominated. Of the 1,025 PhDs awarded by public universities between 1970-2020, only 240 (23.4%)

were female. Of the 172 PhDs awarded by private universities between 2001-2020, only 42 (24.4%) were females. In private universities, of the 172 PhDs awarded between 2001-2020, only 19 (11%) were awarded in STEM fields. In public universities, 699 (68.1%) of the 1,025 PhDs awarded between 1970-2020 were in STEM fields, only 326 (31.9%) were in non-STEM fields.

BOX 3: MAINSTREAMING GENDER IN RESEARCH ACROSS UGANDA'S RESEARCH ECO-SYSTEM

The Gender Equity in Research Alliance (GERA) was established by Uganda National Council for Science and Technology (UNCST) and International Network for Advancing Science and Policy (INASP) in 2019. GERA was subsequently registered as an NGO in 2021. The Alliance was an outcome of the recognition of the peculiar need to mainstream gender in research within higher education institutions in Uganda. This emerged out of the recognition of gender as a driver for research and the underlying equity conversations about access to opportunities for women researchers. Currently, GERA has membership in 70% of universities in Uganda across all regions. GERA has a four pronged strategy that focuses on Mainstreaming Gender In Higher Education and Research Institutions, Research and Knowledge Production, Advocacy, Outreach and Publicity; and Strengthening partnerships and collaboration. From its onset in 2018, the number of stakeholders and institutions directly participating in GERA activities has been increasing. As the Alliance grows, there will be an urgent need to formalize these partnerships in order to lend traction to this GERA Strategy.

Conclusion

As shown from the foregoing analysis. Uganda has inherent capabilities to produce world-class researchers.

, nurtured and supported to engage in a highly competitive global knowledge system. In addition, there are inadequate systems in place to track the overall stock of researchers in Uganda, including their geographical and occupational mobility. Poor coordination and knowledge-sharing among research actors in Uganda further limits their propensity to contribute to local and international research. Harnessing the contribution of Uganda's research talent can only be possible through system-wide reforms that determine research funding and governance, among others. .

14Namukasa, K. I., Quinn, M., & Kaahwa, J. (2010). School mathematics education in Uganda: Its successes and its failures. Procedia Social and Behavioral Sciences, 2, 3104–3110. DOI: https://doi.org/10.1016/j.sbspro.2010.03.473

15Jehopio, P. J., Wesonga, R., Candia, D. A. (2017). Effect of information and communication technology-induced multitasking on academic performance of university students in Uganda. International Journal of Computer Applications Technology and Research, 6(1); 23-31

4. Research Global Performance:

4.1 Overview

Scientific advances and technological change are important drivers of recent economic performance.

The ability to create, distribute and exploit knowledge has become a major source of competitive advantage, wealth creation and improvements in the quality of life. The Third National Development Plan (NDP III)'s Innovation, Technology Development and Transfer Programme (ITDTP) aims at increasing development, adoption, transfer and commercialization of technologies and innovations through the development of a well-coordinated STI eco-system. This is consistent with the Vision 2050 of the East African Community (EAC), the African Union's Agenda 2063, the UN Agenda 2030 Sustainable Development Goals and the STI Strategy for Africa (STISA-2024). Uganda's Vision 2040 aims at transforming the Ugandan society from a predominantly peasant and low-income society to a competitive upper-middle –income country within 30 years. The Vision highlights the importance of manufacturing and value addition in enabling the development of an export-led and internationally competitive economy, which is able to spur growth and provide better employment opportunities to Ugandans at large. Several key indicators can comparably show how Uganda is positioned within the global knowledge system.

4.2 High Level Indicators

4.2.1 Global Innovation index

The Global Innovation Index (GII) ranks world economies according to their innovation capabilities. The GII aims to capture the multi-dimensional facets of innovation. The GII rests upon two sub-indices: the Innovation Input Sub-Index (Institutions, Human capital and research, Infrastructure, Market sophistication and Business sophistication) and the Innovation Output Sub-Index (Scientific outputs and Creative outputs). This index is calculated by averaging the scores of these two sub-indices. According to NDP III, Uganda seeks to Increase the Global Innovation Index from 25.32 to 35 between 2020 and 2025 respectively. Over the past three years, Uganda performed better in innovation inputs than innovation outputs. However, Uganda's aggregate ranking is still low. In 2022, Uganda ranked 116th in innovation inputs; 120th in innovation outputs; and a global innovation index ranking of 119th out of 132 countries as shown in Table 5.

Table 5: Rankings for Uganda (2020–2022)

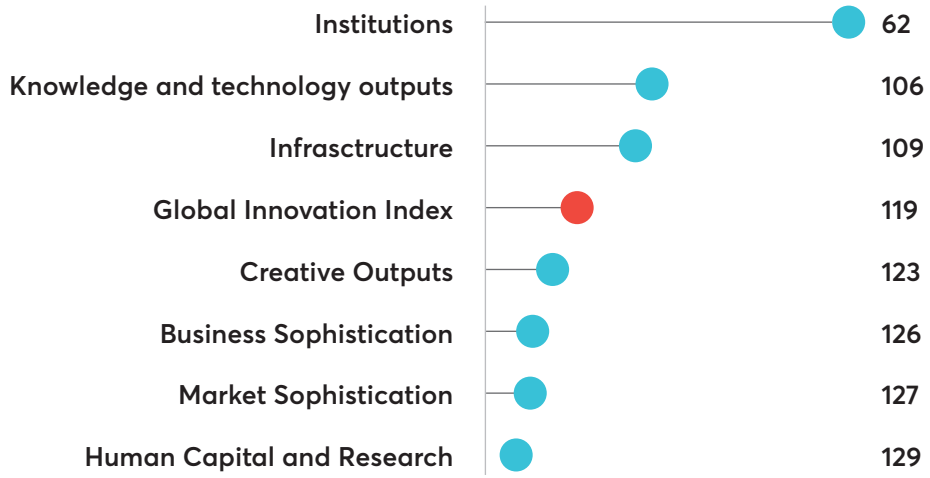
GII Year	GII (Out of 132 Countries)	Innovation Inputs	Innovation Outputs
2020	114	103	123
2021	119	119	122
2022	119	116	120

Source: WIPO (2022)

Uganda performs above the low-income group average in three pillars, namely: Institutions, Infrastructure; and, Knowledge and technology outputs. However as shown in Figure 20, Uganda performs weakest in business sophistication, market sophistication and Human Capital and Research. Whereas research spending in Uganda is still comparatively low, corporate R&D spenders increased their R&D expenditure globally by more than 11% in 2020, and by almost 10% to over USD 900 billion in 2021. This increase was primarily driven by four industries: ICT hardware and electrical equipment; Software and ICT services; Pharmaceuticals and biotechnology; and, Construction and industrial metals. Business sophistication continues to be a major challenge in Uganda as businesses don't foster their productivity, competitiveness and innovation potential through the employment of highly qualified professionals and technicians. On the contrary, the biggest boom in global innovation financing has been through venture capital (VC). Venture Capital has become more inclusive, with Africa witnessing the strongest

VC growth. Uganda is yet to tap into VC-financing towards research and innovation. Regulatory barriers have also inherently limited the pace of market/business sophistication. In 2015, an electronic registry was established as the definitive repository for all licenses issued in Uganda to contribute to reduction of regulatory barriers experienced by businesses. As a result, the time taken to obtain a Trading License was reduced from 15 to 4 days and fees cut by 25 to 11 percent. This and previous reforms of the licensing regime have led to reductions in the cost of doing business in Uganda. Better coordination of agencies involved in business registration have also enhanced the pace of business growth, particularly for small and medium enterprises. Nonetheless, the cost of doing business remains comparatively high and remains a major barrier to private sector growth and job creation. The business environment in Uganda is characterized by limited use of technology applications and red tape. This is reflected in Uganda's low ranking in the annual Doing Business Assessment and related activities, including support on starting a business, paying taxes, getting credit, dealing with construction permits, trading across borders and registering/transferring property.

Figure 20: The Seven GII Pillar ranks for Uganda (2022)

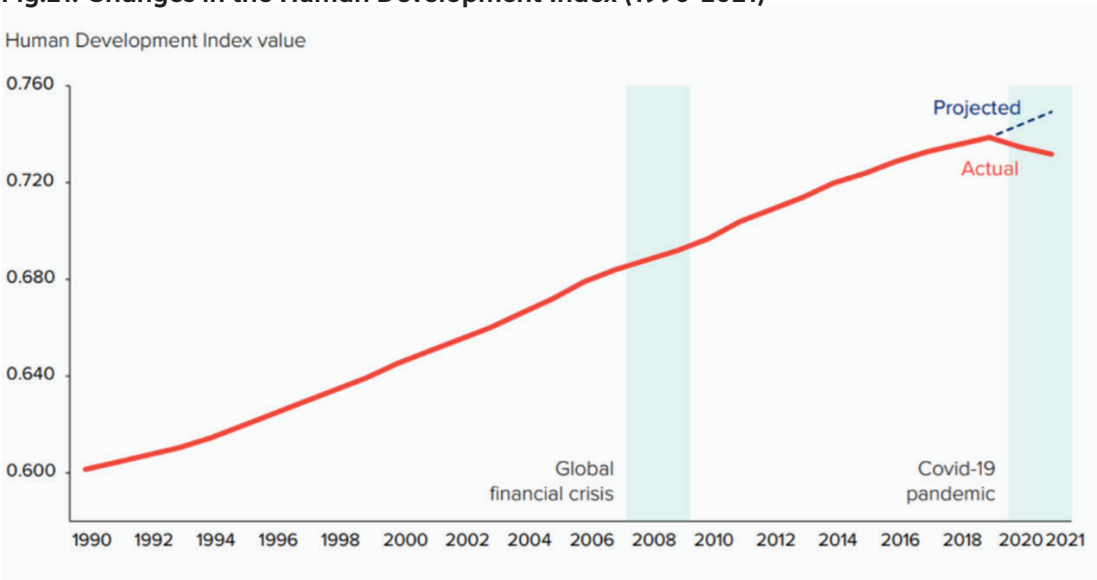


4.2.2 Human Development Index

Between 1980 and 2020, Uganda's HDI value increased from from 0.293 to 0.544 respectively, an increase of 86 percent.

The 2021/22 Human Development Report (HDR) shows that over the last two years, crises like COVID-19 and the war in Ukraine have resulted into sweeping social and economic shifts, dangerous planetary changes, and massive increases in polarization. For the first time, Human Development has declined for two years in a row, with 90 percent of countries registering a decline in their HDI value in 2020 or 2021. Uganda has experienced a decline in its HDI value. The current value at 0.525 puts the Uganda within the low human development category and positions Uganda at 166 out of 191 countries and territories. To change this trend, the Report recommends for a strong push towards investment in critical areas such as renewable energy and preparedness for disaster; Insurance, including social protection, to prepare societies for contingencies; and Innovation in the spheres of technology, economic and cultural systems.

Fig.21: Changes in the Human Development Index (1990-2021)



Source: HDI report 2022

4.2.3 Technology Achievement Index

The Technology Achievement Index (TAI) is defined by Desai and others[16] and the UNDP[17] as a function of four indices that include technology creation, human skills, the diffusion of recent innovation and the diffusion of old innovation.

Evidence suggests the vital importance of capacity to deploy technologies in Uganda, since R&D capabilities for new technology creation are weak. This reality recommends an understanding of strategies to acquire existing technologies that may either be new to the world or may be new only to Uganda. Aspiration 1 of Agenda 2063 aims at transforming Africa's economies through beneficiation from Africa's natural resources, manufacturing, industrialization and value addition. In addition, EAC Vision 2050 targets leveraging industrialization for structural transformation and improved intra-regional and global trade. Uganda Vision 2040 states that a strong and competitive industrial base is important to create employment, advance technology and a resilient economy. To achieve this, the Vision targets; developing industries that utilize the local potential, attracting industries that can be relocated from fast emerging economies, offshoring industries, establishing economic lifeline industries, and investing in strategic industries. Uganda's Technology Achievement Index increased marginally from 0.146 to 0.157 between 2015 and 2019 respectively. This TAI index places Uganda in what are classified as "technologically marginalized countries".

Table 6: Rankings for Uganda (2020–2022)

Composite Indices	2019 Reading
Technology Creation Index	0.000020215
Diffusion of Recent Innovation Index	0.0000245953
Diffusion of Old Innovation Index	0.383
Development of Human skills	0.24505
Technology Achievement Index	0.157

Source: Primary Data

As shown, Uganda's Technology Creation Index and the Diffusion of recent Innovation Index are lowest within the constituent indices of the TAI. Whereas Uganda's human skills index has improved (the gross enrolment and the mean years of schooling), the capacity to create technology remain low. In order to leapfrog out of the marginalized category, there is need to enhance Uganda's participation in the network digital economy. Uganda's Fourth Industrial Revolution Strategy posits that Uganda should take a more proactive rather than reactive posture to creating opportunities and managing risks inherent in this new 4IR world. Harnessing 4IR opportunities for growth, competitiveness and human development will require a coordinated effort, not only among government but also the private sector and civil society. This effort includes targeted support for the process of local innovation, the localization of 4IR technologies applied in specific domains, developing an agile governance framework, upskilling the population and ensuring 4IR connectivity so that all Ugandans can participate in and benefit from the 4IR economy. The TAI also shows that Uganda has a persistent technology gap which has to be bridged by research and innovation. Progress towards the achievement of that target is measured by the proportion of value added in total manufacturing value added (SDG indicator 9.b.1).

4.2.4 Readiness for Frontier Technologies Index

The index yields results for 166 countries with the United States receiving the highest total scores on a scale of 0 to 1 (Table 5).

Based on their rankings, countries are placed within one of four 25-percentile score groups: low, lower-middle, upper-middle, and high values of the index. Uganda's 0.22 total score places the country within the "low" readiness category. That is, there is an urgent need to enhance Uganda's readiness to engage and/or utilize frontier technologies.

16 Desai, M., Fukuda-Parr, S., Johannsen, C., & Sagati, F., (2002), Measuring the Technology Achievement of nations and capacity to participate in the network age, Journal of Human Development, 3(1), 95-122
17 UNDP (2001), Human Development Report, 2001. NY: Oxford University Press

Table 7: Technology Readiness of Uganda and Selected Countries *Source: Author's Compilation*

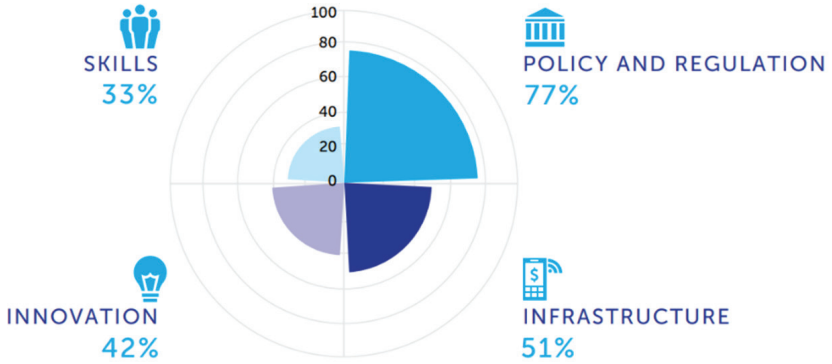
County	Total Score	Total Ranking (out of 158)	ICT Ranking	Skills Ranking	R&D Ranking	Industry Ranking	Finance ranking
United States	1.00	1	11	18	2	16	2
Kenya	0.32	117	120	135	83	93	107
Uganda	0.22	138	133	137	91	120	147
Rwanda	0.22	139	134	142	99	137	126
Tanzania	0.27	127	131	164	79	65	150
South Africa	0.61	56	71	77	36	67	25
Botswana	0.35	108	109	102	103	128	94

4.2.5 Network Readiness Index

Uganda ranks 114th out of 134 economies included in the Network Readiness Index (NRI) 2020 based on the performances in four different pillars: technology, people, governance and impact.

According to the UNCDF Inclusive Digital Economy Scorecard Report (2021), Uganda's main strength lies in governance (ranked 90th) and the weakest link being "Impact" (129th). Limited network readiness negatively affects the propensity for scalable impact. Network readiness has an effect on the quality of research being undertaken and, on the propensity, to engage in research collaboration. As shown in Figure 23 below, low skill levels create barriers to the translation of seemingly good policy into national development outcomes. An alignment of the ICT in education policy with the skills required to support Uganda's Digital Vision is an urgent imperative.

Figure 22. The digital economy score for Uganda, 2021



4.2.6 Global Climate Risk Index (GCRI)

Uganda is moderately exposed to the physical risk associated with climate change.

According to the Global Climate Risk Index (GCRI) 2021 developed by Germanwatch, Uganda was the 66th most heavily exposed country in the world (out of 181 countries surveyed) over the 2000–2019 period. The main channels of exposure to climate risk are: an increase in extreme and average precipitation (already up by 17% over the last 30 years); to a lesser extent, an increase in average temperatures (+1°C over the last 3 decades); and an increase in drought over the largest swath of the country, in the north (where 10% of the population is exposed to it). In addition, Uganda is the 14th most vulnerable country to climate change and the 48th most poorly prepared for it, according to the Notre Dame Global Adaptation Initiative (ND-GAIN) resilience indicator (155th out of 181 in 2016—a ranking comparable to that of other countries in the region). Uganda's agro-pastoralism—there is very little use of irrigation—exacerbates vulnerabilities to droughts, floods, and pest infestations. Uganda's vulnerability

to climate risk should prompt for intentional funding towards research on this critical climate issues.

4.2.7 Gross Expenditure on Research and Development

The Gross Expenditure on Research and Development (GERD) is the main aggregate statistic used to describe a country's R&D activities and covers all expenditures for R&D performed in the economy.

R&D comprise of creative and systematic work undertaken in order to increase the stock of knowledge (including knowledge of humankind, culture and society) and to devise new applications of available knowledge, as defined in the OECD Frascati Manual 2015[18] . SDG Target 9.5 seeks to: "Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people. The year 2020 was an exceptional one for R&D investments. Specifically, investments in global R&D in 2020 continued to grow at a rate of 3.3 percent, down from 6.1 percent in 2019. Business R&D expenditures – the most significant component of total global R&D – grew by 3.5 percent in 2020, down from 6.6 percent in 201919. In Uganda however, anecdotal evidence shows that expenditure on R&D has increased (a national R&D Survey is yet to be undertaken). The most recent survey showed that GERD was 0.17% of GDP. There were just 0.25 researchers employed per 1 million people in Uganda compared to over 300 researchers per 1 million people in South Africa. Uganda had only one researcher per a thousand members of the workforce compared to over five researchers per a thousand in the developed world .This glaring gap in research spending limits Uganda's ability to gainfully engage in a highly competitive global knowledge eco-system.

4.2.8 Technology Balance of Payments

Technology balance of payments measures international technology transfers: license fees, patents, purchases and royalties paid, know-how, research and technical assistance.

Unlike research and development (R&D) expenditure, these are payments for production-ready technologies. As shown below, Uganda's technology exports are mainly in low technology (mainly primary products from agriculture). This inevitably exposes the economy to spontaneous volatilities characteristic of such markets. However, Uganda does have a comparative advantage in agriculture. Investment in research that facilitates large scale agricultural output can provide new opportunities from new agro-markets. Currently, one of the STI value chains is on agro-industrialization through which opportunities in new agro-value chains can be explored and supported.

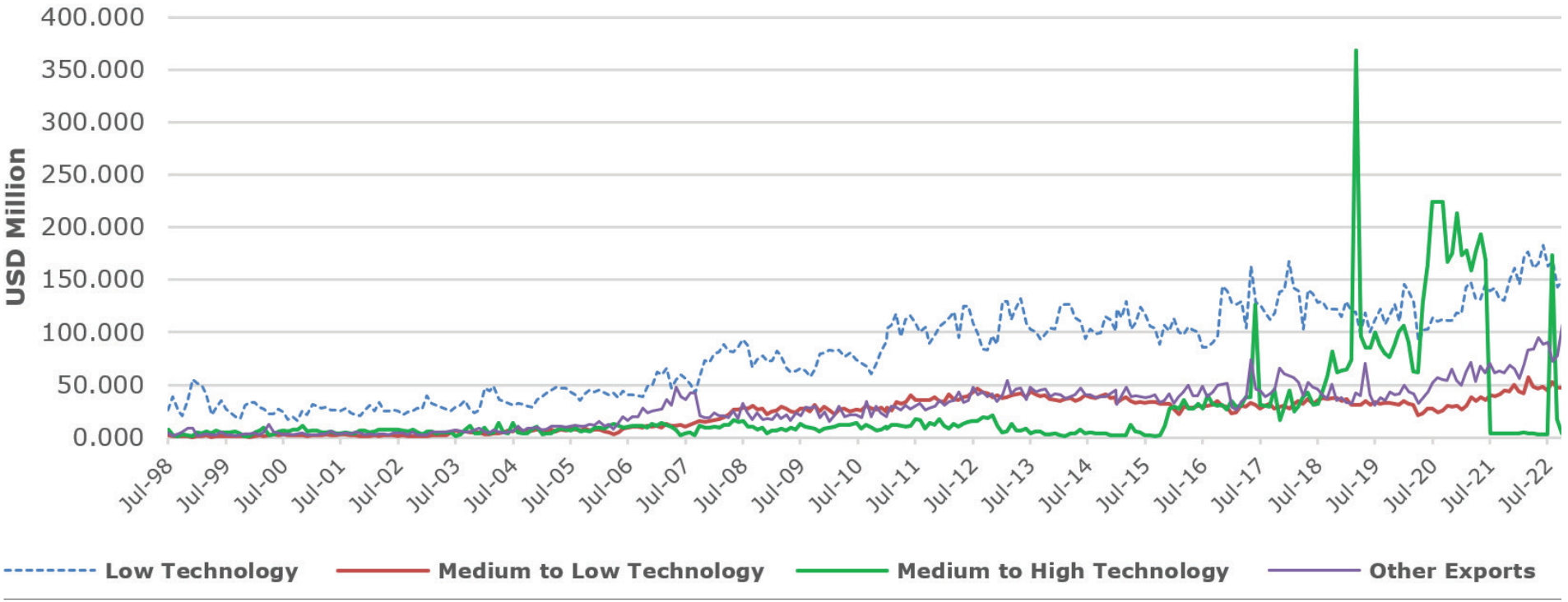
Although there has been a relative increase in the earnings from medium to high technology exports, Uganda mainly exports non-technologically complex products.

With regard to imports, Uganda mainly imports medium-high technology products. According to the World Bank, Information and communication technology goods imports include computers and peripheral equipment, communication equipment, consumer electronic equipment, electronic components, and other information and technology goods (miscellaneous). Uganda's poor export performance compared to imports is reflected in the balance of trade deficit. Whereas the technology balance of payments (TBP) registers the commercial transactions related to international technology and know-how transfers, Uganda's export commodities are predominantly low-value primary products, while imports are mainly in non-food industrial supplies, fuel and lubricants and other capital equipment that is of high value.

Uganda's manufactured exports have not been able to penetrate the advanced economies of Europe and North America to a significant extent.

18http://oe.cd/frascati
19WIPO (2022), Global Innovation Index Report, 2022.

Fig.23: Technology Exports from Uganda (1998-2022) *Source: BOU Statistics*



BOX 4: EXPORT PROMOTION IN NEW VALUE CHAINS: THE CASE OF SERICULTURE IN UGANDA

Sericulture is the science of rearing silkworms for the production of raw silk. Uganda has the opportunity to graduate from subsistence to commercial farming in some strategic sectors like silk production to become one of the leading suppliers. Silk is the most expensive textile fiber whose unit price is 20 times the price of raw cotton.

The global rise in demand for silk and the subsequent increase of the price prompted the Government of Uganda (GoU) to embark on new ways of tapping into the industry. Under the project "Commercialization of Sericulture Technologies and Innovations in Uganda" the government aims at increasing domestic production of silk and it's by products, by raising rural incomes for small-holder producers and ensuring the supply of affordable silk products to Ugandan consumers and export markets. The project is implemented by Tropical Institute of Development Innovations (TRIDI) and funded by the GoU through STI-Secretariat Office of the President. It is projected that the opportunities in sericulture will rake at least $93 million in revenue annually. In addition to the multi-million harvest, the industry will open over 50,000 employment opportunities that will be harnessed by the youthful population to curb the rate of unemployment in the country. In India, the silk industry has employed at least 7.9 million people, and 20,000 weaving families in Thailand.

4.2.9 Relative Comparative Advantage

Revealed comparative advantage (RCA) is based on Ricardian trade theory, which posits that patterns of trade among countries are governed by their relative differences in productivity.

Although such productivity differences are difficult to observe, an RCA metric can be readily calculated using trade data to "reveal" such differences. The plots shown in Figure 24 reveal a snapshot of Uganda's comparative advantage in producing and exporting a full range of products in a given year. As shown in Figure 25, Uganda's relative comparative advantage is in agricultural products (food and animal products). There is limited participation sectors like machinery and transport equipment or in miscellaneous manufactured articles. In order to boost Uganda's high-technology export performance, there is a growing need to strengthen capacity in order to enhance structural transition from low tech to medium tech and high-tech outputs. This can be achieved by targeted investments in high growth activities, the improvement of skills and quantitative increases in STI human resources and technological learning.

Fig.24: Uganda's Relative Comparative Advantage

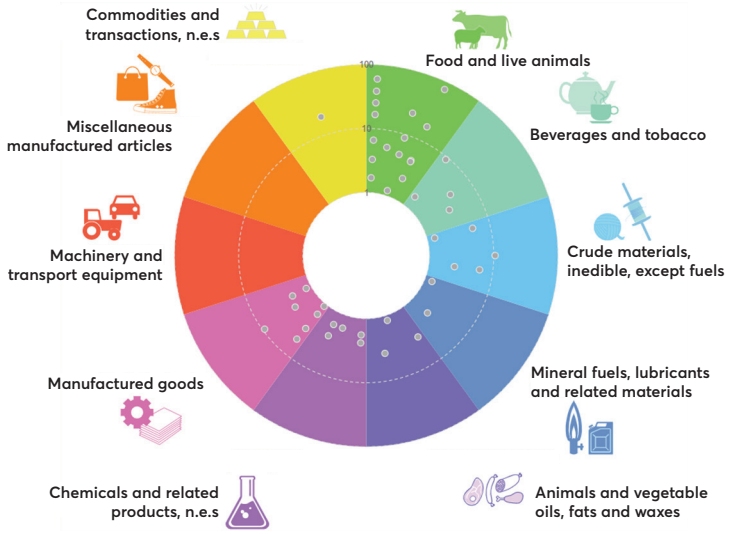
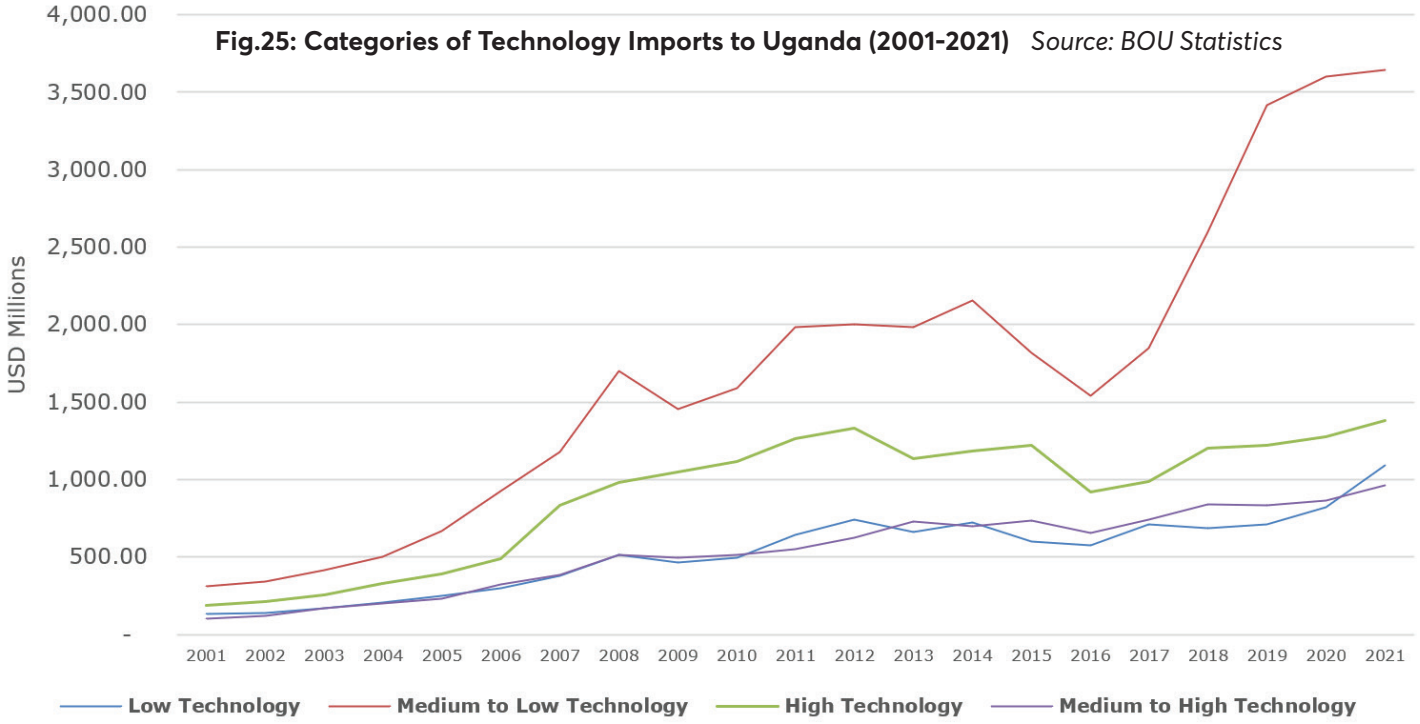


Fig.25: Categories of Technology Imports to Uganda (2001-2021) *Source: BOU Statistics*



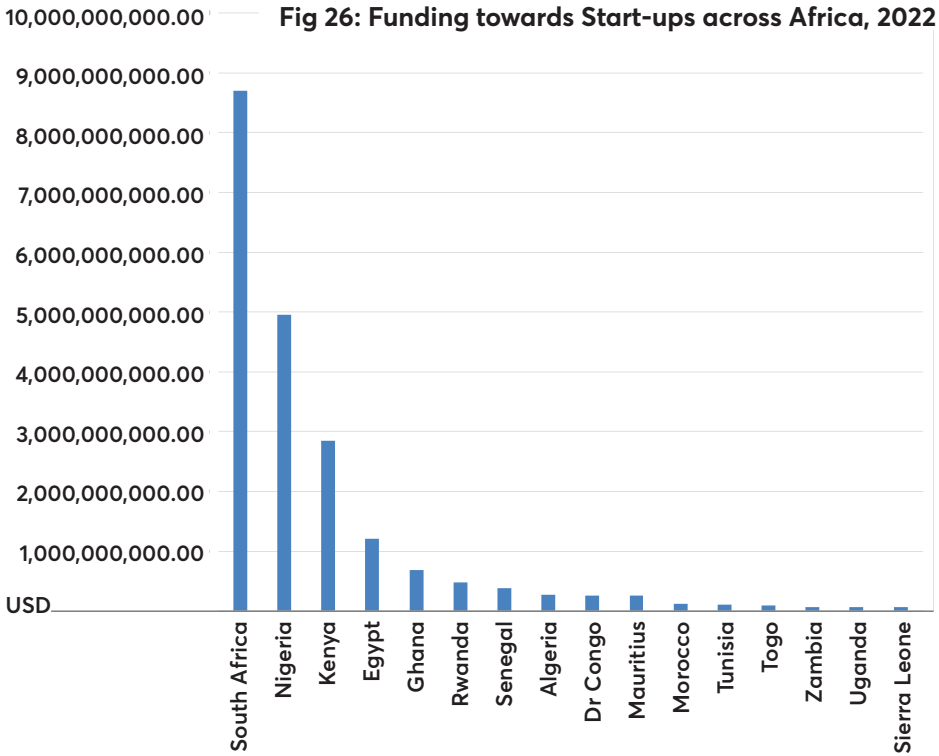
Uganda trades more with its neighbors in East Africa than it trades with the rest of Africa and the world. Two East African countries (South Sudan and Kenya) are the two major destinations for Uganda's exports followed by Europe. With regard to imports, Uganda mainly imports products in the medium to low technology category.

4.3 Innovation in different sectors

The strong role of technology and innovation can also be observed in the services sector, which now makes up 31.2% of the business sector in Uganda.

The traditional view in nascent innovation systems like Uganda is that services are not very dynamic,

Fig 26: Funding towards Start-ups across Africa, 2022



that they have little or no productivity growth potential and that they only offer limited space for innovation. Recent analysis does not support this view. Many services experience rapid productivity growth, several are innovative and new service jobs increasingly require skilled personnel. The services sector is by far the main purchaser of ICT equipment and the performance of several services sectors has been strongly affected by ICT. ICT is important for industries that process information, such as financial services, but also for areas such as logistics because it makes more efficient transport possible. ICT-driven innovations are increasingly becoming critical productivity-enablers in many services sectors, including transport, communications, wholesale and retail trade, and finance and business.

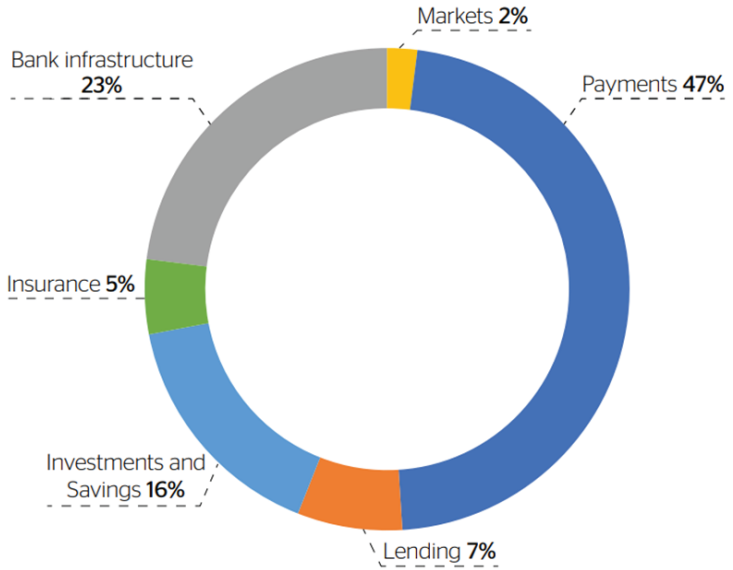
4.3.1 Start-Ups in Uganda

The number of start-ups in Uganda are increasing.

Today the Ugandan start-up ecosystem is home to about 103 start-ups, 16 accelerators and 5 co-working spaces. From e-commerce to e-health, Ugandan start-ups are also the torch bearer for innovation in the country. However, compared to other African countries, the start-up ecosystem in Uganda is still in nascence. For instance, Uganda has only one Start up among the top 100 start-ups in Africa.

Moreover, funding towards start-ups is also far behind many other competitive countries on the continent.

Fig.27: Concentration of FinTechs in Uganda



Source: TrackXN, 2022

Table 8: Africa's Top 100 Start-ups by Funding

Country	Startup
South Africa	Aspen Pharmacare, SA Taxi, Ethomed, Go1, JUMO, Mediclinic, Steinhoff International, Promasidor, WeBuyCars, Africa Leadership Academy, Hollard Insurance, Pepkor, H2O Securities, AgriProtein, Takealot, Tracker Content, MFS Africa, TymeBank, Clickatell, Yoco, One Africa Media, Food Lover's Market, Tekkie Town, Carry1st, Alexander Forbes, VALR
Nigeria	Jumia, HIS Towers,Kuda Bank, Daystar Power, Opay, Flutterwave, Andela, Zola Electric, Teraco Data Environments, Moove, Lumos, PalmPay, Trade Depot, Interswitch, Thrive Agric, Sigma Pensions, MainOne, Beloxxi, Konga, Hygeia HMO, MAX.NG, Yellow Card, Team Apt
Uganda	Tugende
Egypt	MNT-Halen, Tabby, Opontia, Vezeeta, Fawry, Edita Food Industries, MaxAB, Juhayna, Paymob, Cequens, Instabug
Kenya	Greenlight Planet, Tala, d.light, Swvl, M-KOPA, Twiga Foods, Sokowatch, Gro Intelligence, Copia Global, CSquared, Crossboundary, SAma, SunFunder, Aza Finance, Virunga Power, Solarrise Africa, Cellulant, Britam, Apollo Agriculture
Rwanda	Zipline,
Ghana	Chipper Cash, Enterprise Group, mPharma, Fido, PEG Africa
Senegal	Wave Mobile Money, Caif
Mauritius	Bayport Financial Services
Algeira	Yassir, General Emballage
DR Congo	Bboxx, Hellios Towers
Tunisia	InstaDeep
Togo	Oragroup SA
Zambia	Zambeef Products
Morocco	Travax Generaux de Construction de Casablanca, ONOMO Hotels
Sierra Leone	Sierra Rutile

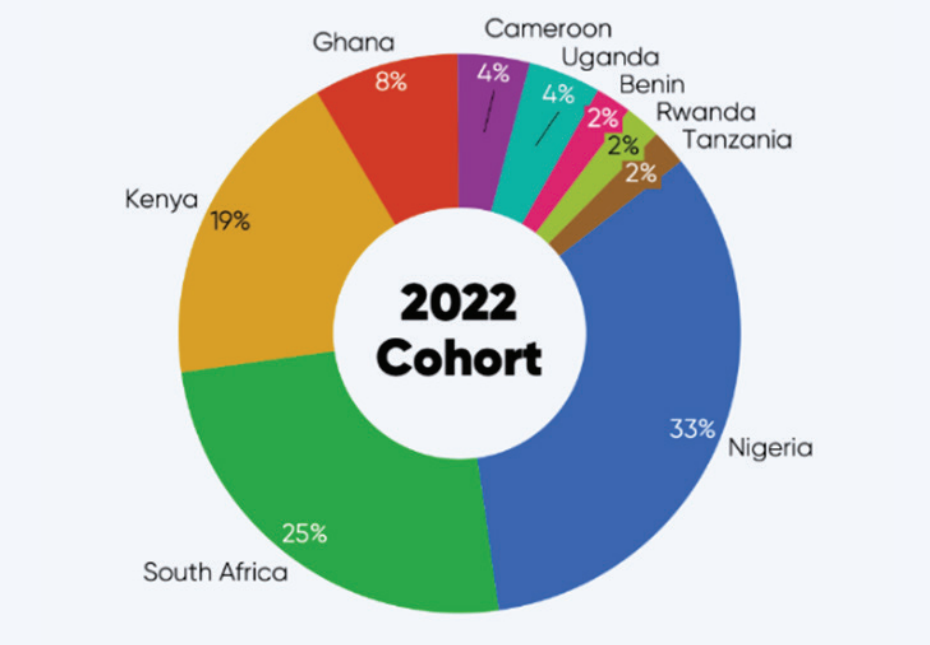
4.3.2 Research in Financial Reforms: Fin-techs

Technological progress has played an integral role in the formation and transformation of the global financial sector.

Over the past decade, the pace of technological progress has accelerated, resulting in the introduction of new business models that aim to make processes more efficient and address the needs of customers better. These technologies have stimulated the development of technology-enabled financial services, or "FinTechs" as it is known. Digital finance has the potential to provide access to financial services to 1.6 billion people in emerging economies by 2025, with more than half of them being women. There are currently around seventy (70) FinTechs operating in Uganda. Payments is the largest area of FinTech in Uganda, with a transaction volume of UGX 17.6 trillion (~ USD 4.7 billion) in 2016. About 60% of the FinTechs that currently operate in Uganda are native to the country, 21% are more generally focused on Sub Saharan Africa, while the rest are global

20Hubs in Africa, GSMA, 2018, www.gsma.com/mobilefordevelopment/wp-content/uploads/2018/03/ Africa

Fig.28: Concentration of HealthTechs in Africa



FinTechs with operations in Uganda. The twin challenges of providing an enabling regulatory environment to support the benefits of FinTech, while balancing the emerging risks which it presents remain a challenge in fully operationalizing a sustainable environment for FinTechs to thrive.

4.3.3 AgriTechs in Uganda

There are 24 AgriTech startups in Uganda.

Currently, Uganda has 24 documented AgriTech startups. Some of them work with farmers to enable them sell their farm produce to verified agro-processors and buy farm inputs such as seeds, fertilizers, pesticides, equipment, agriculture extension services, consultancy services, plant & animal inputs, etc. from authorized suppliers across Africa. Jaguza, another startup, provides livestock farm monitoring solutions. It provides microchips which can be placed on cattle to collect data and monitor livestock animals through the companion mobile application. It provides information including the heart rate, respiratory rate, blood pressure, and location of farm animals. It also collects aerial images of livestock farms leveraging drone technology and allows users to access real-time updates on their livestock farms. Also, offers identification and traceability solutions. However, available data shows that in Kenya, Uganda and Rwanda fewer than 30% of AgTech firm owners are women. Investors have largely focused on Kenya, which received 64% of the funding, followed by Uganda (26%), Tanzania (6%) and Rwanda (3%). South Sudan and Burundi make up less than 1%.

20Hubs in Africa, GSMA, 2018, www.gsma.com/mobilefordevelopment/wp-content/uploads/2018/03/Africa

4.3.4 HealthTech

Currently, there are twenty-nine (29) HealthTech startups in Kampala.

Rocket Health, for instance, provides an online platform that enables users to access and purchase a range of healthcare services. It offers medical delivery, teleconsultation, laboratory testing, vaccination, clinic appointment booking, and other services. However, as shown in Figure 28, Nigeria and South Africa account for more than half of the 2022 cohort. Only 4% of the Health Techs across Africa are concentrated in Uganda. The pandemic has had a profound impact on the global healthcare market and African health tech startups have undeniably been boosted by the fast-track implementation of 'virtual first' healthcare.

4.4 Incubation Hubs

According to the GSMA (2018), Uganda has 16 active innovation hubs[20].

Some of these include: Space Hub, Venture Labs East Africa, Microsoft Innovation Centre and iLab@MAK hosted by College of Computing and Information Science, Makerere University, Outbox Hub, Design Hub Kampala, Hive Colab, Afrilab, Techbuzz, Angels Hub, the @TheHub work space; FinAfrica - which has a particular focus on training); Center for Innovations and Professional Skills Development (CiPSD) and RAN Innovation lab at Makarere University; Women in Tech Uganda (WITU) Hub ; Mawazo Innovation Hub , TechBuzzHub and The Innovation Village Kampala and NFT Mawazo. These hubs are social communities that offer facilities, such as shared workspaces, mentoring and knowledge sharing, funding, subject-matter expertise on technology trends and strategic innovation management. The Innovation Spaces are focused on

providing Pre-Incubation (Hive CoLab, Outbox), Incubation (Angels Hub, Women in Tech Uganda (WITU) Hub, FinAfrica, Innovation Village, TechBuzzHub), Co-working spaces (Hive CoLab, Outbox, The Hub, Mawazo Innovation Hub, Innovation Village, TechBuzzHub), Entrepreneurial Training (FinAfrica) and commercialisation of apps (Grameen Foundation AppLab) . Other related activities include: the UNICEF supported Uganda Innovation Lab and the UN Global Pulse supported Pulse Lab Kampala , which focuses on applications of Big Data; Telesat International - a non-profit trade school in Kampala that prepares students for self-employment; CURAD - Consortium for enhancing University Responsiveness to Agribusiness Development; FabLab Kampala and business Innovation services provided by the Uganda Industrial Research Institute. Uganda academics and youth dominate the ICT innovation spaces. Over the years a number of exciting products have emerged from these spaces. ICT is therefore one of the key sectors that has the potential to generate jobs critical to Uganda's drive towards a knowledge-based economy.

Summary

For Uganda to catch up and forge ahead, there is need to adopt frontier technologies while continuing to diversify its production base by mastering existing technologies. This means strengthening innovation systems, while aligning STI and industrial policies, building basic digital skills, and closing gaps in ICT infrastructure. As such, the government of Uganda should engage a wide range of actors who can help build synergies between STI and other economic policies – industrial, trade, fiscal, monetary, as well as educational policies. In light of the COVID-19 response, it is imperative that the country develops digital skills through inclusive education and training programs. This will ensure that Uganda can move up on some of the global indices highlighted in this report.

5. Research Funding and Support Mechanisms:

5.1 Introduction

Over the past five years, STI have become synonymous with economic competitiveness and modernity, as developing countries seek to diversify their economies and make them more knowledge-intensive.

Although several AU level pronouncements and declarations to support research and innovation have been made, state funding of research in many African countries remains low. Uganda is yet to increase its research funding intensity from the current 0.23% of GDP although government programmes are increasingly playing a prominent role in the funding of research. Increasing the sources of R&D funding is vital for ensuring that Uganda can sustainably respond to local and global emerging challenges. Government incentives towards research, including tax concessions, payment of bonuses for R&D, exemption from taxes and tariffs on R&D equipment, etc., should be supported to provide the much needed competitive edge of Uganda's research in a highly dynamic global research ecosystem.

5.2 Funding Research in Uganda

Several studies have shown that funding for research in Uganda is generally foreign-led.

The National R&D Survey showed that 56% of Uganda's research is foreign-funded. A subsequent study by UNCST (2020) showed that between 2015 and 2019, almost 40% of the research registered in Uganda was funded by foreign private companies. As shown below, local private companies fund only up to 7% of research studies conducted in Uganda.

Fig. 29: Main Funders of Research (2015-2019) *Source: Author's Compilation*

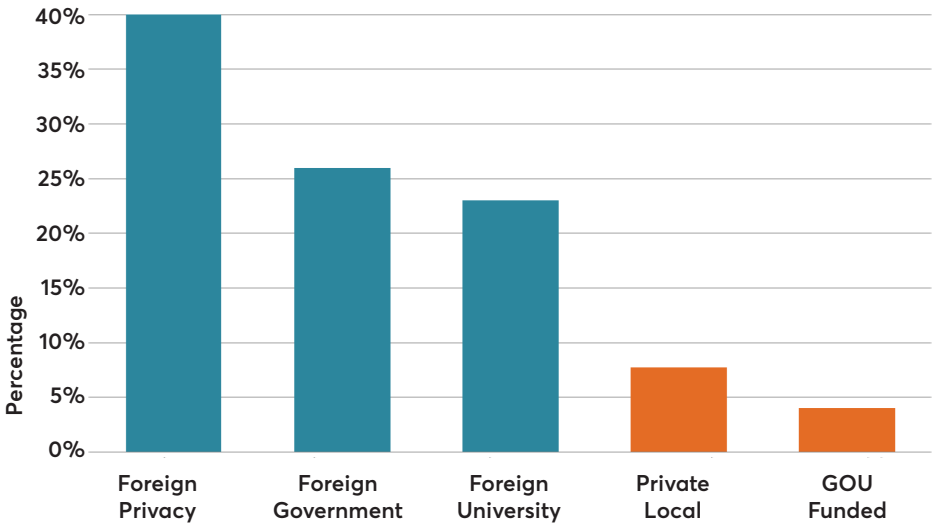
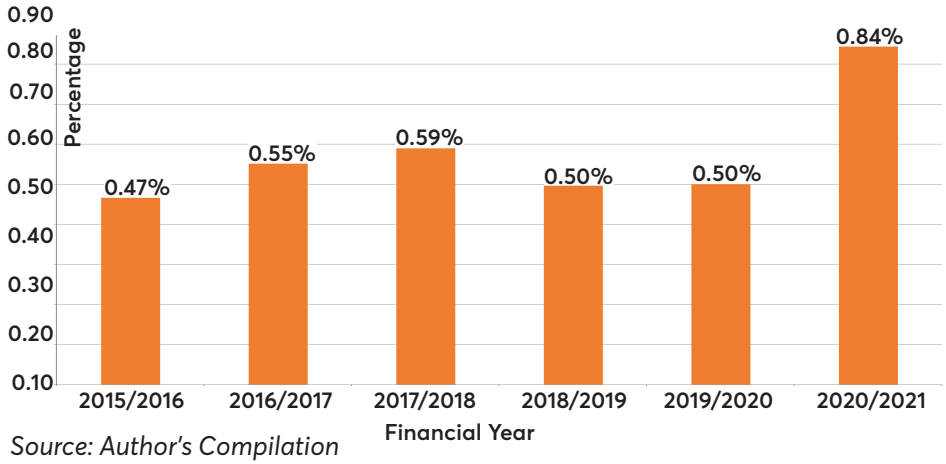


Fig. 30: Budget Allocations for Research and Development, 2016-2022



Source: Author's Compilation

5.3 Government budget allocations for R&D (GBAORD)

Government funding of R&D is an indication of the national commitment towards research. GBOARD covers only the funding of R&D performance.

Government budgets for R&D may include a provision for the costs of administering R&D programs and projects, including for example the formulation of calls, competitive procurement processes and grant solicitations, as well as the monitoring and evaluation of programs. Direct public support for research and development (R&D) is currently the primary tool of the government to support the performing of R&D. Research and development is supported by both the targeted (grant projects, operational programs) and institutional form of support (funding of long-term conceptual research institution development and specific university research). As shown in Figure 31, government budget allocations for research and development has been increasing. Government budget allocations for R&D budget allocation for R&D grew 3.5 times from 109 billion in FY 2015/16 to 384 billion in FY 2020/21 absolute terms.

Over the next five years, the government of Uganda has made a commitment to make substantial investments in science, technology and innovation to take advantage of the growing sophistication of markets and global value chains. Since 2021, over 100 projects have benefited from the Research and Innovation Fund (RIF) at various stages of innovation. More private research institutions have also started to directly support research activity. Whereas government has made gains in supporting research in higher education institutions, the funding landscape still remains skewed towards foreign sources. As shown in Figure 32, research funding is mainly resourced from external grants, a trend which has been increasing since 2017/18. For instance, research activities in public universities are funded by internal grants from university resources and government contributions and grants from external partners. The Government of Uganda committed a total of UGX.134.3bn ($35.27M) in the years 2017/18, 2018/19 and 2019/20 while external grants amounted to UGX.244.3bn ($64.16M) in FY2017/18, UGX.146.1bn ($38.37M) in FY2018/19 and UGX.231.2bn ($60.7M) in FY2019/20

Whereas universities have three cardinal mandates, including teaching, community service and research, the latter is often the least funded in many developing countries. Proportionally, public and private universities allocate 5.1% and 1% of their budgets to research activities (See Figure 33).

Fig. 31: Funding for Research activities for selected public universities (UGX)

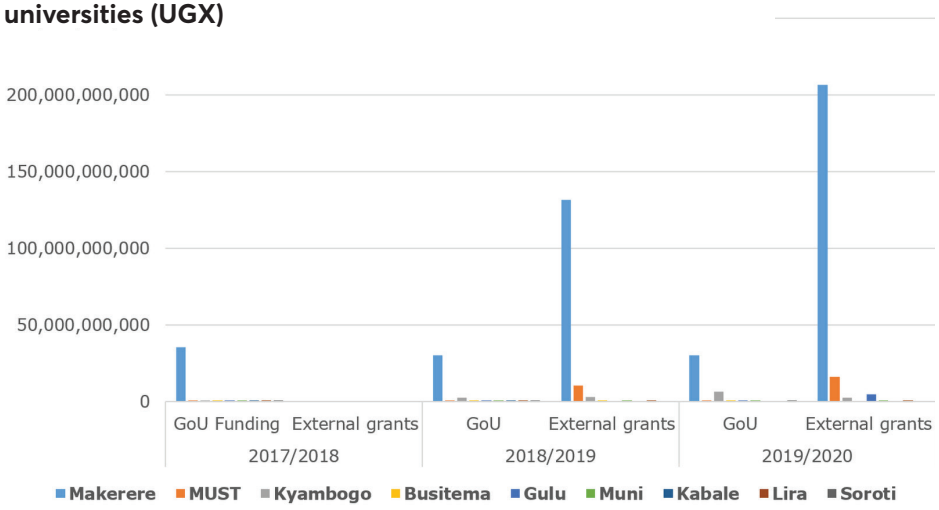
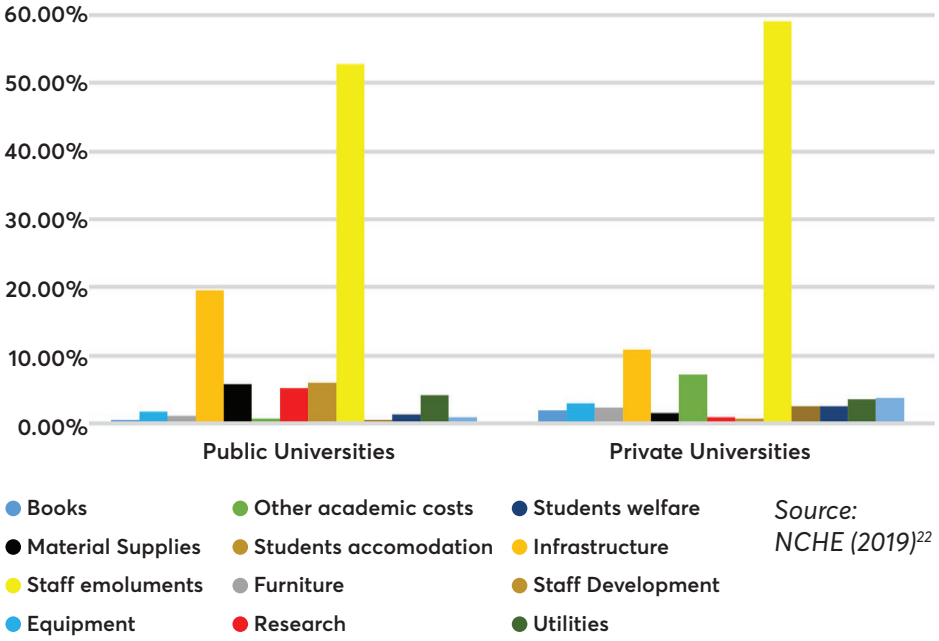


Fig. 32: Proportional Budget Allocations for Private and Public Universities



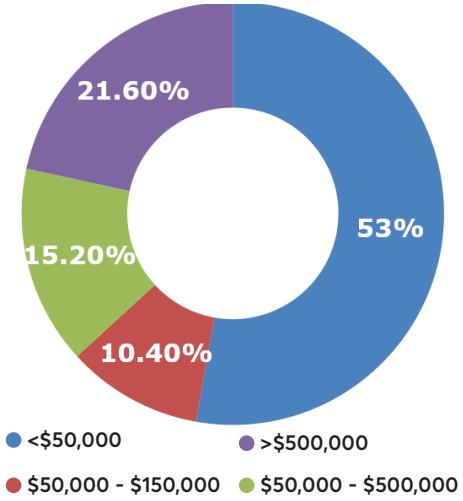
Source: NCHE (2019)[22]

Increasingly universities are ranked according to how much they allocate towards research. This criterion has driven universities to invest in research and to undertake resource mobilisation and to strengthen their research partnerships and research quality assurance systems.

Financing Collaborative Research

As shown below, most of the researches conducted between 2015 and 2019 had a budget of less than USD50,000 with an estimated median budget of USD27,500. However, 21.6% of the research budgets are over $500,000 with almost all of them being collaborative in nature (undertaken with at least one research partner from a non-Ugandan institution). Collaborative research has a higher budget on average ($258,520) compared non collaborative research ($52,144).

Fig. 33: Research Budget Categories



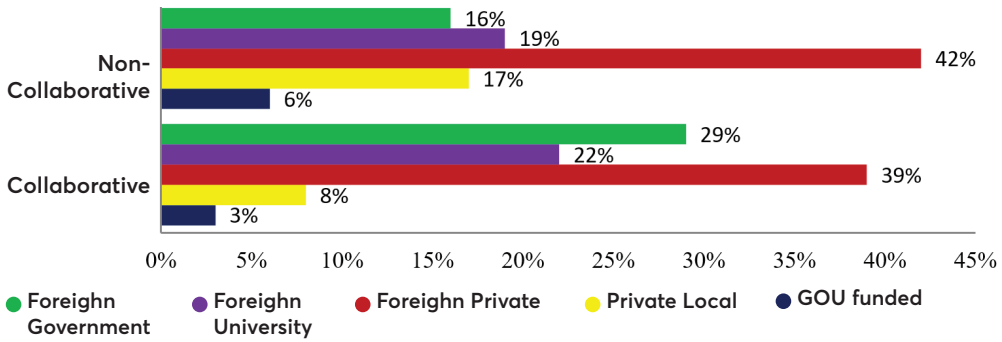
Source: Primary Data

Source of Funding and Collaborative Status

Foreign Private entities dominate the funding for international research collaborations in Uganda. This corroborates previous findings by Zink (2017) who showed that funding for Ugandan research and research training almost entirely originates from international donors. Government of Uganda funded research and research funded by local companies account for 11% of collaborative research as shown below. Further statistical analysis confirms the statistically significant association between sponsors of research and the collaborative status of the research.

22NCHE (2019), State of Higher Education and Training in Uganda, 2017/18. A Report prepared by the National Council for Higher Education

Fig. 34: Source of Funding and Collaborative Status *Source: Primary Data*



Summary

Uganda cannot afford to miss this new wave of technological change. This will demand for enhanced funding and investment towards STI with a view towards diversification and adaptation. Funding for STI in general and R&D in particular remains below commitments made in planning documents. The emergence of a Value Chain approach provides a new impetus for new and sustainable research funding options. Deliberate engagement with the private sector in research and development activities can provide new funding options for the STI sector through contract research activities, royalties and licensing. Strengthening Science Diplomacy platforms, capacity building of researchers and formalizing inter-governmental partnerships on R&D can establish co-funding opportunities for research funding. Capitalising the Research and Innovation Fund (RIF) can support translation activities and especially the handover from technology development and proofing to scaling up and commercialization across the STI value chains. The new STI Policy should provide for new allocative capacity towards R&D using new tools like R&D subsidies as market-signalling mechanisms to promote research and innovation. ■

23Zink, E (2016), Research Training, International collaboration, and the agencies of Ugandan scientists in Uganda, In Tor Halvorsen and Jorum Nossum (ed.), North-South Knowledge Networks: Towards equitable collaboration between academics, donors and universities (pp 57-84). Cape Town: African Minds

BOX 5: NEW MODES OF RESEARCH FUNDING: OLIVER THAMBO RESEARCH CHAIRS INITIATIVE

First announced in 2017, the Oliver Reginald Tambo Africa Research Chairs Initiative (ORTARChI) is an initiative aimed at supporting high-quality research leadership; and talent; as well as individual, internationally-recognized researchers to contribute to the development of long-term, mutually beneficial, research collaboration across Africa. Makerere University won one of the OrTARCHi Chairs on Sustainable Agriculture. The ORTARChI will leverage partnerships with civil society, the private sector, and the government, a highly commendable approach to implementing excellent research.

6. Research Collaboration and Partnerships:

6.1 Introduction

Global challenges like the COVID-19 pandemic, Water contamination, food insecurity, global health, poverty etc. cannot be tackled without international research collaboration.

Uganda remains committed to collaborate, co-create and foster strategic S&T partnerships with high-potential partner countries or institutions for socio-economic growth through Memoranda of Understandings (MoUs), agreements and treaties. Ugandan research institutions are involved in a plethora of inter-agency research partnerships across business, Government and Higher education. These partnerships are between local institutions while others are with foreign research partners. However, some of these partnerships operate within a regulatory vacuum. In some cases, universities don't have independent international or partnership offices. That affects the sustainability of many partnership projects. They grind to a halt or gradually fall apart when the collaborators aren't able to continue coordinating the projects. Several universities have begun developing formal organisational structures, policy and regulatory frameworks to guide research partnership and management practices.

Table 9: State of research Collaboration in Public and Private Universities

University type	University US/Europe		International Foundation or Partnership	Asia Foundation / University	African University / Foundation
	US	Europe			
Public Universities	98	72	69	22	39
Private Universities	20	15	23	12	12
TOTAL	118	87	92	34	51

Source: UNCST data

BOX 6: HARNESSING UNIVERSITY-ACADEMIA LINKAGES: THE TECHNOMART

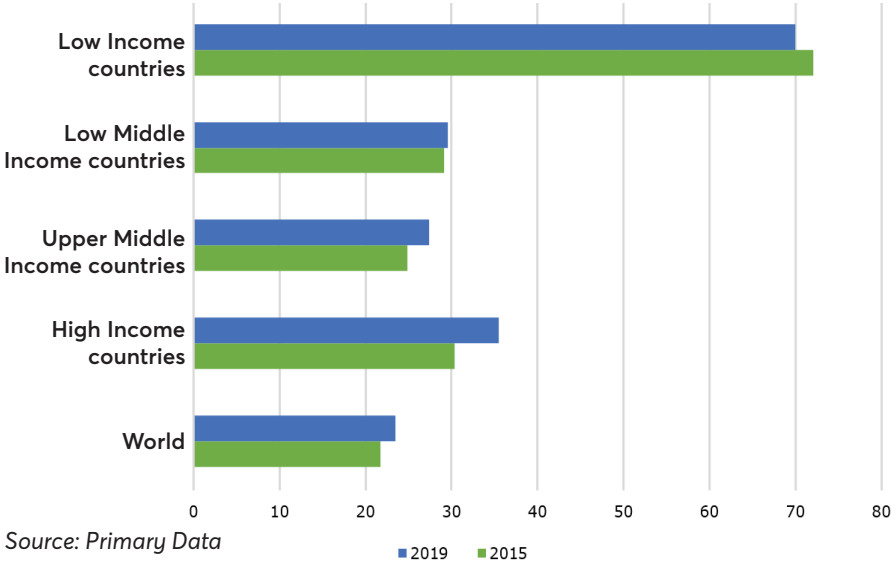
The Science Granting Councils Initiative (SGCI) provided support to Uganda aimed at strengthening public private partnerships to support manufacturing through research. As part of this work, the UNCST is developing an Online Gateway that aims at bridging the Private Sector and Academia. The TechnoMart is expected to be a collaborative platform that acts as a "convergence spaces" for the fusion of diverse disciplines, actors and technologies with a broad aim of enhancing visibility of the university research by reducing lags between innovation and commercialisation. This Online Gateway should bridge academia and industry by alerting R&D teams to commercially-viable academic research in their areas of interest, with a team on-hand to organize and coordinate the initial introduction. The Online Gateway should also provide a space where international collaborations can be established between local researchers and international partners.

6.2 University-Industry Collaboration

Companies are increasingly intensifying their collaboration with universities in Uganda. The identification of the specific measures for each of these stages is a real challenge, especially if we want to determine both prospective and retrospective measures and subjective and objective measures. Collaboration between both the industry and universities are crucial for undertaking new product development activities for potential market and subsequent generation of income through product commercialization. And yet, studies have shown that only one out of four newly-developed products are a success and approximately 40-50% of resources invested in product development are wasted on

canceled products or projects that yield poor results. Over the last ten years, there has been a growing interest for collaboration between partners in university and industry in Uganda. Such challenges arise from the fact that while the primary goal of universities is to create open and public knowledge, and provide education , their industrial partners have a strong focus on capturing valuable knowledge that can create competitive advantage. The UNCST undertook a Needs Assessment on the interface between academia and industry. The assessment showed that strengthening their R&D capacity and increasing their competitive advantage were identified as two key drivers for companies to engage in collaborative research projects with universities. Applying research developed in academia to solve industrial challenges and developing new innovative products or improving existing ones were also motivations identified by companies to take part in university-business collaborations. In addition, some companies mentioned that part of their organizational strategy specifically included developing partnerships with academia and investing in research and development activities. Finally, companies indicated that having access to academic expertise on specific research areas and working with high-profile institutions with strong research capacity in areas relevant for the company were important drivers to engage

Fig. 35: Share of Publications at UNCST involving co-authors from two or more countries, 2015 and 2019 (%)



Source: Primary Data

BOX 7: RESEARCH COLLABORATIONS AND NETWORKS MAKERERE-SIDA BILATERAL RESEARCH PROGRAMME PHASE IV 2015-2020

The Government of Sweden entered into a mutual agreement with the Government of Uganda to implement the Sweden-Uganda Research Collaboration programme 2015-2020. Makerere University was awarded SEK275,000,000 to enable Ugandan public universities and Swedish partner universities implement joint research projects including training of 125 PhD students, 147 MA students, and 65 post-doc fellows, divided between the five public universities of Makerere University, Kyambogo, Busitema, Gulu and Mbarara University of Science and Technology. This graduate training, including institutional support, brings the Swedish contribution to USD32 million over five years. The main objective of the bilateral research cooperation was to increase the capacity of Makerere and partner public Universities to generate knowledge and promote research uptake for national and regional development.

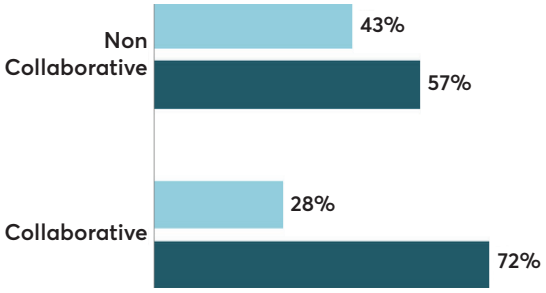
in collaborative research projects with universities.

6.3 International research collaboration

International collaboration is an essential part of the way science operates. In Uganda, given the limited resources devoted to R&D activities and the crucial role that scientific knowledge generated through research activities can have in socioeconomic development, IRC may be an opportunity to strengthen scientific capabilities. Increased international research collaboration activity has been prompted by the pervasive nature of global challenges like pandemics, climate change, migration, poverty, green energy options, that transcend national boundaries and which cannot be resolved by any one country acting alone.
In Uganda, the research teams are increasingly multicultural and represent the changing face of research in the global south. The share of publications of internationally co-authored research has increased (See Figure 36 below). This could be due to lower costs of global communication and increased pressure to produce greater research output.

Over 76% of papers reported by Scimago have been produced as a result of international research collaborations, and Ugandan research is increasingly highly cited. Despite having inadequate systems to facilitate knowledge exchange, Uganda is developing robust knowledge transfer practices and a good system for

Fig.36: Collaborative Status and Type of Research (2015-2019)



Source: Primary data

intellectual property protection. A study undertaken by UNCST showed that there are several factors that drive international research collaboration. Most (72%) of the international collaborative research conducted in Uganda is non-academic.

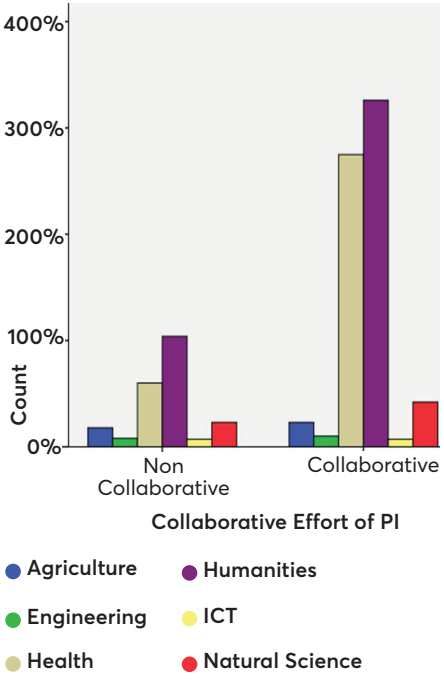
6.3.1 Research Collaboration and Field of Science

Research collaboration is undertaken mainly to share expertise and the costs associated with research and to boost research productivity and scholarly impact.

As shown below, most collaborative research undertaken in Uganda between 2016 and 2019 was in the humanities and health science fields. More recently, the rapid development of COVID-19 vaccines relied on strong international research collaboration which underscores the fact that national interest will most often be best served by building sustainable research partnerships to counter the emerging global challenges. collaborative research is undertaken in the health and humanities.

Fig.37: Research Collaboration in different research fields

A graph showing collaboration in different research fields



Source: Primary Data

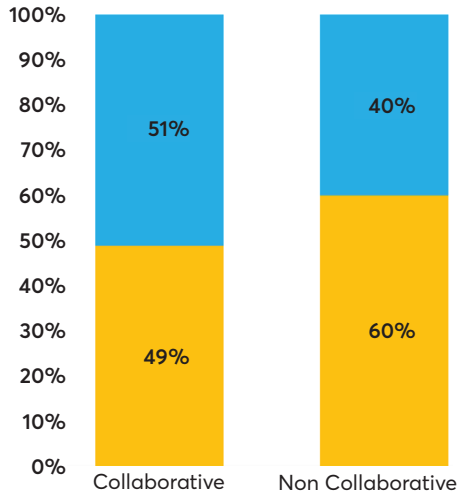
6.3.2 Gender Participation in International Research

Women researchers engage less in international research collaboration due to a complex set of individual factors and "glass fences" that limit their participation in elite research activity[27].

Between 2015 and 2019, almost an equal number of males and females were engaged in collaborative research.

Even though male PIs are generally collaborating more than female PIs, female researchers in Uganda are collaborating more than their male counterparts especially in academic-related research. A UNCST study shows that the gender of the researcher significantly impacts his or her ability to collaborate in research with a higher percentage of male researchers (51.47%) collaborating more than their female counterparts ($p<0.05$, $\chi^2 = 5.0246$), however, the difference in collaboration between the two gender is almost minimal (less than 2%).

Fig.38: Gender of the PI and Collaborative Status



Source: Primary Data

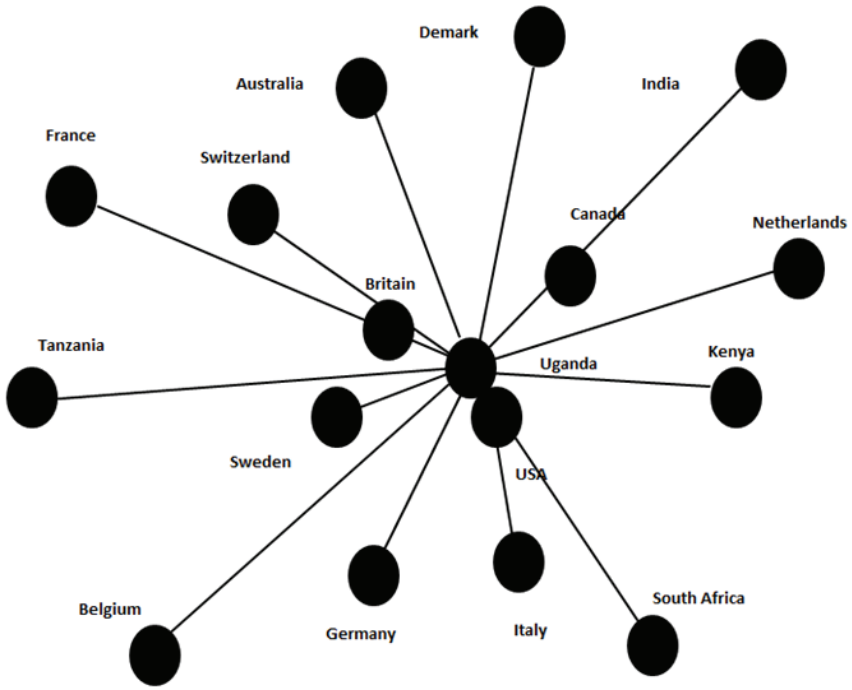
6.3.3 Countries of international research collaboration

Ugandan researchers collaborate with partners from different countries.

Ugandan researchers collaborate with partners from different countries. The network graph below shows the extent to which Ugandan researchers collaborate with other countries. The nodes of the network

27Uhly, K., Visser, LM.; and Zippel KS., (2017), Gendered Patterns in International Research Collaborations in Academia, in Studies in Higher Education 42(4):760-782

Fig. 39: Network chart showing Sponsor of the Research and Collaboration



graph represent countries which collaborate with Uganda and the edges represent the degree (propensity) of collaboration. The nearer to the centre node (Uganda), the greater the collaboration power and the further a country is from the centre (Uganda) the less the collaboration power.

The network graph in Figure 33 reveals that USA is Uganda's major research partner and other top research partners include United Kingdom, Canada, Sweden, Germany, Kenya and Norway.

Summary

International research collaboration can strengthen national capacities in STI, smoothen technology transfer (even for locally relevant products and services) and enhance cross-learning between Ugandan researchers and their counterparts in other countries. Even so, the landscape of international research collaboration is rapidly transforming. Driven by increasing global competition and rapid technological changes, more and more countries have deemed the science and technology (S&T) collaboration across countries as a critical pathway towards fostering and maintaining their global innovation competitiveness. A country with more collaborative linkages with other countries is placed in an advantageous position, which endows it with privilege to leverage the domestic S&T capabilities and exploit the foreign investments in Research and Development (R&D). Thus, IRC has been perceived as a dominant driving force for promoting S&T advancement, industrial innovation and economic growth. Strengthening science diplomacy will be critical to ensure that the benefits from such collaborations are impactful and sustainable for medium to long term socioeconomic transformation. ■

16Evanschitzky, H., Eisend, M., Calantone, R. J., & Jiang, Y. 2012. Success Factors of Product Innovation: An Updated Meta-Analysis. Journal of Product Innovation Management, 29: 21–37.
25Menold, J., Simpson, T., & Jablokow, K. 2016. The Prototype for X (PFX) framework: assessing the impact of PFX on desirability, feasibility, and viability of end Designs. ASME 2016 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference.
26Lee, K. J. 2011. From interpersonal networks to inter-organizational alliances for university–industry collaborations in Japan: the case of the Tokyo Institute of Technology. R&D Management, 41(2): 190–201.

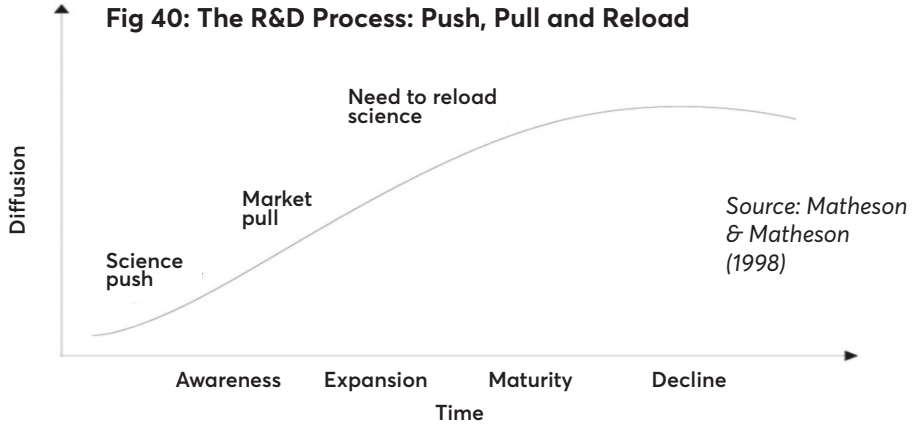
7. Research and Innovation Products:

7.1 Introduction

The objectives of Research and Development are to develop existing and new core competencies; to further existing knowledge, to increase the range of new products, and to develop existing and new business processes through invention and innovation. [28]

The R&D process is the engine that drives product and process differentiation. At its basic, Research is typically considered to be science-oriented whereas development is the mechanism for translating the science into commercial products and services. Several studies have demonstrated the difficulty in shifting from research to development. How much and how fast countries, industries and companies invest in transforming research and development (R&D) resources, both human and financial, into new technologies will in large part determine future economic growth, standards of living and overall global welfare. As shown below, the diffusion and awareness of technologies follows an S-curve.

Fig 40: The R&D Process: Push, Pull and Reload



As a technology matures and takes off, there is propagation of awareness with increased insight of the possibilities.

7.2 Research in Higher Education

A survey of Ugandan universities in 2014-6 revealed that few of them do significant research.

A survey of Ugandan universities in 2014-6 revealed that few of them do significant research. Not many of their staff engage in innovative studies, produce impressive publications, or register acclaimed patents . For instance, between 2001 to 2007, the productive capacity of a Makerere academic staff was 0.2 compared to 0.5 for South Africa . The average lifetime publication of a typical Ugandan PhD holder was found to be ten pieces and patent registration to be 0.6 . However, this has since improved.

For instance, the number of research publications by academic staff at Makerere University has increased from 325 publications in 2008 1o 1400 in 2021. This has trebled the rate of publications from 0.32 publications per academic staff per year in 2008 to one (1) publication per academic staff per year in 2021. Nevertheless, Ugandan universities do not allocate more than 5% of annual institutional budgets to research. Globally, the importance of universities and their research, development as well as commercialization (R, D & C) activities has been widely documented and commercialization is often referred to as the "fourth mission" of universities . Some studies have shown that successful research product commercialization by academic researchers can achieved through knowledge, skills and personal traits of the researcher; development, packaging, and promotion of the research product and the availability of facilities, among other factors. This is shown in Figure 2 . Researchers in the universities produce innovations as a result of their research activities

28Matheson, D., Matheson., J (1998), The Smart Organization. Harvard Business School Press: Boston
29Kasozi, A>B>K (2017), The Impact of Governance on Research in Ugandan Universities, MISR Working Paper No. 31, Makerere Institute of Social Research. Available at file:///C:/Users/s.sebbale/Downloads/MISR%20WP%2031%20Kasozi.pdf
30Cloete, Nico, Peter Maassen, and Tract Bailey (2015 a). Knowledge Production and Contradictory Functions in African Higher Education. Cape Town: African Minds

Fig 41: Elements of the Research/Industry nexus

which in turn can be exploited commercially. However, the transformation from research and development into commercialization is a path strewn with many pitfalls. The impact of Ugandan research in Uganda remains low compared to other countries as very few research ideas go through to innovation stages and eventually get commercialized. Between 2017 and 2021, patent applications fluctuated between seven (7) and twenty-two (22). As shown in Table 6, patent grants ranged from one (1) to five (5) and fell to zero in 20201/22. Uganda having no patent grants in 2021/22 could be attributed to the COVID-19 pandemic although research and IP filings increased globally during this period . Other intellectual property applications between 2017 and 2021 were utility models fluctuating between thirteen (13) in 2017/18 and nineteen (19) in 2020/21 with grants also fluctuating between three (3) and eleven (11) 2017/18 respectively.

Minister of STI-OP (C) and the Vice President of Uganda (2nd right) at an exhibition during the National Science Week, 2022

Table 10. Uganda's Intellectual Property Applications and grants[36]

	2017/18	2018/19	2019/20	2020/21	2021/22
Patent Applications (Grants)	22 (1)	7 (5)	10 (4)	15 (2)	17 (0)
Utility Model Applications (Grants)	13 (11)	17 (6)	16 (5)	19 (3)	14 (0)
Local Trademark Applications (Registrations)	1314 (1082)	1613 (1204)	1267 (1039)	1711 (992)	2129 (1593)
Foreign Trademark Applications (Registrations)	1325 (1589)	1827 (1723)	1557 (1623)	1364 (1226)	2171 (1850)
Copyright Applications (Registrations)	134 (62)	128 (74)	138 (51)	119 (49)	154(106)
Industrial Designs Applications (Registrations)	71 (10)	117 (27)	94 (48)	76 (17)	59 (34)

Source: Authors compilation

Trademark applications also fluctuated between 2881 in 2017 and 4021 in 2021 with registrations increasingly fluctuating from 2159 in 2016 and 2772 in 2021. Industrial design application and registrations grew from zero (0) in 2016 to 90 and 32 in 2021 respectively. These are few and according to the Global Innovation Index (GII) 2016, most patent applications made in between 2016 and 2021 were foreign, while no local patents of Ugandan origin were filed abroad in 2020 and 2021. The majority of IP applications submitted to URSB are for trademarks. Unfortunately, most trademark applications are not granted mainly due to failure of applicants to complete the registration process[37].

Until 2014 when The Industrial Property Act, 2014 came into force, there were no provisions for local industrial design applications save for The United Kingdom Designs (Protection) Act, Cap. 218 which provided for automatic protection of UK designs in Uganda. Consequently, there is lack of incentive for value addition, innovation and creativity in design-centric industries such as handicrafts, fashion and artisans, among others, all of which can be protected through the industrial design system. Similarly, there are few applications for utility models in spite of growing capacity for local technology development and adaptation in academia, public, private and informal sectors.

7.3 Intellectual Property Protection and Research in Uganda

The level of Intellectual Property protection has an impact on the prevailing research regime in the country.

According to the World Intellectual Property Organization (WIPO) patent applications for Ugandan residents fluctuated between 6 and 25. The patent applications fell from 25 in 2017 to 6 in 2018 but rose again to 14 in 2019 and 13 in 2020. This low level of IP protection is attributable to a number of critical factors that include: capacity constraints in identification of potential IP assets; low level of public awareness of IP system and services and few IP professionals and service providers, among others. Many potential beneficiaries of the IP system are

30Cloete, Nico, Peter Maassen, and Tract Bailey (2015 a). Knowledge Production and Contradictory Functions in African Higher Education. Cape Town: African Minds. 31Ssembatya, Vincent (2012). The Careers and Productivity of Doctorate Holders (CDH) Survey: Uganda Report 2012. Kampala: Uganda National Council for Science and Technology. 32Ssembatya, Vincent (2022). PhD Training as a Pillar in Uganda's Economic and Sustainable Development. A Presentation for the NORHED Workshop, Makerere University, April 2022. 33Collier, A & Gray, B 2010, The commercialization of university innovations – A qualitative analysis of the New Zealand situation, Research Report, viewed 24 April 2022, <http://www.otago.ac.nz/entrepreneurship/docs/Qual%20report_31%20August%202010.pdf> 34hahidan, N. H., Abdul Latiff, A. S. and Abdul Wahab, S. (2019). Need for a University Start-up Framework for Commercialisation of Intellectual Property Rights (IPR): A Malaysia Perspective. Sustainable Business and Society in Emerging Economies, 1(2), 123-134. 35WIPO (2022), Global Innovation Index Report, 2022. A Report by the World Intellectual Property Organisation.
36URSB. 37Ministry of Justice and Constitutional Affairs.

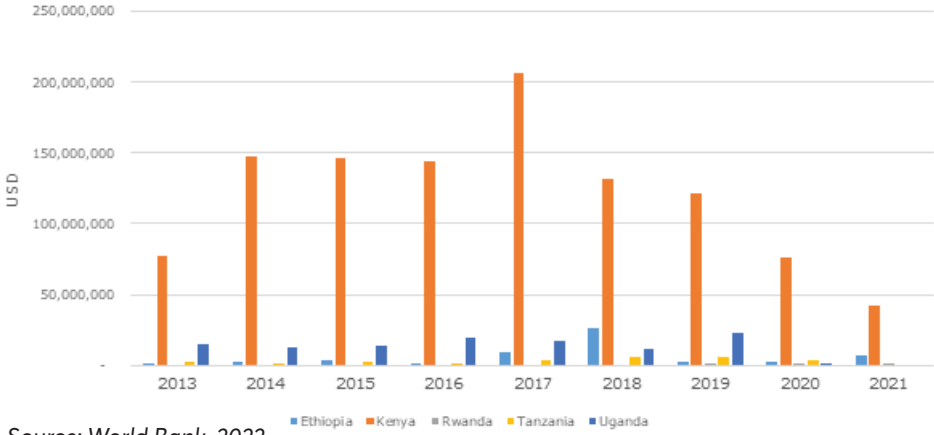
not aware of the value of IP assets in their possession and mechanisms for acquiring appropriated IP protection . Within the university system, only three public universities have Intellectual Property Policies. The Government of Uganda is promoting innovation in universities and has set a target of registering 6,000 patents by 2040. Over the last five years, the Uganda Registration Services Bureau (URSB) which is the national intellectual property office has engaged universities and research institutions on the importance of IP as a tool to improve research quality and yield tangible research outcomes. The WIPO Technology and Innovation Support Centers (TISCs) program provides innovators in developing countries with access to locally based, high quality technology information and related services, helping them to exploit their innovative potential and to create, protect, and manage their intellectual property (IP) rights. Services offered by TISCs include: access to online patent and non-patent (scientific and technical) resources and IP-related publications; assistance in searching and retrieving technology information; training in database search; on-demand searches (novelty, state-of-the-art and infringement); monitoring technology and competitors; basic information on industrial property laws, management and strategy, and technology commercialization and marketing. As of June 2018, there were over 25 TISC host institutions TISC institutions are based in Institutions of Higher learning and Research Institutions. The establishment of the TISCs is to provide access to technical information stored in patent and non-patent databases so that less time is spent working on what has already been done and more time is spent on developing new solutions. Shown below are the different TISCs.

38Ministry of Justice and Constitutional Affairs.
39International Monetary Fund, Balance of Payments statistics yearbook and data files.

7.3.1 Charges for the use of intellectual property

Uganda's charges for the use of intellectual property (payments and receipts) between residents and nonresidents for the authorized use of the country's proprietary rights (such as patents, trademarks, copyrights, industrial processes and designs including trade secrets, and franchises) and for the use, through licensing agreements, of produced originals or prototypes (such as copyrights on books and manuscripts, computer software, cinematographic works, and sound recordings) and related rights (such as for live performances and television, cable, or satellite broadcast) has been increasing.

Fig. 42: Charges for the use of intellectual property Receipts, (BoP, Current US$)

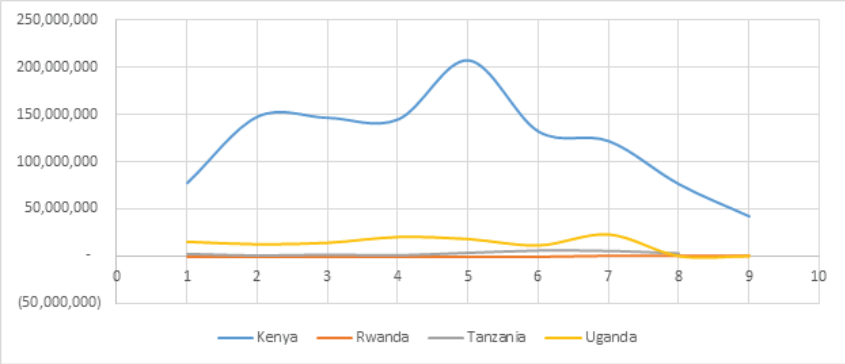


Source: World Bank, 2022

Table 11: Active TISC Institutions

Institution Type	TISC
Regulators	Uganda Registration Services Bureau, Uganda National Council for Science and Technology, Uganda Pharmaceutical Society
Universities	Mbarara University of Science and Technology, Makerere University-Main Library, Busitema University, Kyambogo University
Research Institutes	Infectious Diseases Institute, Uganda Industrial Research Institute (UIRI), National Agricultural Research Organsation Institutes (NACCRI, NAFORRI, NABUIN, MUZARDI, NALIRRI, RWEBITABA, NARL, NASARRI, NACORI, KAZARDI, ABI ZARDI, MBAZARDI, BUGIZARDI, NGETTA-ZARDI, BULINDI, NAFIRRI)

Fig. 43: Charges for the use of intellectual property, Payments (Bop, Current US$) *Source: World Bank, 2022*



However, available data shows that Uganda trails behind Kenya in the receipts for the use of intellectual property[39]. Uganda's charges for the use of intellectual property Receipts, (Bop, current US$) grew by 64.6 percent in 2012 and increased further to over 100 percent in 2013 but drastically fell by 14.3 percent in 2014. The charges again fluctuated going higher by 68.3 in 2015 but fell to 2.6 percent in 2017.

Uganda's Payments for the use of intellectual property have generally been on a plateau. Compared to Kenya, Uganda pays generally less than USD50million for the use of intellectual property products. This may point to the type of research and the quality of research collaboration being undertaken by researchers in the country.

7.4 Research Products

Over the last decade, there has been a surge in research outputs and innovation within universities and research institutes.

This is demonstrated in the increasing number of grants won both by individuals and research teams; the number of research collaborations with leading research universities worldwide evident from the increasing number of Memoranda of Understanding (MoUs) and research agreements between local universities and international partners. However, whereas the NDP III cites "import replacement/promotion of local manufacturing" as one key development strategy, the country has remained a net importer of manufactured products, including very low-skill manufactures . Total merchandise imports stood at US$ 6.2 billion in 2019, compared to US$ 0.74 billion in 2001. This shows merchandise imports have grown six-fold in the past 20 years. In 2018 Uganda imported products such as cereals (US$ 236.4m), edible fats (US$ 248.4m), Plastics (US$ 386.5m), salt (US$ 133m), sugars and confectionery (US$ 96.6m), wheat (87.5m), rice (US$ 66.6m), used clothing (US$ 60.6m), animal food (US$ 20.5m), fake hair (US$ 10.4m), fruit juices (US$ 1.5m) and straws (US$ 267,000) etc. To reverse this trend, Uganda needs to upgrade its domestic manufacturing capacity by investing heavily in technological capabilities and innovation, as well as addressing Uganda's longstanding binding constraints to manufacturing especially patient capital, energy quality and costs, and quantity & quality of raw materials, among others.

7.5 Scientific publications

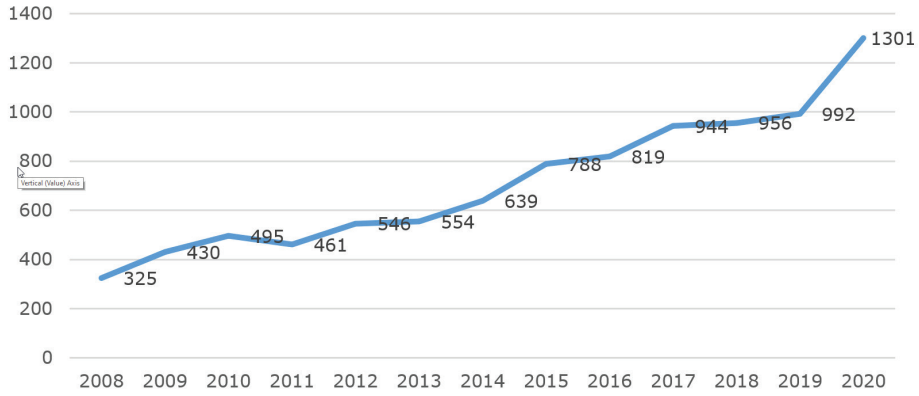
Another important indicator for characterizing the STI profile of a country is the number of published scientific and journal articles.

Health and medical sciences contribute more than 45% of the research output in Uganda followed by Agriculture and Biological Sciences at 12%. Several universities and research institutes in Uganda has increased their scientific research output. For instance, research publications at Makerere, University rose from 992 papers in 2019 to 1,301 in 2020. The highest number of research publications produced in 2020 came from the College of Health Sciences. Since 2012, Makerere University has been churning out over 500 publications annually and it has paradoxically emerged that the most prolific publishers are the non-PhD staff in medical disciplines.

Between 2020 and 2022, 738 publications were produced at Mbarara University of Science and Technology (16% of these were on COVID-19). Mbarara University of Science and Technology has

40Ggoobi, R., (2020), Import Substitution Uganda's Post-Covid-19 Industrial Policy Strategy, August 2020 . Available at https://library.fes.de/pdf-files/bueros/uganda/17015.pdf

Figure 44: Makerere University publication output 2008-2020



produced 2,053 publications from 1993 to 2022 (an average of 71 publications per year). Kyambogo University's research initiatives have yielded some results with both ongoing research and publications from the various departments. Since 2000, the university has produced over 250 research publications in refereed journals, published over 15 books, 10 book chapters and presented over 60 papers at international conferences. Web of Science and Scopus are the most authoritative global research indexing databases. Web of Science and Scopus are critical components of the current global research ecosystem, providing data for global university rankings and bibliometric analysis for global research assessments. Uganda is yet to reflect comparably on these global research platforms. A Comparative study of the coverage of African Journals in Web Science, Scopus and Cross Ref shows that Uganda has only one (1) and two (2) journals in Web of Science and Scopus respectively.

7.6 Innovations in some selected Universities

Table 12: Number of Journals production in Web of Science, Scorpus and CrossRef

Country	Web of Science				Scorpus			
	Journals		Papers		Journals		Papers	
	N	Percentage (%)	N	Percentage (%)	N	Percentage (%)	N	Percentage (%)
Nigeria	7	4.2	12,347	10.1	10	11.5	14,138	11.0
South Africa	122	73.5	30,139	24.7	108	62.1	30,796	23.9
Egypt	18	10.8	30,919	25.4	21	12.1	31,818	24.7
Kenya	2	1.2	4,468	3.7	7	4	4,4442	3.5
Uganda	1	0.6	2,572	2.1	2	1.2	2,436	1.9

Source: Asubiaro (2023)

7.6.1 Some Innovations at MUST

a. The CAMTech co-creation Lab

The Consortium for Affordable Medical Technologies (CAMTech) co-creation lab is one of the Innovation Hubs under the Centre for Innovations and Technology Transfer (CITT). The lab takes in Innovators of all disciplines that have identified gaps in their communities that they are innovating to find solutions for. The Innovators under CAMTech co-creation Lab are taken through an Acceleration program and offered incubation for their ideas for a complete process comprised of various programs from which an innovation is transformed from a simple idea to a physical prototype that is market viable. The Innovators are also given access to CAMTech resources like mentorship, scientific writing lessons, 3D Printing services, software purchase as well as Grant Proposal Writing among others. Over the years, CAMTech has produced several award winning innovations from its co-creation lab which include; PRISMS a phone application that connects patients to pediatricians, MobiCare, Sanidrop, Digital Speech Assistant, Motap among others

b. I-SOFT Demonstration Site

The I-SOFT Demonstration is one of the outputs of the Innovative

World Development Indicators Report.
Ggoobi, R., (2020), Import Substitution Uganda's Post-Covid-19 Industrial Policy Strategy, August 2020
. Available at https://library.fes.de/pdf-files/bueros/uganda/17015.pdf

Sustainable Organic Farming Techniques (I-SOFT) Project set up for agricultural organic farming techniques. I-SOFT produces bio-organic fertilizers which are processed from biowaste from animals and plants. The 100% fertilizer is processed and packaged at the site in both liquid and solid form and sold to customers in the market. There is also biogas production from bio-waste as demonstration for production of energy from a circular economy. The I-SOFT App is another brainchild of the i-SOFT Project. The I-SOFT market App seeks to develop a digital platform for directly connecting to farmers using the I-SOFT bio-organic fertilizer products as well seeking digital marketing opportunities for the products produced under I-SOFT. The Demonstration Site also produces organic products that are revenue generating projects. The site champions production of; Organic Fertilizer, Bio-gas, Organic Pesticide and Innovations by the I-Soft Club which include the I-Soft App, Mineral lake.

c. PHARMBIOTRAC Product Development Laboratories

PHARMBIOTRAC is an innovative center that accelerates the development of medicines from traditional natural herbs. The center develops, incubates and nurtures medicine from herbal products and transforms these innovations into commercial products. Among the key products from this Centre is Covidex, Liquid and Gel formulation Hand Sanitizer, locally Produced Chloroquine and Hydroxychloroquine in an effort to defeat COVID-19 pandemic in Uganda using appropriate scientific research, technologies and innovations. The Software Incubation and Innovations Unit (SIIU) has innovated and developed a number software that are used by the university as well as commercial software that are sold to the general public.

7.6.2 Some Innovations at Makerere University

a. The RAN innovation portfolio

These include: The Low-Cost Solar Irrigation Pump; Pedal Tap (a Non-Touch Water Dispensing System currently being used in several of the Kampala City Council Authority public washrooms and Mulago National Referral Hospital); The Maize thresher (a low-cost optimized post-harvest technology for mechanized threshing and winnowing of maize. It has eased labour costs among farmer groups in Nakasongola, Kasese and Hoima districts; The Solar Dryer (an ancient, express dryer that uses solar technology to facilitate faster drying of a broad range of agricultural produce retaining the food aroma, colour and nutrients. This technology has been used in Matugga a suburb in Luwero district and currently being used in parts of Kampala); Community Radio in a bucket (a technology that uses a transmitter and telephony to replace a conventional radio studio for broadcasting. This is currently serving in Northern Uganda (Oyam, Kitgum and Agago districts); Improved Push and Pull Technology: (an innovative approach to inter-cropping that dually suppresses nuisance weeds and pests. This has been tested in Eastern Uganda areas of Iganga district); Village Egg Bank (a model that encourages savings among small holder farmers. This concept thus becomes the 'currency' in the community. This 'bank currently operates in Yumbe district, West Nile region of Uganda); Matibabu (a pocket-sized hardware device that uses a beam of red-light to detect malaria parasites in blood tissues).

b. Utility Models: ICT Research

Traffic Monitoring (a traffic congestion monitoring app for developing cities, which is cheaper compared to the prevailing technology and can help users predict their traffic time); Kudu-mobile (a mobile auctions system for buying and selling agricultural produce in Uganda. The traders send a single text message and the system takes into account price, location and other factors to find the best matches); Whitefly App - an automated mobile survey technology and spatial modeling of viral cassava diseases in Uganda.

The app was tested by researchers at the National Crops Resources Research Institute (NaCRRI) and is set to boost cassava production; This work is part of the a broader programme supporting work in the Artificial Intelligence and Data Science Research Group of the School of CIT; Telecoms Data (an App to predict Infectious Disease spread in Uganda. The project involves analysis of statistics collected from telecom companies in Uganda to monitor the movement of the population in order to predict the spread of threatening infectious diseases); Mobile Laboratory Diagnostics (the App uses 3D-printed Microscope Adapters on which phones with cameras can be mounted on a microscope eyepiece.

The software then carries out image processing in order to count parasites and pathogens. Work has focused on malaria diagnosis and is expanding into identification of tuberculosis bacilli; intestinal parasites); E-Musawo Apps (a mobile app that helps to authenticate drugs, show drugs' details, identify the cheapest drugs and the nearest hospital from which people can access those drugs); MDex: (a windows phone app that uses attached external objective

lens and computer vision to diagnose sickle cell); ASKARI (a mobile security application that acknowledges the power of communication using powerful features to help keep a person safe);Ocula (an automated mobile microscopic diagnosis; a platform for carrying out microscopic tests automatically, on smart phone or note book; E-Liiso (a smart phone mobile application aimed at cheaply diagnosing trachoma of human eyes by people in rural and urban areas; Tech4farmers (a digital agricultural commodity exchange to help farmers sell produce directly to consumers or traders, negotiate for better prices while minimizing the need for middlemen and facilitating access to genuine agricultural input)

7.6.3 Some Innovations at Kyambogo University

Improved low cost baby incubator, low cost egg incubator, security robot, digital platforms; Fruity Cycle for rural peasant farmers; Screen-less Maize Mills; Motorized Groundnut Sheller and sizing; Ethanol /Bio-fuel Production for Petrol Engines; Bio-Gas production; Motorized Disabled Wheelchair; Gasification Technology; Micro-Hydro Turbines; Multifunctional Platform functioning on diesel; Bio-Multifunctional-Platform operational on Bagass; Carpentry Machines Design and Fabrication; Interlocking Block Making machines.

BOX 8: TRANSFER OF BANANA TISSUE CULTURE TECHNOLOGY TO SMALL-SCALE FARMER

Since 2006, Agro-genetic Technologies Ltd. (AGT) has set out to commercialize agro-biotechnologies to increase yield, reduce spread of diseases and improve farmers' income. Kawanda Agricultural Research Institute (KARI) being the only source of tissue cultured planting materials in Uganda, has led to an insufficient supply and unavailability of quality planting material to farmers throughout the country. The laboratory mainly produces banana plants, but also produces planting material for other crop like coffee, pineapples, etc. The company's activity also involves the transfer of modern agricultural techniques and practices through organized training for farmers. AGT first established a laboratory (with a production capacity of 1 million plantlets) and related nurseries. It then worked on developing awareness of the new tissue culture technology among farmers, notably by creating partnerships with local and international NGOs and Government agricultural organizations. Once awareness among farmers increased, AGT then established distribution centers in farming communities, as a way to bring the technology closer to farmers (the laboratory itself is based in Kampala). Demonstration gardens were then set up to train farmers in modern agronomic practices. In 2006, AGT opened the biggest tissue culture laboratory in Eastern and Central Africa, with a production capacity up to 8 million plantlets per annum. It is the only Ugandan company commercializing agro-biotechnology research to farmers. Furthermore, AGT has set up 15 banana nurseries and demonstration gardens for distribution purposes.

Technologies transferred & recommendations adopted

Technology transfer, also called transfer of technology (TOT), is the process of transferring (disseminating) technology from the places / groups of its origin to a wider audience among more people and places. It occurs along various axes: among universities, from universities to businesses, from large businesses to smaller ones, from governments to businesses, across borders, both formally and informally, and both openly and surreptitiously. It often occurs by concerted efforts to share skills, knowledge, technologies, methods of manufacturing, samples of manufacturing, and facilities among governments / universities / other institutions to ensure that scientific and technological developments are accessible to a wider range of users who can then further develop and exploit the technology into new products, processes, applications, materials, or services.

There were several barriers faced by institutions during technology transfer processes such as; poor linkage between R&D sections and the industry, lack of trained staff for technology transfer, lack of funds and inputs, low priority given due to not being included in institutional mandate, unwillingness of investors, etc.

The National Science, Technology and Innovation Plan highlights technology transfer as the "weak link in the technology development chain". Uganda scores 3.6/7 for university-industry collaborations according to the World Economic

Table 13. Some selected indicators of Technology Transfer

Component	Indicator	Value
National users of research	Firm Level technology absorption	4/7
	Government procurement of Technology products	3.5/7
	FDI and Technology Transfer	4.2/7
Knowledge exchange support and administration	University- industry collaboration (score)	3.6/7
	University- industry collaboration (ranking)	52/137
	Quality of incentives for research diffusion	Below average

Source: SRIA 2019

Forum, despite having put in place an institutional set up dedicated to knowledge exchange and technology transfer. Many research organisations and Universities lack technology transfer offices and often operate in isolation from the government and other in universities. As shown in Table… below, university –industry linkages remain weak.

However, as shown in BOX 5, there are strong signals of emerging technology transfer platforms arising from private-sector led research.

Source: SRIA (2019), Assessing the needs of the research system in Uganda. SRIA paper available at https://assets.publishing.service.gov.uk/media/5ef4adad86650c129b9af059/NA_report_Uganda__Dec_2019_Heart_.pdf

Some Made-in-Uganda Products

The year 2020 was another year of many events for science, technology and innovation in Uganda. It was marked by several innovations by Ugandans who braved the challenges of living and working in Uganda to put world class innovations.

The Vein Locator is a device that uses light emitting diodes for locating veins for cannulation (IV) in pediatric patients. The vein locator uses red light absorption by deoxy-hemoglobin within the patient's vein, allowing the veins to show up more clearly on the patient's skin.; Improving the safety of intravenous cannulation among patients requiring emergency care is a big challenge that has been neglected. It is a challenge both in adults but more specifically in children.
Dr Mubiru believes that having the device in hospitals and clinics will cut down on critical treatment time by getting medication administered quickly, reduce tissue trauma from multiple needle insertions, and greatly help children with collapsed or barely visible veins. While it was designed with children in mind, it works on patients of all ages.

In 2020, The Ventilator Project undertaken by Makerere University acting through the Resilient Africa Network and Kiira Motors Corporation developed a low-cost medical ventilator to support the management of Acute Respiratory Distress Syndrome caused by the coronavirus among other medical complications.

Nineteen children die per 1,000 live births in Uganda; Of these, 30 per 100 die in rural areas, while in urban areas, 31 die per 1000 live births. The main cause of death are asphyxia (lack of oxygen), prematurity and sepsis (infections) A total of 76,000 babies have been saved under prototype for mass production.

Device that can ensure the safe administration of intravenous fluids and drugs to children under the age of five. Uses gravity flow as opposed to a pumping mechanism that imported infusion sets use. Gravity-feed infusion set is operated using batteries which makes it more reliable for the Ugandan situation where power-cuts are common

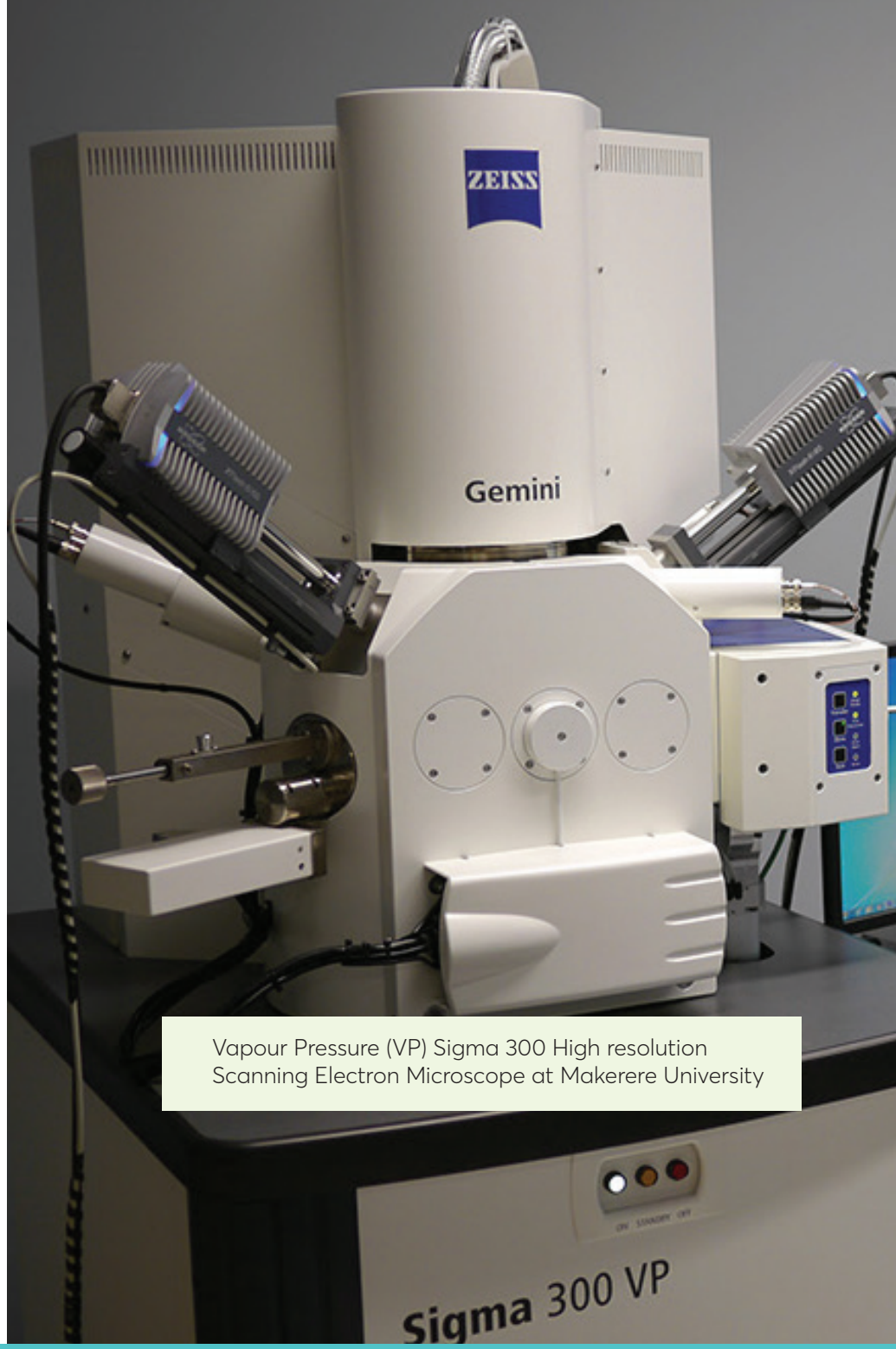
Paper-strip test used in detecting Ebola and Marburg viruses. The STDS-Agx (swab tube dipstick agglutination) COVID-19 test kit can produce results in a minute of two, compared to the four-to-six hours it takes to get results from the German and Chinese kits now in wide use.

Of the 216 million malaria cases worldwide in 2016, 445 000 were fatal. 90% of these cases were in Africa. The device is capable of diagnosing malaria without drawing any blood. Device received international recognition after winning the Royal Academy of Engineering's Africa Prize in June 2018. Uses magnetism and light to diagnose the disease. Unlike regular tests that work by detecting molecules produced by the malaria parasite, Matibabu works by shining a beam of light onto a person's finger to detect changes in red blood cells that could result from malaria infection. These results are then sent to a cell phone within two minutes.

COVIDEX® is a prepared plant extract of Zanthoxylum and Warbugia species that is reported to have antiviral agents, one of which berberine with in vitro activity against SARS COV-2, the causative agent for COVID-19 disease. Others constituents in COVIDEX include alkaloids, sponins, reducing sugars and acidic compounds. The research for this product was undertaken at Mbarara University of Science and Technology

The International University of East Africa, in partnership with Clean Air Initiative Africa and with support from the United Nations, is set to produce electric motorcycles. The motorcycles are expected to reduce gas emissions, which cause pollution.

Ticks are among the most important vectors of pathogens that cause some of the most devastating tick-borne diseases (TBDs) in the livestock sector in eastern Africa, resulting in loss of productivity and mortalities. Ticks and tick-borne diseases cause an economic loss of shs3.8 trillion annually to Uganda. The anti-tick vaccine will significantly reduce this loss. Uganda will save USD 83.3 million in forex (Approximately Shs 315 billion) which it incurs from importing about 378,000 liters of acaricides and 83,000 liters of associated drugs



Vapour Pressure (VP) Sigma 300 High resolution Scanning Electron Microscope at Makerere University

8. Research Infrastructure:

Introduction

Researchers often require advanced tools and infrastructure in order to conduct world class research activity.

Research Infrastructures (RIs) are facilities that provide resources and services for the research communities to conduct research and foster innovation in their fields. This infrastructure encompasses a wide range and variety of facilities, tools, resources and services that enable researchers in public and private institutions to achieve excellence in research and innovation. They are critical enablers in knowledge production, acquisition, adaptation, diffusion and commercialization. These include: major equipment or sets of instruments, knowledge-related facilities such as collections, archives or scientific data infrastructures, computing systems and communication networks, databases, research facilities, biobanks and large-scale computational tools, among others. Research infrastructures constitute the bedrock and foundation of a vibrant research, technology and innovation system. Good RIs is needed by research universities to train top-notch professionals in almost all areas. The absence of many Ugandan universities in the top 100 research universities in Africa is largely due to limited RI which affects both research and teaching environment and performance on which such rankings are based. Research Infrastructure affects training at all levels and more so in technologically demanding and newly emerging fields.

8.2 Digital Infrastructure

In a growing global knowledge ecosystem, the propensity to undertake research is inevitably shaped by the quality of digital infrastructure available to researchers. Uganda scores poorly on different global ICT indices. The primary reason for being ranked 152 out of 176 countries in the International Telecommunications Union's IDI; 121 out of 139 countries in the Network Readiness Index; and 64 out of 75 countries in the latest Economist Intelligence Unit (EIU) Inclusive Internet Index (3i), is the poor information infrastructure and low levels of Internet penetration in the country . Although over half the population has access to mobile services, only a sixth has access to the Internet. The Government of Uganda is implementing the National Data Transmission Backbone Infrastructure and e-Government Infrastructure (NBI/EGI) Project which aims at improving and retooling Uganda's ICT knowledge base through the establishment of robust ultra-high-speed, pervasive, and intelligent ICT infrastructure. This project is consistent with Vision 2040 that seeks to improve the availability of digital content and e-products; to provide automated government processes and inter-agency connectivity; to bridge the gap between industry and academia; and to enhance the commercialization of research and development. Currently, seven (7) Public Universities have been connected to the NBI to enable access to high speed Internet connectivity and facilitate e-learning and research. These are; Gulu University, Mbarara University, Kyambogo University, Busitema University, Makerere University Business School (MUBS) and Uganda Management Institute (UMI). Several projects have been undertaken under the Industry 4.0+ value chain as shown in Table 13.

Table 14: Mobility 4.0+ Supported Projects

Project	Institution
Yo Waste –a mobile and cloud-based hauler and garbage collection service app	Yo-Waste Limited
KAWU Financial Platform	Lira University
V-CHEMLAB – a virtual chemistry laboratory simulator	Kabale University

8.3 Research Infrastructure by Institution

The aspiration of Agenda 2030 is to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation by 2030 (SDG 9).

41Gillwald, A., Mothobi, O., Ndiwalana, A., and Tusubira, T.., (2019), The State of ICT In Uganda, Policy Paper Series No. 5 After Access: Paper No. 8. Available at https://researchictafrica.net/wp/wp-content/uploads/2019/05/2019_After-Access-The-State-of-ICT-in-Uganda.pdf

Similarly, Agenda 2063 (Goal 10) aspiration is to put in place the necessary infrastructure to support Africa's accelerated integration and growth, technological transformation, trade and development. Relatedly, infrastructure is the first of the five pillars in the EAC Vision 2050 that seeks to ensure access to modern, fast and affordable infrastructure that is essential for economic development and wellbeing of the population. Additionally, the Uganda Vision 2040 aims to have access to world class infrastructure and services, and modern technology to improve productivity and production. Currently, no audit has been undertaken on the specific research infrastructure in Uganda. Reports by the National Council for Higher Education show that research infrastructure is limited owing to the increasing student enrollments without commiserate investment in such critical infrastructure. The available research infrastructure has been largely provided by foreign collaborators. For instance, under the Africa Center of Excellence in Materials Product Development and Nanotechnology (MAPRONANO ACE), the College of Engineering, Design, Art and Technology (CEDAT), Makerere University acquired a state of the art Vapour Pressure (VP) Sigma 300 High resolution Scanning Electron Microscope for nanomaterial's characterization.

BOX 9: SPECIALIZED MODERN STATE OF THE ART LABORATORIES AT THE COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES (CAES), MAKERERE UNIVERSITY

The College has specialized modern state of the art laboratories that support teaching and learning. The specialized laboratories include: the Remote Sensing/GIS, Genetics/ Molecular Biology Laboratories, the Biotechnology Laboratory, Tissue Culture Laboratory, Genomics Laboratory(RNA and DNA), Proteomics capacities laboratories, Quarantine laboratories, and Green houses, Gene-bank and ex-situ conservation facilities in Kampala. The college also has Research institutes, centres and field stations used for field courses, practical training including Land for field research and seed multiplication. The college has a total of 19 Research laboratories (12 in School of Agricultural Sciences (SAS), 5 in the School of Forestry, Environment and Geographical Sciences (SFEGS and 2 in School of Food Technology, Nutrition and BioEngineering (SFTNB); 14 Teaching laboratories (7 in SAS, 4 in the SFEGS and 3 in SFTNB); 410 Computers (150 in SAS, 180 in the SFEGS and 80 in SFTNB) and total office space of 114 (77 in SAS, 15 in the SFEGS and 22 in SFTNB)

This is the first of its kind equipment in Sub-Saharan Africa for nanotechnology research. The VP Sigma 300 Scanning Electron Microscope can be used for Minerals identification, size measurements of micron and nanosized materials, determining the morphology of biological specimens (structural biology), nanoparticle analysis and detection, drug research (testing new vaccines and medicines), drug discovery and identification of new pathogens (Viruses, bacteria & fungi),Tissue imaging such as Cancer Imaging, device testing and characterization, pharmaceutical quality control, forensic science, toxins identification; Determining the crystallographic structure of specimens (topology, morphology and composition),Materials science research, detection/ elemental analysis and cathodoluminescence microscopy (CL); Quality control and failure analysis, reliable performance of semiconductors; Effectiveness of new production and fabrication methods. The equipment is also accessible to industry and regional partners.

42Rothaermel, F. T.; Agung, S. D.; Jiang, L. (2007-08-01). "University entrepreneurship: a taxonomy of the literature". Industrial and Corporate Change. 16 (4): 691–791. doi:10.1093/icc/dtm023. ISSN 0960-6491.
43Research universities are mainly responsible for offering research-oriented programmes in an academic setting.
44Susan Karungi, S., and Ntambirweki, B., (2013), Institutional Technology Transfer Policies and Strategies in East Africa: Lessons from Universities and R&D Institutions in Uganda. Background Paper for ACODE, 2013.

BOX 10: EDUROAM SYSTEM IMPLEMENTED BY RENU

The Research and Education Network of Uganda (RENU) launched the Metro Eduroam in 2020, the first deployment of its kind in Africa to make it possible for students, university staff and researchers to access free, secure and trusted wireless Internet connectivity while they work off-campus. Users from institutions that are signed up for Eduroam are able to use their institutional details to access Eduroam hotspots in over 500 locations within Kampala, Wakiso and Mukono at no cost. The Eduroam benefits of students and staff ciao connecting 61 educational institutions from 42 service locations. Since the launch of Metro Eduroam, 609,916 successful logins have been registered, out of which 1,556 are unique with the average daily peak traffic being 33.37 Mbps. More recently in 2022, RENU introduced Eduroam on the Go, a pocket-size routing device specially made to enable researchers and university staff connect to Eduroam and the Internet Anytime, anywhere. This means that for the first time, Eduroam users do not have to access the free WiFi from only a few fixed locations.

Table 15: Infrastructure Innovations Supported Projects *Source: STI-OP*

Project	Institution Project
Direct Production Technology for metallization of Ugandan Iron Ore	Makerere University
Recycling of plastic waste into interlocking blocks	Mbarara University of Science and Technology
Eco-beneficiation of gold ore by substituting mercury with cassava in artisanal gold mining	Uganda Martyrs University
Harnessing gravitational potential energy for domestic and precision agriculture apps	Gulu University
Design and fabrication of a continuous flow reactor for production of bio-diesel from locally available waste	Makerere University
MakSol Cooker: Smart solar electric cookers; production, scale-up and commercialization	Makerere University
The Parish Level Night – a day solar crop dryer and 30-tonne silo storage system	Busitema University
Development of Iron Oxide Nanoparticles from steel waste for applications in water treatment	Makerere University
Bio-electricity production for wastewater treatment and soil fertility enhancement	Gulu University
Valorization of cassava peels into nano- absorbents for wastewater treatment in Uganda	Makerere University

8.4 Regional distribution of Research Infrastructure

The distribution of research infrastructure is invariably shaped by the location of research-performing entities like universities and research institutes.

Currently, most of the research Uganda has one of the lowest (14%) Internet penetration rates compared to other countries like Ghana, Kenya, Lesotho, Nigeria, Senegal, South Africa, and even Tanzania. Moreover, Uganda has a huge urban–rural gap in internet use of 70 percent, where only nine percent of Ugandans living in rural areas have access to the Internet and about a third (30%) of urban area dwellers using it. The lack of electricity and underdeveloped ICT infrastructure are the primary causes of huge discrepancies in urban–rural Internet use and mobile phone penetration rates in Uganda. Only 18 percent of households in Uganda have an electricity connection, with an urban– rural electricity gap of 85 percent. Half of those who do not use the Internet (86% of the total population) have no Internet-enabled devices

such as computers and smartphones. Uganda has the second-lowest smartphone device ownership in the countries surveyed at 16 percent of the total number of mobile phone users, with only Rwanda's nine percent performing worse. Other than poor supply-side factors, human development factors are also a cause of concern in Uganda. Just over one-third (36%) of non-Internet users are digitally illiterate, 23 percent stating that they do not know how to use the Internet and 13 percent gave a negative assessment about their need of the Internet. As such, there is an over-concentration of research infrastructure in urban areas owing to those structural realities. Moreover, there are limited opportunities for sharing of research equipment as this has not been embraced as a standard practice for a more inclusive research outlook.

8.4.1 Distribution of Research and Satellite Centers

Research in Uganda is conducted across different universities, research institutes and centers of excellence.

Some of the universities have developed their own research centres that undertake research on specific problems. Makerere has the Makerere University Agricultural Research Institute Kabanyolo (MUARIK), Budongo Forest Reserve and Research Centre, Buyana Stock Farm and Nakyesasa Farm, Kasangati Health Centre, Demographic Surveillance Site Mayuge and the Resilient Africa Network (RAN Lab). Other Centres have been established within different departments at the different universities. For instance, the Afri Child Centre at the College of Humanities and Social Sciences was set up to improve child protection practice and inform policy through research, analysis and knowledge development.

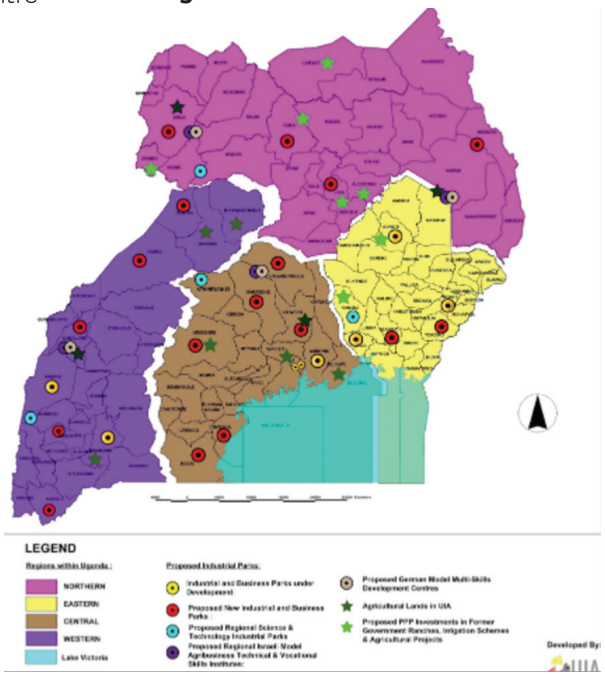
8.4.2 Centres of Excellence

Under the African Centres of Excellence (ACE) funded by the World Bank, five centres of excellence have been established.

The Makerere University Regional Centre of Excellence for Crop Improvement (MaRCCI) which was established to meet the demand for skills required for Africa's development in areas such as agriculture, energy, extractive industries, etc.; Centre of Materials, Product Development & Nanotechnology (MAPRONANO) (CEDAT) which focuses on value addition of raw materials for the explicit purpose of enabling industries in the Great Lakes region develop products that are of high quality and of internationally accepted standards; The Makerere University Climate Change Research and Innovations (MUCCRI) Centre which was established to generate and disseminate innovations for climate change mitigation and adaptation in agricultural sciences and natural resources sectors; The Plant Breeding, Biotechnology and Seed systems Research Centre (CAES): was identified to serve as a focal node for training in the above areas for the region. The Centre in partnership with a private biotechnology company (Agro-technologies Uganda Limited) is developing and distributing disease-free tissue culture banana; The Centre for Soybean Improvement and Development which was established in 2016 to look at different innovations in soybean. A pilot plant for human vaccine manufacturing to facilitate the clinical trials is under construction. The Good Manufacturing Practice (GMP) facility is the first end-end vaccine manufacturing line in Uganda.

The President opening the Alfasan Vaccine Manufacturing Plant

Fig.45: Distribution of Science Parks



Other centers include the East African Centre for Renewable Energy and Energy Efficiency (EACREEE) launched in June 2016 to contribute towards increased access to modern, affordable and reliable energy services, energy security and mitigation of negative externalities of the energy system (e.g. local pollution and Green House Gas emissions) by creating an enabling environment for renewable energy and energy efficiency markets and investments. The East African Oncology Centre of Excellence under the Uganda Cancer Institute was launched in 2016 to train specialized pediatricians and related health staff in paediatric haematology and oncology. The Food Technology & Business Incubation Centre (FTBIC) under the School of Food Technology, Nutrition and Bio-engineering (CAES) is the first University-based technology and business incubator in the East and Central African Region. The Centre for Research in Transportation Technologies [CRTT] produced the famous Kiira EV and the Kayoola Solar Bus; The Centre for Technology Design and Development (CTDD) is committed towards commercialization of two projects, i.e. the solar food drier and the collapsible bodaboda helmet. The Centre for Research in Energy and Energy Conservation (CREEC) has enhanced access to modern types of energy through applied research, training and consultancy within Uganda and the East African region. and is working with the Ministry of Energy (the Rural Electrification Project) to extend the usage of solar to rural communities and reduce the usage of candles and fuel lamps. Centre for Tobacco Control in Africa (CTCA) was established in July 2011 by the World Health Organisation to provide technical and institutional support to governments in Africa with policy formulation, legislation and enforcement of tobacco control. It also helps to build and sustain the institutional capacity for tobacco control.

8.5 Research Infrastructure and Facilities

8.5.1 Incubation Centers

According to the NDP III, Uganda has not adequately prepared to use STI to industrialize.

This is because; i) there are no formal mechanisms put in place to facilitate technology transfer; ii) the country's budget allocation to STI is currently very small; iii) the country is yet to establish any incubation and technology parks to facilitate innovation and technology development; and iv) there are no formal established mechanisms linking universities and research institutions with industry to facilitation development and commercialization of new innovations. Under NDP III Programme 18 – Innovation, Technology Development and Transfer Programme (ITDTP), all agencies within STI are towards developing requisite STI infrastructure; building human resource capacity in STI, strengthen Research and Development capacities and applications and increase development, transfer, and adoption of appropriate technologies and innovations.

8.5.2 Industrial Parks

The Government of Uganda, through the Uganda Investment Authority (UIA) plans to establish twenty-seven (27) industrial parks, including four (4) regional science and technology industrial parks making a total of 31. The completion of these industrial parks will add value to locally available raw materials thus boosting the agricultural and mineral sectors. Currently, there are three Government-owned industrial parks within the Kampala-Mukono region. These include the Kampala Industrial and Business Park (KIBP), Namanve, Luzira Industrial and Bweyogerere Industrial Parks.

8.5.3 Technology transfer offices

Technology Transfer Offices (TTOs) established by universities can provide business models and explore local partnerships (e.g., venture capital, entrepreneurs, firms) to commercialize innovations and generate revenue.

Sometimes called Technology licensing offices (TLOs), these offices are responsible for technology transfer and other aspects of the commercialization of research that takes place in a university.

TTOs engage in a variety of commercial activities that are meant to facilitate the process of bringing research developments to market, often acting as a channel between academia and industry . Most major research universities have established TTOs in the past decades in an effort to increase the impact of university research and provide opportunities for financial gain. Uganda does not have a research university. Currently, whereas Universities & R&D Institutions in Uganda have developed university plans, policies on research, innovation and IP management, most of them do not have explicit policies on TT. Institutions mainly use informal mechanisms and practices for transfer technology with the main object of learning and community development and less focus on commercialization .

Table 16: Technology Transfer in Selected Universities and Research Institutes

Institution	Technology Transfer Mechanism
Mbarara University of Science and Technology	Centre For Innovation and Technology Transfer (CITT)
Makerere University	The Directorate of Research and Graduate Training (DRGT) in liaison with the Directorate of Legal Affairs (DLA) is in charge of all Intellectual Property (IP) and Patenting activities
Uganda Industrial Research Institute	Technology Development Centre
National Agriculture Research Organization	Intellectual Property Management Committee
Makerere University (College of Engineering)	Center for Technology Design and Development

Table 17: Active TISC Institutions

Regulators	Uganda Registration Services Bureau
	Uganda National Council for Science and Technology
Universities	Uganda Pharmaceutical Society
	Mbarara University of Science and Technology
	Makerere University , Main Library
	Busitema University
	Kyambogo University
Research Institutes	Infectious Diseases Institute
	Uganda Industrial Research Institute
	NACCRI (NARO)
	NAFORRI(NARO)
	NABUIN(NARO)
	MUZARDI(NARO)
	NALIRRI(NARO)
	RWEBITABA (NARO)
	NARL(NARO)
	NASARRI(NARO)
	NACORI(NARO)
	KAZARDI(NARO)
	ABI ZARDI(NARO)
	MBAZARDI(NARO)
	BUGIZARDI(NARO)
	NGETTA ZARDI(NARO)
	BULINDI (NARO)
	NAFIRRI(NARO)

8.5.4 Research Repositories

Institutional repositories are an increasingly significant component in the provision of academic publication and information resources. They are being developed throughout the world as a consequence of the availability of scholarly resources in digital formats, and in response to Open Access policies and mandates. Several universities and research institutions in Uganda have digital repositories for the storage of outputs from research undertaken. Some of them are either open access, closed access or a hybrid. Content on these repositories includes research papers, working papers, reports, datasets, and other digital objects resulting from research. As shown below, Uganda

Research repositories provide an indication of the level of openness of the intellectual collections aimed at promoting the practice of open science in the institutions. The paradigm towards a notion of Open science is increasingly bridging the divide between researchers from the global north with their counterparts in the global south. As shown below, most private and public universities in Uganda do not have these knowledge platforms which can aid the visibility of their research activity. A third of public universities in Uganda have repositories while only 13% of private universities have developed this vital research infrastructure.

Fig.46: Number of Research Repositories across Africa

Source: Bezuidenhout et al (2020)

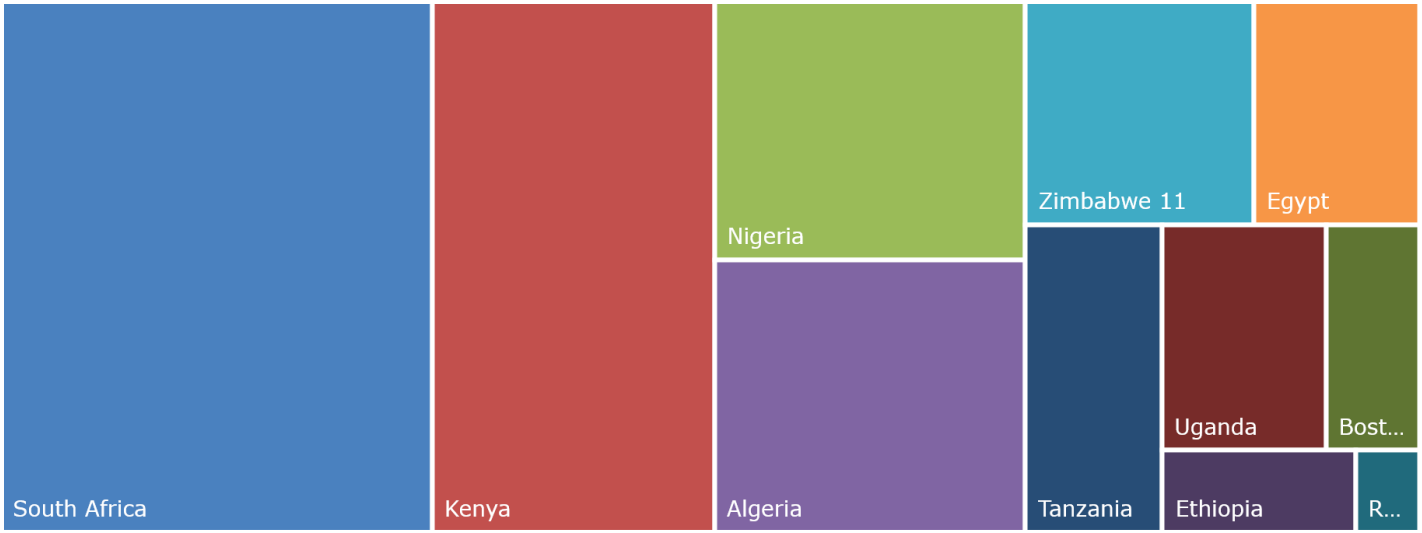
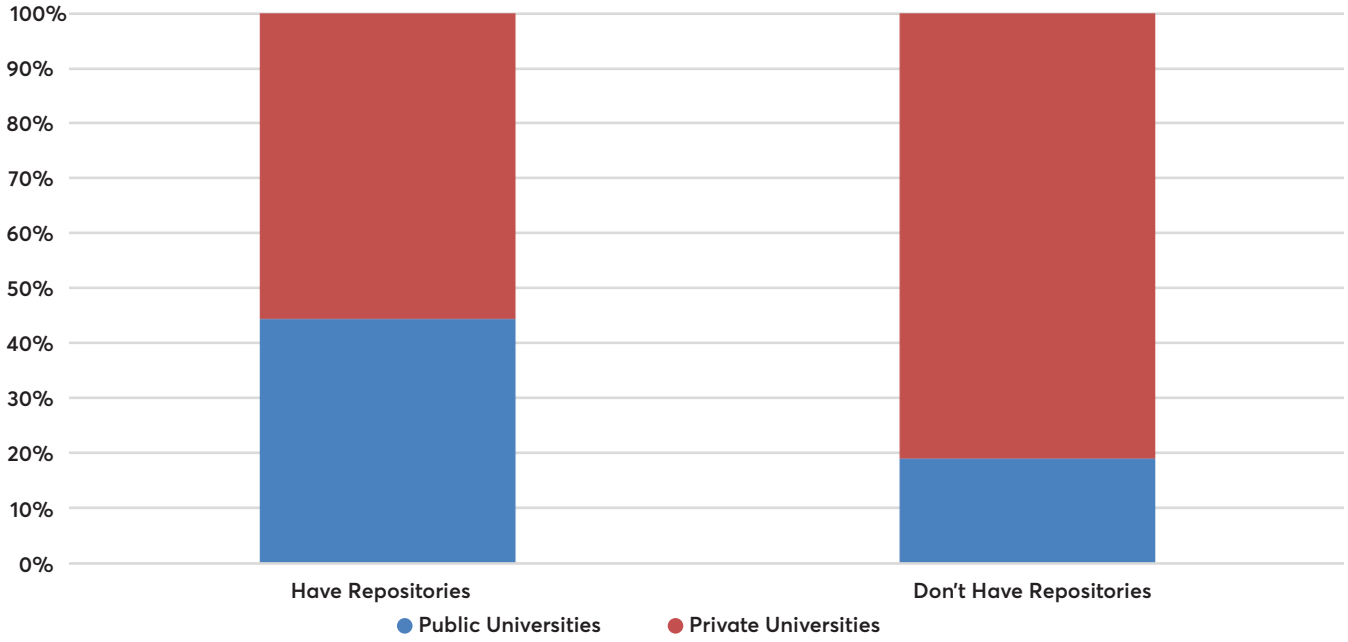


Fig.47: Research Repositories in Public and Private Universities in Uganda



BOX 11: THE NATIONAL RESEARCH REPOSITORY OF UGANDA AT UNCST

National Research Repository of Uganda (NRRU) is a repository system managed and maintained by the Uganda National Council for Science and Technology (UNCST). Hosted on DSpace, the Repository captures, preserves and distributes Uganda's intellectual output. The NRRU serves as a resource for data, working papers, teaching materials, bulletins, as well as peer-reviewed articles. It is envisaged that the NRRU can showcase national research content, including: Electronic (digitized) books, Electronic Journals, Electronic newspapers, Government Publications, Images, Audio and Video files, Digital manuscripts, Web resources & Content Archive, Databases / Research repositories from Universities and Research Institutes, Documents (e.g. articles, preprints, working papers, technical reports, conference papers), Books, Theses and dissertations, Data sets, Computer programs, Visualizations, simulations, and other models, Multimedia publications, Learning objects. The NRRU is being developed with engagement with other research regulators and research facilitators in Uganda's knowledge system. Fully optimising the practicability of this platform will demand for policy reforms within institutional knowledge management systems and the broader national policies on Open Science, including Open Access and Open Data imperatives.

BOX 12: SHARING RESEARCH INFRASTRUCTURE: THE CASE OF THE UNCST NSTEI-SEP PROJECT

The UNCST has established the National Science, Technology, Engineering and Innovation Centre (NSTEIC) and the Technology and Business Incubation Centre (TIBIC) as well as the Manufacturing Machining and Skills Production Centre. This innovation infrastructure will provide workspaces, incubation facilities, analytical laboratories and other common user facilities that will enhance the ability of innovators who receive funding from the fund and from elsewhere to rapidly commercialize their technologies, processes and other innovations.

8.5.5 Access to Research Infrastructure

Scientific infrastructure is the foundation of research and innovation and facilitating its availability, accessibility and sharing needs to become a key goal, particularly for countries like Uganda with limited resources. Over 90% of the high-end research equipment to Uganda is imported and not shared among the research community. Currently, there is no policy framework to facilitate sharing of research infrastructure. Even publicly-funded scientific research infrastructure is often not made available to other researchers due to the absence of modalities for access and optimal use by the research communities. For instance, researchers from smaller research centers or universities are not able to access expensive research infrastructure at state-funded institutions or other facilities.

8.6 Conclusion

Enhancing the potential of research infrastructures to support scientific advance and innovation, and to enable open and excellent science should be an aspiration of Uganda's STI Policy. The establishment of National Scientific Research Infrastructure Sharing and Maintenance guidelines will ensure researchers from the smaller research institutions get access to cutting-edge equipment. Such guidelines can reduce fragmentation of the research and innovation ecosystem, avoid duplication of effort, better coordinate the development and use of Research Infrastructures, establish strategies for well-established inter-institutional research that can respond to global challenges and/or foster combining skills, data and efforts of the Uganda's best scientists. Such a policy will also foster the innovation potential of RIs by making industry more aware of opportunities for product development and other opportunities for knowledge co-creation and transfer. Other public research institutes can be incentivized to share or provide access to their research infrastructure through the

establishment of grants subsidies and other such incentives. There is also need to promote the domestic instrumentation industry by encouraging universities and R&D-performing institutions to set up start-ups that manufacture research instruments and also develop the workforce for its maintenance. Technology transfer processes require greater policy support in order for Uganda to realize its development aspirations and commitments to Agenda 2030. Institutions mandated to engage in technology transfer processes (e.g. Universities) should allocate more funding towards technology transfer, embedded in products and services in order to achieve notable commercial results in the national market.

9. Research Governance:

Introduction

Research governance is a process for ensuring the quality of research, and for protecting the rights, dignity, safety and wellbeing of those involved.

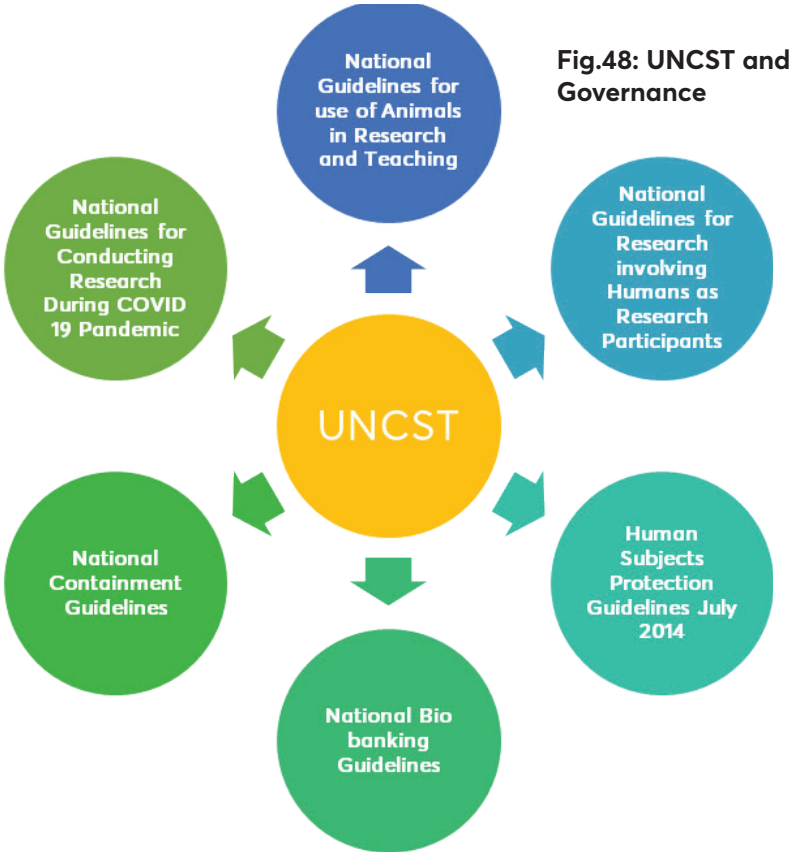


Fig.48: UNCST and Research Governance

It includes the systems, processes, regulations and frameworks that facilitate the proper conduct of research. The roles that various actors in the innovation system play, the rules that govern the actors, and the process by which decisions concerning research are made, intrinsically determine Uganda's readiness to engage in an increasingly interwoven global knowledge system. Uganda's research governance framework was birthed in 1970 with the establishment of the National Research Council (NRC). Later on, this gave rise to the establishment of the Uganda National Council for Science and Technology by an Act of parliament. An effective research governance structure depends on leadership, coordination and adequate resourcing for all STI activities within the national system of innovation. To enhance the effective coordination, direction and management of research activities in Uganda, it is essential to strengthen the institutions and governance structures required to provide sound administration and quality leadership at all levels of government. Good governance creates a platform for inclusiveness, ownership and sustainability and inter-agency collaboration among key actors and stakeholders.

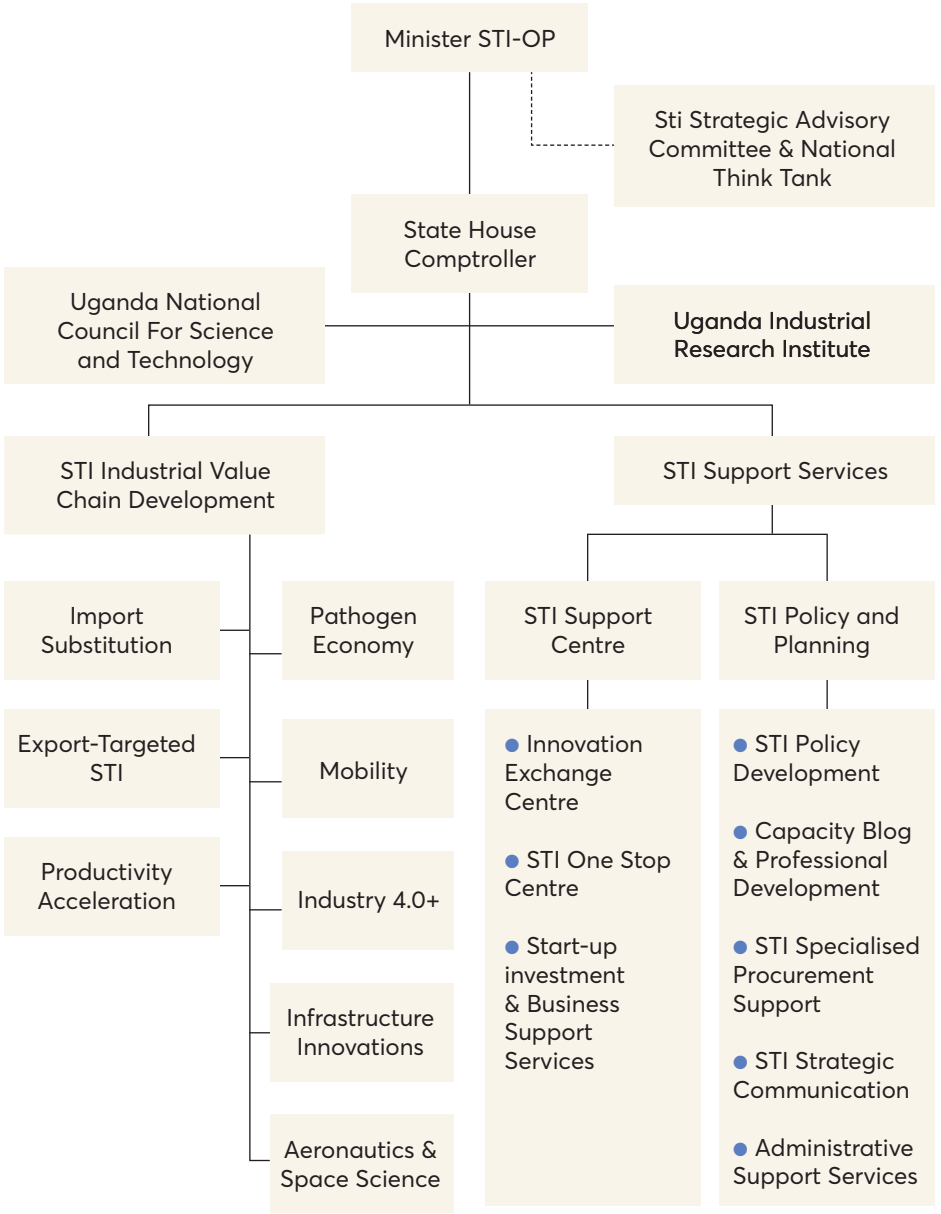
9.1 Current Status of Research Governance

Uganda's research landscape is multifaceted and characterized by variety of institutions and entities ranging from Ministries Departments and Agencies, Universities and research institutes, private sector actors, NGOs, foreign collaborators, independent consultants, among others. Most research is undertaken under different institutional policies, guidelines or frameworks. Over the last two years, new structural reforms within Uganda's STI sector have strengthened UNCST as a regulator of all aspects of STI in Uganda with the added mandates of: monitoring and evaluation of the STI activities and their compliance to STI regulations; homing of science professional institutions and continuing professional development; and translating STI policies into regulations and standards to guide the operations of the entire STI system. The Council is structurally under the STI Secretariat within the Office of the President as shown. The regulation of research is undertaken within this broader outlook. It is expected that this new structure should give the UNCST a stronger regulatory purview to ensure that research regulations are developed and complied with in line with international best-practice.

9.2 Research Ethics in Uganda

Over the past two decades, Uganda has experienced a significant

Fig. 49: Organogram of the STI System in Uganda



increase in clinical research driven by both academia and industry. This has been combined with a broader spectrum of research proposals, with respect to methodologies and types of intervention that need evaluation by Research Ethics Committees (RECs). Currently, Uganda has thirty-three (33) RECs spread across different universities and research institutes. However, the spread of their activities is still limited. As shown in the map, the RECs are concentrated within the institutions in the central region. Data at UNCST shows that the five busiest RECs (by number of applications) are Mbarara University of Science and Technology, Makerere University School of Social Sciences, Makerere University School of Public Health, Mild May Uganda and the Makerere University School of Medicine. Only six (6) private universities have a REC. Limited funding and capacity constraints limit the UNCST's ability to support the establishment of RECs across most of the universities and research institutes. The absence of RECs in these research institutions presents a danger to Uganda's research system and limits the propensity for research excellence and quality assurance.

Nevertheless, the institutions that have active RECs have been performing excellently, largely through the support of the UNCST. As shown below, most of the RECs have a performance work-rate (the number of submissions and finally approved) of greater than 83%. Only two RECs have less than a 50% work-rate.

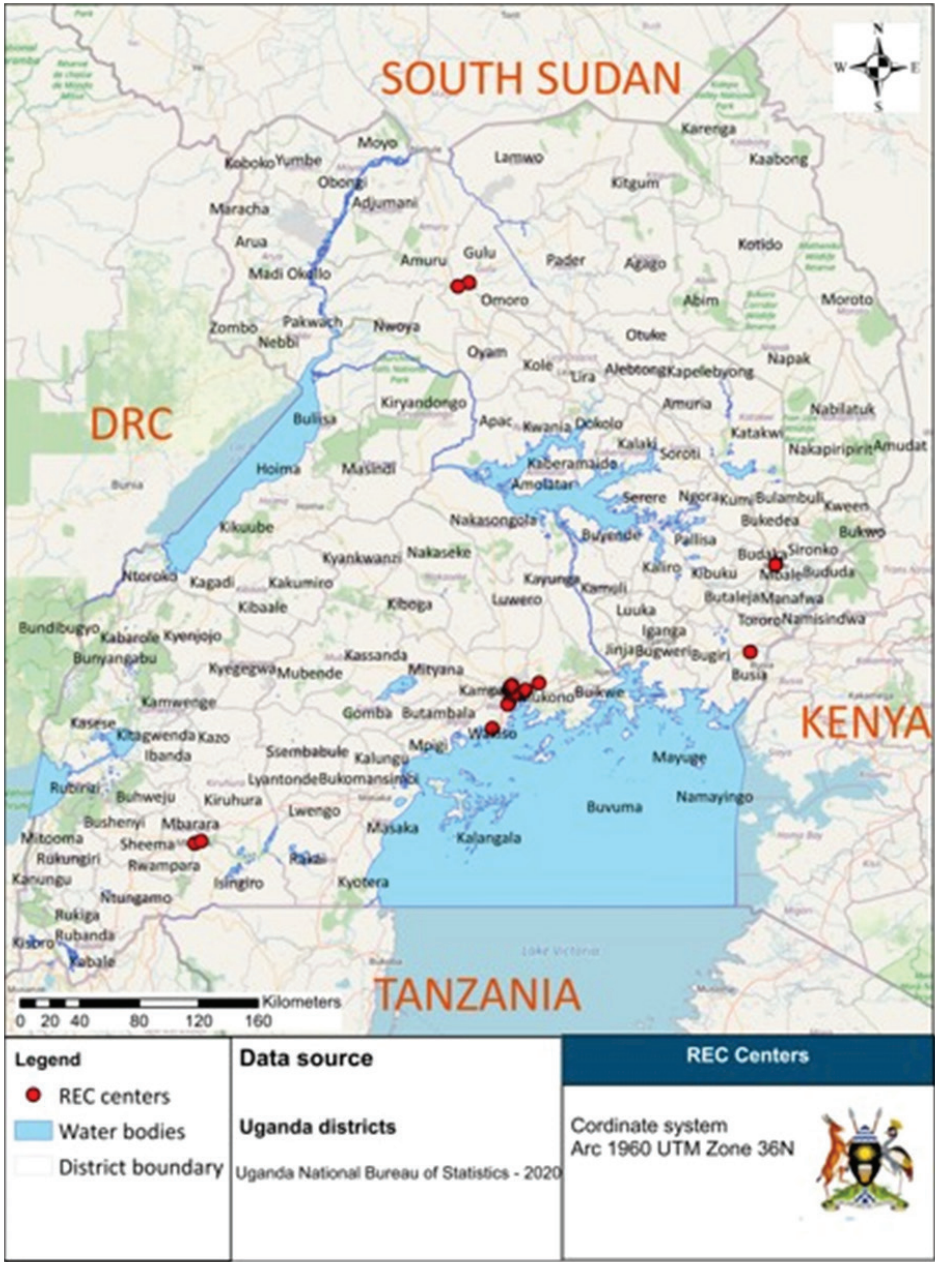
9.3 Research Registration

Analysis of research records show that submission of research protocols to UNCST since 2016 has been on the increase (from about 500 in 2016 to more than 1000 in 2022). And it is the same trend of increase for protocols renewal. UNCST registers research and categorizes them into either Agricultural Sciences; Engineering and Technology; Humanities; Information & Communication Sciences; Medical and Health Sciences; Natural Sciences; Physical Sciences and Social Sciences. Over the period 2016-2022, the records of UNCST research registration show that most of the research conducted are in the field of Medical and Health Sciences Social Sciences at (2418) and (1414) respectively. This total of 3,832 for both Medical, Health Sciences and Social Sciences contributes up to 86% of the entire research conducted in Uganda. It's also worth noting that there is no research conducted in the fields of Humanities; Information & Communication Sciences and Physical for that period.

9.4 Transfer of Research Materials

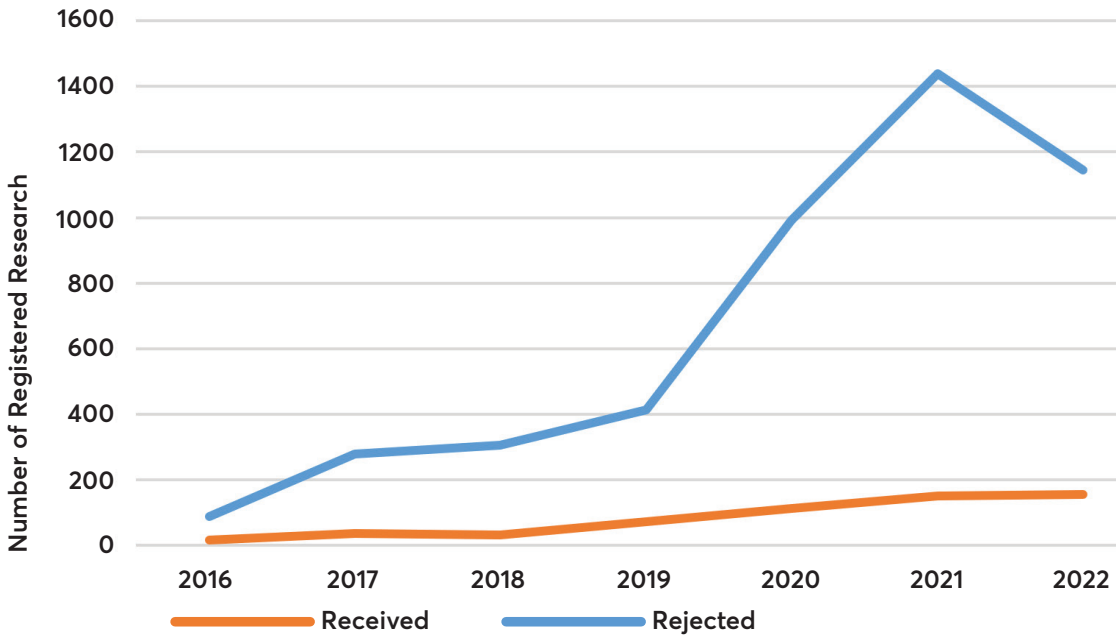
The transfer of materials and research tools is an essential aspect

Fig. 50:



of scientific research. The types of materials exchanged are varied and are utilized in all areas of research including chemistry, biology, physics, computer science, and engineering but the vast majority of these transfers occur in the life sciences. A transfer between provider and recipient may serve to facilitate the confirmation of research findings or may provide a unique material to further a new line of investigation. UNCST oversees the contracts that govern the transfer of tangible research materials between two entities (including institutions and between Uganda and other countries) when the recipient intends to use it for his or her own research purposes. The MTA defines the rights of the provider and the recipient with respect to the materials and any derivatives. Biological materials, such as reagents, cell lines, plasmids, and vectors, are the most frequently transferred materials, but MTAs may also be used for other types of materials, such as chemical compounds and even some types of software. Since 2012, there has been an increase in the number of MTAs issued. As shown in Figure 3 below, the number of material transfer agreements have been on the rise over the last five years.

Fig. 51: Research Quality Assurance at UNCST



9.5 Research Policies, Guidelines and Regulations

Research is conducted for the benefit of society. Since 1990, the UNCST has established a system that promotes beneficial research and guards against unethical research. Several guidelines and regulations have been put in place to promote the sustainable implementation of research in Uganda (See Figure 3 below). However, several research performing entities have also developed institutional guidelines for research that are expected to conform to the national guidelines. Of the 53 universities in Uganda, only twelve (12) have developed research policies or other intellectual property policies or guidelines.

Currently, the UNCST has supported the establishment and capacity building of thirty-one (31) research ethics committees. As shown in BOX 11, UNCST developed a National Research Information System (NRIMS) to enhance research registration and regulation.

9.6 Research Monitoring and Oversight

The UNCST routinely assesses, records and monitors research activity occurring in the country. To undertake its regulatory function, UNCST has established mechanisms (like the National Biosafety Committee) to directly support monitoring of specific aspects of scientific practice. The UNCST also works with other regulators like the National Drug Authority (NDA) and Uganda National Health Researchers Organization (UNHRO) to monitor research involving clinical trials. .

Fig.52: Performance: Percentage distribution of RECS in Uganda (2016-2020)

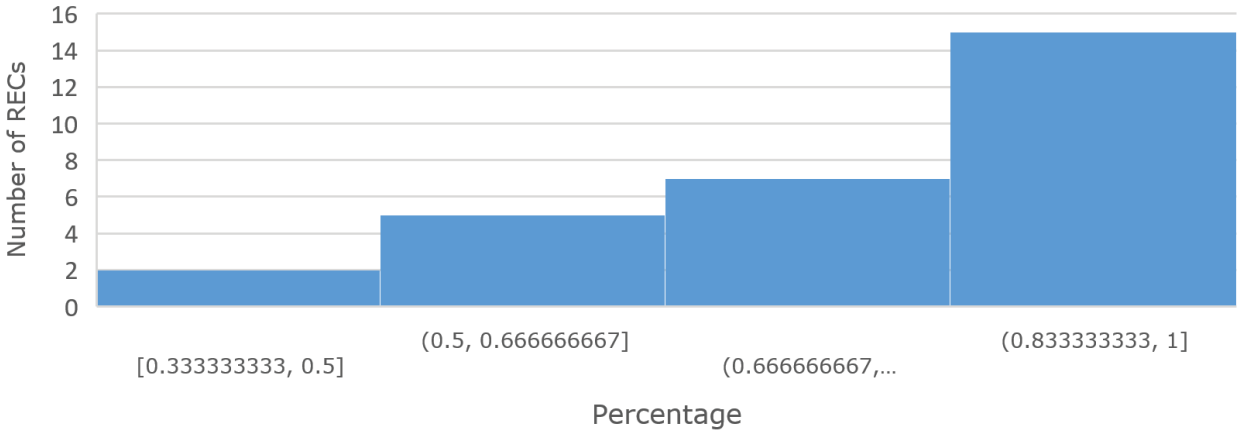


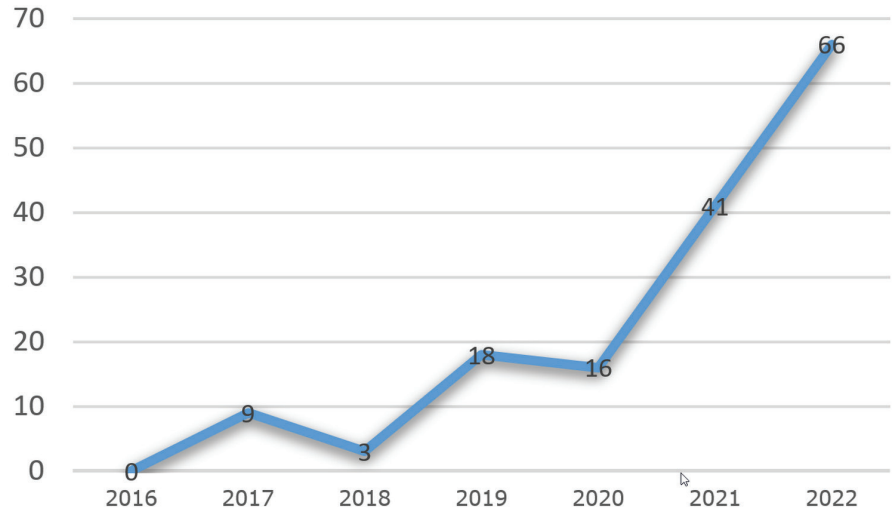
Table 18: Research Registration

Category	Total Submissions
Agricultural Sciences	192
Engineering and Technology	103
Humanities	-
Information & Communication Sciences	-
Medical and Health Sciences	2418
Natural Sciences	337
Physical Sciences	-
Social Science	1414

BOX 13: THE UNCST NATIONAL RESEARCH INFORMATION MANAGEMENT SYSTEM (NRIMS)

In 2020, the UNCST developed an online platform to support the National Regulatory Authorities (i.e. National Drug Authority, Uganda National Council for Science and Technology; and the Uganda National Health Research Organisation) and Research Ethics Committees in the regulatory oversight of clinical research to be carried out in the country. The platform supports research coordination and enables management of research records. The system provides efficient reviews of research and provides the researcher with an interface with the regulatory agencies in the data capture, data management and data validation, quality control and overall regulatory compliance to clinical research management processes. As of May 2023, the NRIMS has had 16,301 submissions, has processed 9,901 approvals, has registered 20,394 users and is being used by 33 Research Ethics Committees. The NRIMS implementation has reduced the turnaround time in approvals for research by at least 50%; NRIMS has reduced paperwork and the cost of printing applications by over 95%; Improved quorum with 90% of the RECs recording 100% attendance for meetings in the last 1 year; and reduced average time of PIs response to comments (from 4 weeks to 1-4 days). The best practices of the NRIMS have been shared with other Science Granting Councils over the past three years under the SGCI Framework.

Fig.53 : Trend of Material Transfer Agreements (2016-2022)



The new strategic focus on industrial value chains will require new frameworks to address the gaps and harness the greatest value from the eight priority value chains. Strengthening coordination and building awareness among stakeholders will go a long way in building a robust STI governance system.

BOX 14: THE NATIONAL BIOSAFETY COMMITTEE

Under the auspices of the Cartagena Protocol of Biosafety, the UNCST established the National Biosafety Committee (NBC) as an independent Technical Committee under section 5 (e) of the UNCST Act (cap 209) to facilitate the testing and development of potentially useful genetically engineered organisms. The NBC serves to protect individuals, the community, and the environment from potential risks of genetic engineering, while at the same time, facilitate the beneficial utilization of the technology. The Committee has developed Inspection Manuals, Trial Manager's Handbooks, Standard Operating Procedures for Institutional Biosafety Committees, National Guidelines for Contained Field Trails among others. UNCST provided decision of approval for Confined Field Trials (CFTs) on the following GM crops: transgenic banana enhanced with provitamin A caroteriods; transgenic potato resistant to phytophore infectious potato blight disease; and Cassava engineered for Cassava Brown Streak disease resistance. Furthermore, the UNCST undertook inspections for Fifteen (15) Confined Field Trial sites for transgenic banana enhanced with pro vitamin A, cassava resistant to cassava brown streak disease, potato resistant to potato blight disease and banana resistant to nematodes and weevils conducted at Buginyanya, FortPotal, Kabale, Namulonge, Serere and Kawanda and in Uganda to provide guidance to organizations that are undertaking regulated bioscience research and development. UNCST also developed guidelines for application of genetically modified Vaccines, mosquitoes, import of genetically modified products, the harvest of transgenic Cassava and rice.

10. The Impact of Research on Emerging Challenges:

10.1 Introduction

The COVID-19 crisis may bring lasting socioeconomic changes, that are likely to forever affect our outlook on science, technology and innovation (STI).

Specifically, the effects on R&D spending across sectors, accelerated the adoption of digital tools and techniques, and changes in the openness and inclusiveness of research and innovation ecosystems. Moreover, the Fourth Industrial Revolution (4IR) has accelerated and increased Uganda's need for technology agility and adaptation. As the global economy rapidly digitalizes, an estimated 70% of new value created over the next decade will be based on digitally enabled platform business models. In Uganda, despite the potential that ICT has, utilization of its services across the country is still limited due to: (i) Limited network coverage; (ii) Poor quality services (iii) High cost of end user devices and services; (iv) Inadequate ICT knowledge and skills; and (v) Limited innovation capacity. The continued exponential rise in the power of information and computing technologies has had a dramatic impact on research across many disciplines. These technologies have not only increased the speed and scope of research but have made it possible to conduct investigations that were not possible before. Information technology advances have enabled new forms of inquiry such as those based on numerical simulation of physical and biological systems and the analysis of massive datasets to detect and assess the nature of relationships that otherwise would go unseen. The impact of research on emerging challenges will depend on how prepared or robust the current systems and people are.

10.2 Employment changes induced by digital transformation

The extent to which digital disruption in Uganda will translate into employment and occupational changes will also depend on many other factors, including the availability and quality of digital infrastructure (physical networks, software and data), structures of global value chains, current local employment structures, job content, the applicability of digital technologies to different existing kinds of work, the speed of adoption of technologies, their cost-effectiveness as compared to existing technologies, skills availability, access to credit enabling the processes of technological reorganization, investment and trade policies (UNCTAD 2018). Although technology usage (and adoption) is generally slower, the necessity for digital policies and digital investments can enable Uganda leap forward and gain access to the very latest technologies.

10.3 Industry 4.0+ and Research 4.0

Uganda developed and adopted the Fourth Industrial Revolution Strategy in 2020 in recognition of digital convergence of technologies and applications across sectors like manufacturing, health, agriculture, environment, education, defense and STI among others.

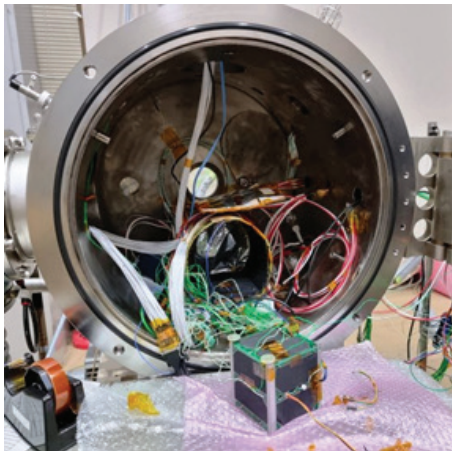
45Ndawula, I., Asiimwe, D., Mushakangoma, S., and Senkindu, P.M (2020), Effective Application of 4th Industrial Revolution Technologies During Engineering Research and Teaching in Ugandan Universities. Presentation at thehe 2nd Annual Higher Education Conference, Hotel Africana Kampala, Uganda. March 16-17th 2020

Digital technologies such as cloud computing, AI and block chain, physical technologies such as autonomous vehicles and 3D printing, and biological technologies such as bio printing and neuro-technology are becoming a mainstay. Unfortunately, Ugandan researchers have not fully adopted or mainstreamed the use of these technologies. A recent study from Uganda has shown that more than 84% of academicians have never heard of 4IR technologies. More than half (53.8%) of the academicians indicated that 4IR technologies are not widely spread into their current curriculum and have not adapted to use these technologies in teaching and research. According to the UNESCO Science Report, women form a minority in Industry 4.0+ fields, accounting for one in three (33%) researchers in 2018. Globally, women still make up just one-quarter (28%) of tertiary graduates in engineering and 40% of those in computer sciences. Just 22% of professionals working in the field of AI are women. The irony is that these fields are not only driving the Fourth Industrial Revolution; they are also characterized by a skills shortage. Universities and research institutes will have to review their research processes, including the choice of tools and techniques. This means producing research that is more individualized and scalable. In collaboration with several universities across the country, the STI-OP has developed an Industry 4.0+ Academia to Business Framework to accurately identify and incubate innovations emanating from student research. In partnership with UNCST under the NSTEI, the Secretariat is supporting a consortium of researchers in manufacture of smart electronics including consumer electronics like portable computers and radios, smart meters for water and electricity, electronic control units for vehicles and medical devices.

10.4 Space Commercialization

According to UNESCO, the African space market was estimated to be worth US$ 10 billion in 2014.

This industry covers areas ranging from telecommunications, environmental monitoring and space debris monitoring. The African Space Strategy (2017) has four components: Earth observation, navigation and positioning systems, satellite communications and space science and technology. The ultimate aim is to create an African Space Agency, to be hosted by Egypt. In 2022, Uganda successfully launched its first ever satellite into the international space station following its construction by three Ugandan and Japanese engineers under a multinational satellite design programme. It's expected that the PearlAfricaSat-1 will provide research and observation data for solutions in weather forecast, land, water bodies management, mineral mapping and agriculture monitoring. Others are disaster prevention, infrastructure planning and border security. In order to build a robust ecology for space science, intentional support to R&D in space systems and strengthening collaboration with partners in this industry will be critical. Universities in Uganda should promote research and collaboration and develop new programs in planetary sciences, remote sensing, planetary geology, astronomy and astrophysics. Currently the space science market is mainly built around non-Ugandan expertise and resources. In February 2021, the Pan-Africa Planetary and Space Science Network (PAPSSN) mobility scheme was launched with students, academics and support staff across several African universities offering MSc and PhD programs in planetary and space sciences. The next generation of Ugandan scientists, leaders and entrepreneurs in this new space will call for a lot of transdisciplinary research in other areas such as sustainable agriculture, green energy, land-use management, early warning systems, climate hydrology, among others. Such programs will place Uganda at the forefront of Africa's space program over the next decades.



10.5 Data Analytics, Management, Security, Privacy, Robotics and Artificial Intelligence (including Machine Learning)

Driven by advances in ICT and the generation of large volumes of data, the applications for data analytics are becoming ubiquitous.

The potential benefits from data analytics in the broad life sciences

BOX 15: UGANDA'S JOURNEY IN THE PATHOGEN ECONOMY

Uganda has set up several research facilities to support R&D of vaccines, diagnostics and therapeutics.

- State of the art –level -2 Biobank Facility: Located at Makerere university, the facility is a repository for human biological materials including blood, saliva, urine, faecal, matter for R&D and testing of vaccines, drugs and diagnostic kits. Currently, overt 20,000 samples have been collected; 8 therapeutic and 3 diagnostic projects that required COVID-19 samples have been supported
- In-Vitro Studies Facility: Located at Uganda Virus Research Institute, this facility was established to carry out pre-clinical studies to support development of vaccines, therapeutics and diagnostics. Analysis on twenty-three (23) natural drug products for COVID-19, RTIs, Kidney Disease and Influenza have been completed.
- Biomarker Research Centre: The facility located at Makerere University was established to strengthen Uganda's capacity to develop point-of-care disease diagnostic and prognostic assays kits, with the mission of reducing over dependence on the importation of diagnostic kis and to also innovate better diagnostic technologies locally.

Source: STI-S Report

and healthcare sector are high in terms of personal healthcare, population health, genomics, and the economics of healthcare. The application of data analytics has great potential too in the agriculture, marine and food production sector for increasing quality and productivity. In the climate change and environment areas, this priority area can facilitate availability and access to underlying data sets and undertake modelling of potential impacts and assessment of capability. Artificial Intelligence and Cybersecurity are large global markets in which Ugandan-based enterprises already compete (or can realistically compete). Artificial Intelligence consists of deep learning, advanced robotics, digital personal assistants, querying methods, natural language processing, neural networks, and context-aware processing. This area will also support opportunities in markets that span a large number of sectors such as Fintech, Pharma, Digital Health and Analytics, Digital Media, Biopharma, Augmented Reality and Virtual Reality and Smart Manufacturing. Continued developments in the semantic web, and evolution towards Artificial Intelligence in key technology areas such as natural language processing and understanding, machine learning, and advanced machine vision, will allow for improved decisions based on holistic data, overcoming inefficiencies in energy demand, mobility and transport. Technologies identified that are relevant for IT and data security includes data encryption technologies, data anonymization technologies, multi-biometrics and cyber forensics. Handling the enormous datasets that are generated from astronomy research will also lead to the creation of advanced enterprise relevant skills for emerging data rich sectors such as retail, health, transport, agriculture and public services. These new technology frontiers will demand for a stretching of university research systems, the development of new research quality assurance frameworks and the establishment of specialized research centers to tackle some of these emerging areas. Moreover, research collaborative frameworks will have to be established to front locally-contextualized breakthroughs in these emerging research fields.

10.6 Pathogen Economy

One of the strategic value chains identified in Uganda's new STI roadmap is to spur growth through the pathogen economy.

This includes research, development, technology transfer, and commercialization of innovations targeting pathogen control and management such as vaccines, diagnostics and therapeutics. Research around these pathogenic imperatives will provide solutions for the range of human and health challenges facing Ugandans. Over the last two years, Uganda has learnt several lessons in responding to the COVID-19 pandemic. Whereas the pandemic exposed capacity gaps in the resilience of the healthcare system, it also revealed the vast opportunities within Uganda's latent pathogen economy. According to the World Bank (2021), only about 200 million people (less than 30 percent) of SSA's population has any access to modern health care and pharmaceuticals. The other 480 million people in the region rely on traditional medicines, mainly from multi-purpose medicinal plants (MMPS). Natural products (herbal medicines) have an estimated global market value of US $65 billion . Even a fraction of this market should be economically appealing to Uganda. This global market demand should no longer be ignored by communities, governments and donors. The COVID-19 pandemic has marshalled research and development around the pathogen economy. Uganda can prioritize research around its rich biodiversity resources. Investment in research infrastructure including further utilization of IoT, AI, Digital Media,

46WHO. 2001. "Herbs For Health, But How Safe Are They?" WHO News. Bulletin of the World Health Organization. 79(7) p691.

In-Vitro Diagnostics, Drug Delivery Devices, Implantable Devices and Personalized Medicine can facilitate leapfrog for sustainable health outcomes for all Ugandans. New research on digitized health systems, telemedicine, connected health, health analytics, innovation in medical devices can aim at contributing to improvement of patient safety and outcomes at affordable cost. Other technologies – such as 3D printing technologies – and the rise of nanotechnology, advanced diagnostics and combination devices will drive innovations across the industry. Engineered implants, such as bioengineered tissues and organs, or developments in artificial skin or 3D printing of body components, will also be a set of key technologies that will drive innovative applications in healthcare. Drug Delivery Devices (including drug-eluting stents, nebulisers, pre-filed syringes, and IV packs) is a core relevant market. Implantable Devices (dental implants, orthopedic implants, cardiovascular implants, breast implants, intraocular lens, orthobiologics, and other implantable products), also represents a large global market in which Ugandan-based companies can invest. The COVID-19 pandemic demonstrated the urgent need to build biomedical diagnostic devices for diagnosing disease and sustaining human health. Diagnostic products form a critical part of healthcare delivery, enabling the early and accurate detection that is vital in ensuring successful treatment, and reducing health costs. Next generation diagnostics will play a critical role in addressing these challenges. New, innovative therapeutics make it possible to prevent, treat and possibly cure a wider range of diseases than before, delivering better clinical outcomes and improving quality of life for Ugandans. Gene editing technologies could make it possible to stop disease development completely and help address genetic disease predispositions. Countering antibiotic resistance will be crucial to ensure effective drug treatment overall. Technologies such as anti-microbial resistance countering will be important to minimize and stop the spread of anti-microbial resistance. Advances in drug delivery systems for optimization and personalization will be driven by innovations in advanced materials, such as coating technologies and smart materials, with nanotechnology being utilized in medicine for therapeutic drug delivery and the development of treatments for a variety of diseases and disorders. Technologies such as pharmacogenomics and organs-on-chips are enabling effective targeted medical treatment. These are closely linked to technologies in advanced materials such as smart sensors, 3D printing and nano- and micro-electronics, and the use of bio-marker identification technologies. Uganda has successfully developed three (3) candidate human vaccines in acute respiratory tract infections. Two of these have completed pre-clinical trials and clinical trials in humans planned in the next year.

10.7 Agro-Security Research

The agricultural sector is a core sector of Uganda's economy in terms of its contribution to the GDP, the number of people it employs, as well as its contribution to ensuring food security.

However, the sector's performance has been declining. The food sub-sector has not been improving for a long time, mainly because of; adverse weather conditions; crop diseases; and inability of the small-scale farmers to respond to these challenges. The industrial crops have not been expanding although government has put measures to improve production and productivity, with a specific focus on addressing crop pests and livestock diseases, provision of good breeds and stocks, promoting the use of fertilizer, mechanization, and irrigation, as well as enforcing quarantines and other regulations. The food supply chain is currently being significantly impacted by climate change, the requirements of sustainability, and digitalization in food markets, where there has been a resultant impact in GHG emissions, competing uses of land and the rise of ethical consumer habits relating to food sources. Research can address national agri-food challenges by improving the competitiveness of agriculture, food and the wider bio-economy, to support sustainable farming and the environment, and to encourage diversification of the rural economy and enhance the quality of life in rural areas. Particularly the need for "climate smart and environmentally sustainable food systems" and the need for "circularity and resources efficiency of food systems" is a gap that research in Uganda can speak to. The National Agricultural Research Organization (NARO) has been at the forefront of Uganda's agricultural research and has provided leadership in this space. The role of ICT in agriculture can become a critical pathway for Ugandan research with a view

Table 19: Number of vehicles in Uganda

Vehicle Types	2019 /20	2020 /21	Percentage Change
Motor Vehicles	4,276	4,360	2%
Motor cycles	59,655	63,878	7%

47Africa Automotive Market - Growth, Trends, Covid-19 Impact, And Forecasts (2022 - 2027)

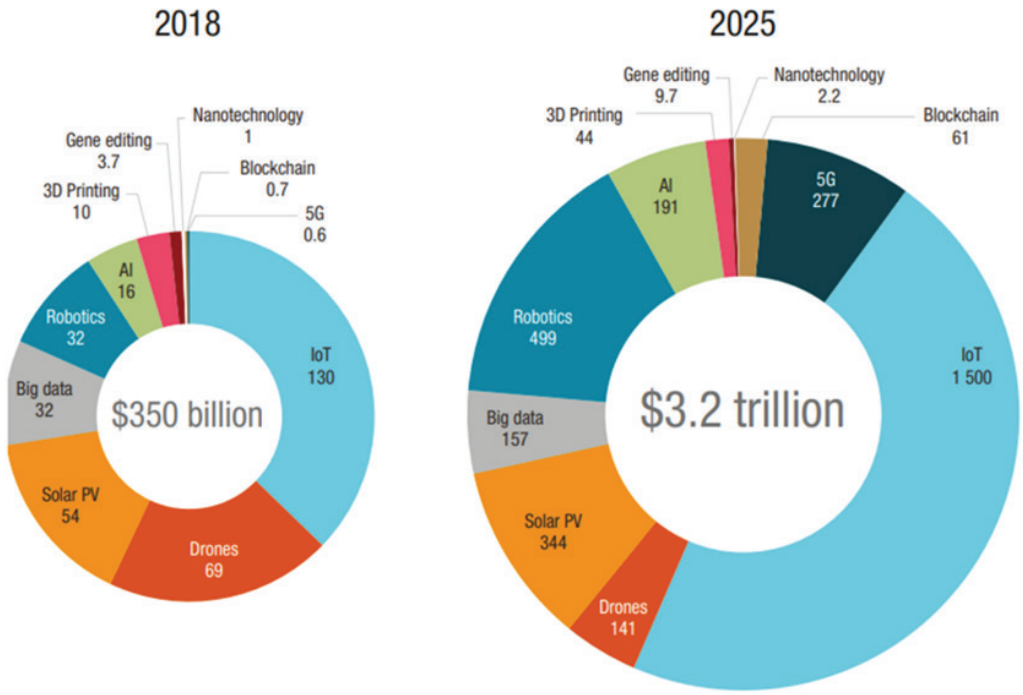
of improving the competitiveness of agriculture, food and the wider bio-economy. Precision Farming (including guidance systems, remote sensing, variable rate technology, hardware automation and control systems, and sensors and monitoring devices), Biotechnology, Agri-biologicals, Feed, and Advanced Animal Breeding could support new value chains in Uganda's agricultural sector. Water treatment technologies can also support the sustainable agricultural primary production and food processing.

10.8 Mobility Economy

The African automotive market was valued at USD 28.45 billion in 2020, and it is expected to reach USD 39.87 billion by 2026, registering a CAGR of 5.55% over the forecast period47.

The prioritization of the mobility industrial value chain is to provide an unprecedented opportunity for harnessing Uganda's population dividend in promoting value addition to Uganda's mineral and other natural resources with the view of import substitution and export promotion of vehicles, parts, components, systems and mobility engineering services.New imperatives around connected vehicles, autonomous driving and the industrial internet have emerged as major driving factors of automotive digitalization which has the potential to radically transform Uganda's transport and mobility patterns. Research, development, technology transfer and commercialization of innovations that augment the national mobility eco-system to develop, make, sell and use sustainable mobility solutions will be critical. Uganda's mobility economy encompasses domestic will domestic manufacture of motor vehicles, motorcycles, bicycles wheelchairs, and other mobility devices, parts and establishment of environmentally friendly, efficient, integrated, inclusive and safe transport systems. The automotive sector in SSA constitutes less than one per cent of global production. The industry is relatively small when compared to other parts of the globe and expected to produce only 2.3 per cent of the 82 million vehicles estimated to be built globally in 2020, when compared to China's 30 per cent, Europe's 22 per cent and North America's 17 per cent. As part of Uganda's import-substitution strategy, Uganda needs to invest in research in mobility systems over the next decade. Uganda has established the Kiira Vehicle Plant in Jinja with an investment of USD 80 Million it is expected that this mobility value chain will directly and indirectly create 500,000 green jobs by 2040, reduce transport based emissions by over 25% and produce 10,000 electric buses, 1,000,0000 electric motorcycles by 2030 and increase sector-contribution to GDP of up to 12.5% .

Fig. 54: Market size estimates of frontier technologies, $billions



48UNCTAD (2021), Technology and Innovation Report, 2021. Catching technological waves Innovation with equity. Available at https://unctad.org/system/files/official-document/tir2020_en.pdf

49UNCTAD (2021), Uganda: Science, Technology & Innovation Policy Review. A Report by the United Nations Conference on Trade and Development, 2021. Available at https://unctad.org/system/files/official-document/dtlstict2020d4_en.pdf

10.9 Energy Technologies

The challenges of climate change and sustainability have increased markedly in importance over the last five years, as evidenced by significant policy developments at national and international level.

Uganda ratified the 2015 Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCC) on 22 April 2016 as part of a major progression in the global response to climate. Research efforts in Uganda can aim at de-carbonising the Energy System with the adoption of green energy derivatives. Increasing the resilience to climate change impacts should begin with research in novel technologies associated with the low carbon energy including ICT, renewable energy, mobility for growth, resource efficiency, and smart construction. Additional technologies including marine renewable energy, wind power solutions, solar, low power wireless networks, smart and context-aware sensors, ultra-resilient electronics, energy storage technologies, micro-energy harvest solutions and advanced building fabrics could be explored. Using sustainable materials and tapping into new emerging markets in waste, water and infrastructure management can be explored. Makerere University's Centre for Research in Energy and Energy Conservation has been leading on biomass research and has also launched a Testing and labeling laboratory. In Ndejje University, the Energy Research and Development Center (ERDC) is also championing research in Hydro-electricity, Biomass (briquettes), Solar energy, Wind energy and Biogas

11. Other Frontier Technologies

According to some estimates, frontier technologies already represent a $350-billion market, and one that by 2025 could grow to over $3.2 trillion48.

These technologies can be used to boost productivity and improve livelihoods. AI, for example, combined with robotics can transform production and business processes. 3D printing allows faster and cheaper low-volume production and rapid, iterative prototyping of new products. To put this into perspective, the current global market for laptops is $102 billion and for smartphones is $522 billion. Among the frontier technologies, the largest by market revenue is IoT. On the demand side, growth is expected to come from the use of robots in large-scale manufacturing, packaging, and the automobile industry. But even some small and medium-scale enterprises that are facing higher labour costs or cannot recruit enough skilled workers are adopting industrial robots. New areas like Solar PV are expected to expand due to increasing energy demand, favorable government regulation and a shift towards sustainable consumption which has encouraged the use of renewable energy. Only a few countries currently produce frontier technologies and in the short run this is unlikely to change. But all countries, including Uganda need to prepare for them. Frontier technologies offer a window of opportunity for developing countries to increase productivity and improve livelihoods. But technological change, which is now driven mainly by developed countries, could also widen the gaps between countries and make it even more difficult to catch up in terms of production or consumption. Also, frontier technologies could transform jobs and labor markets with profound implications for societies as a whole. According to Uganda's most STI Policy Review[49], policymakers need to be mindful of the changes in export markets for Ugandan products. The development of artificial intelligence and robotics, and other frontier technologies, in the markets of a developed export destination mean that Uganda will be decreasingly able to compete on lower labor costs. With insufficient development of industry and value-added services, Uganda risks being marginalized in the global economy and indefinitely entrapped at the lowest end of global value chains as an exporter of primary commodities. Harnessing research in these frontier technologies is non-negotiable.

In conclusion, research is the best way Uganda can prepare to engage in a rapidly evolving global environment. This urgent reality calls for recalibration of strategies that can enable a radical leapfrog in knowledge development and its transfer; establishing robust systems that facilitate and nurture good science; and crystalizing a national research agenda that has Ugandans at its core. The new and emerging challenges provide opportunities for new-learning and bring to the fore the potential catalytic role that research can play in facilitating rapid growth in these uncertain times. ■

11. Policy Recommendations:

11.1 Introduction

Overall, Uganda's research system is in nascence albeit with rapidly-evolving components.

This report offers an overview of key imperatives that are shaping the current state of research in Uganda. In an era of major advances in science, the report highlights challenges and opportunities that can accelerate progress and aspiration to be a center of excellence for global research. Uganda's current vision for STI is to "Make Uganda the Best". The different themes discussed in this report, including human resources in research, governance, infrastructure and funding need to be appreciated from an eco-system outlook. If Uganda is to become the best in terms of research brokerage and management, each of these imperatives need to be reviewed and this report should provide some of the evidence that can shape the necessary policy-mix. Recent challenges, including the COVID-19 pandemic have demonstrated the need for coordination, collaboration with a s sharper focus on research impact. It is expected that this report will catalyze and contribute to conversations around a national research agenda; on Uganda's participation in the global knowledge system; on cataloging the existing actors in Uganda's rapidly expanding research system; and, on highlighting the new actors that need to be included in Uganda's research-led development roadmap.

This report lays out five overarching recommendations, each of which requires actions from a variety of actors: (a) Underscore the importance of scientific research and international collaboration as a key component of Uganda's research ecosystem; (b) the need to strengthen Uganda's research quality assurance system to address the new and emerging challenges; (c) the criticality of working across sectors and institutions to develop more integrated, coordinated and effective research policies is necessary to craft a research culture across the public and private sector;
(d) the delineation of a national research agenda as a vital pivot to better align national, regional and global development aspirations; and (e) the building of a strong research human capacity component. Policy reforms are needed to strengthen innovation and productivity outcomes. More innovation-friendly regulation, combined with lower barriers to trade and foreign direct investment would enhance competition and should foster the flow of technology and know-how across borders. Reforms in how higher education is funded and the centrality of research in HEIs should be implemented to facilitate system-wide adjustments that strengthen their agency for knowledge creation and transfer.

Research leadership

The governance of research in Uganda strongly depends on leadership and effective coordination. and adequate resources for all STI activities within the national system of innovation. The supportive inter-relationships between researchers, innovators, investors and regulators makes it difficult to define and coordinate their roles. Researchers often work in isolation. To enhance the effective coordination, direction and management of research activities, it is essential to establish and strengthen the institutions and governance structures that are needed to provide sound research administration, good governance and quality leadership. Good governance creates a platform for inclusiveness, ownership, sustainability and inter-agency collaboration among the key actors and stakeholders. Creating a research governance structure that is inclusive and broad-based; reconstitute and/or establish research committees (including Research Ethics Committees) in all universities and research institutes and have them embedded within university structures; Create specific roles and responsibilities for each of the actors involved in research governance in order to avoid role-duplication; strengthening the UNCST to coordinate R&D activities and promote linkages and collaborations among relevant institutions as well as with the private sector.

Research Funding

Funding towards research remains below international trends. Anecdotal evidence shows that research funding is largely derived from external sources. As a result, alignment to national strategic priorities remains a challenge. Many of the funders come in with already fixed ideas that do not tackle the

local challenges or are contextually deficient. Uganda has for many years failed to meet the Lagos Plan of Action target of investing 1% of GDP in research and innovation. In the current investment landscape, the lack of long-term financing and the incoherence between the different activities and cooperation between the actors is seen as an obstacle. There is need for more intentional research funding from government. Getting from research to market launch requires a long, iterative process and this process is disrupted if investments are not predictable. Private operators will more readily join research and innovation projects if the government is a long-term co-investor and if there is coordination and a shared vision on the "pathway to impact.". Addressing economic and particularly societal challenges also requires a long-term approach. Long-term investment in all activities in research and innovation ecosystems is therefore very important. Uganda should collaborate with international organizations to support the development of research centers performing research in key areas of national priorities through initiative such as the Africa Centers of Excellence II Model.

Linking Research and Uganda's STI value-chain approach

Whereas research activity has been on the rise, the pathway from idea/concept, through R&D, market validation and commercialization has been characterized by a range of factors that have limited its full potential contribution. This has been further complicated by public skepticism about research impact and inadequate systems for sharing research results to such a public. It is expected that Uganda's new STI strategic posture through the eight value chains can strengthen the linkage between research and product commercialization. A policy framework that puts research at the Centre of the STI value chains could provide a fitting framework for increasing the velocity between research and product commercialization.

Research and Innovation Management

In view of the changing environment for innovation, it is also important to consider how the current system of IPR rules and practices stimulates innovation while allowing access to knowledge. In certain cases, the abuse of the control with which IPR owners are endowed could hamper competition, fair use and the diffusion of technology. However, regardless of issues related to the flexibility of the IPR system, stronger efforts are needed to combat counterfeiting and piracy, which are serious and growing problems. Government policies can support innovation by continually reforming and updating the regulatory and institutional framework within which innovative activity takes place. In this context, reforms are needed to make public policy and regulatory frameworks more supportive to innovation in a range of policy areas. Public investment in science and basic research can play an important role in developing ICT and other general-purpose technologies and, hence, in enabling further innovation. This highlights the importance of reforming the management and funding of public investment in science and research, as well as public support to innovative activity in the private sector. The latter calls for an appropriate mix of direct and indirect instruments such as tax credits, direct support and well-designed public-private partnerships, support for innovative clusters and rigorous evaluation of such public support.

Research Collaboration

There are very few active long-standing collaborations with external partners to support the establishment of translational research locally. Whereas Ugandan research is peppered with international partnerships and collaboration, the supporting framework that ensures that Ugandan researchers are protected in such collaborations is still missing. Developing internationally recognized research institutions and centers of excellence can strengthen the propensity for international research collaboration. Harnessing new options around Science Diplomacy and strengthening and/or facilitating collaborations through incentives should become a mainstay. Uganda with its fast-changing research system needs to collaborate more while enhancing what it brings to the "global high-table of research". The focus here is to encourage more collaborative approaches to big challenges; curtail risks to research collaboration and ensure compliance to global, regional and local standards.

Research Infrastructure

As shown in this report, Uganda has a limited range of research infrastructure. Infrastructure such as supercomputers, large-scale databases and observation and measuring instruments such as satellites and telescopes, as well as pilot and test facilities in laboratories or real-life environments, such as field labs and living labs, are vital for research. Such facilities are not only required for research and innovation, but they also provide spaces where researchers and organizations work together, can exchange knowledge and develop new ideas. Research facilities are also relevant to education (internships, practical assignments and stimulating interest in technology) and informing potential

users and investors. Such research facilities can help businesses to develop new products and allow for co-creation. Investment in research infrastructure is vital to ensure that research undertaken is globally competitive and responsive to emerging challenges. The policy framework around research infrastructure ought to be strengthened to ensure access to and use of such infrastructure reduces the cost of doing research in Uganda.

Capacity building for Research

The pathway towards developing a sustainable and world-class research system resides in the establishment of processes and mechanisms to translate research into innovation. Efforts within the universities aimed at strengthening their research mandate are still ongoing. The collective capacity of all actors in the research value-chains needs to be developed to ensure that research quality is optimized to effectively provide solutions to the challenges facing Ugandans. Efforts could focus on developing capacity and good practice not just in research-performing departments but also in research organizations where such capacity appears to be largely missing.
The existing and new centers of research excellence could be the obvious starting point of this work.

Investment in Research Digitization

Investment in digitization is positively correlated with uptake and diffusion of research. The use of ICT is closely linked to the ability of firms to innovate (i.e. introduce new products, services, business processes and applications); of researchers to collaborate and of research networks to emerge. Over the last five years, the UNCST has registered an uptick in registration of research after the introduction of the National Research and Information Management System (NRIMS). The continuous development of digital tools and innovative software has increasingly enhanced the efficiency and performance requirements in research. Universities and other research performers need to be encouraged to digitize their research products by employing collaborative and crowd-sourced software; by developing digitization roadmaps, supporting access to research publications, research data and public data; making research results (publications, data, etc.) easily retrievable and available for reuse; facilitate interaction with other researchers across disciplines and sectors, nationally and internationally; encourage and coordinate measures to promote Open Science with other research institutions in a manner that helps to boost the aggregate effect; ensure that research data in Uganda conforms to FAIR principles (findable, accessible, interoperable and reusable); to simplify research administration within universities and establish authoritative research IDs for enhanced quality assurance. These and other innovations around research digitization will enhance visibility of Uganda's research and make Uganda a destination of choice for research funding and collaboration.

Engaging the Informal Sector

Uganda can develop its technological innovation capabilities by harnessing the vast knowledge locked in its informal sector, tapping from the wealth embedded in indigenous knowledge, leveraging the biodiversity and biotechnology assets in the country and deploying information and communications technologies. Innovative startups and scale-ups are essential for generation of new knowledge and innovations within the ecosystem. Currently the inadequate support, including the limited access to early-stage capital and continued lack of growth capital for scale-ups are limiting the expansive growth of this critical aspect of the ecosystem. Knowledge-intensive startups have difficulty raising early-stage capital on the right terms, with the result that promising innovations become trapped in the 'valley of death'. This has impeded the success of promising innovative businesses. The attendant risk is that young businesses, and the talent working in them, may either get lost or marginally contribute to development. Stronger engagement with these new actors, including the informal sector will be vital to achieve the technology-leapfrog that Uganda seeks. Linking research to the informal sector will facilitate relevance and allow for more inclusive research-led development.

Adoption and use of existing and emerging technologies/innovations.

Like most low-income countries, production and services in Uganda are done by very small, informal firms in manufacturing and services, and subsistence agriculture. They have limited knowledge of existing technologies that could improve the production and delivery of better goods and services that can help meet the SDGs. Innovation is largely indigenous or grassroots with a minimalist modern sector. Thus, the key focus should be to encourage the use of existing technology/ innovation and to scale up grassroots innovation. The instruments should be aimed at providing technological information and innovation dissemination, strengthening management capability and skills upgrading to ensure "technology-readiness" for technology norming. The linkages that allow the use of research within local contexts for impact must be explored. For

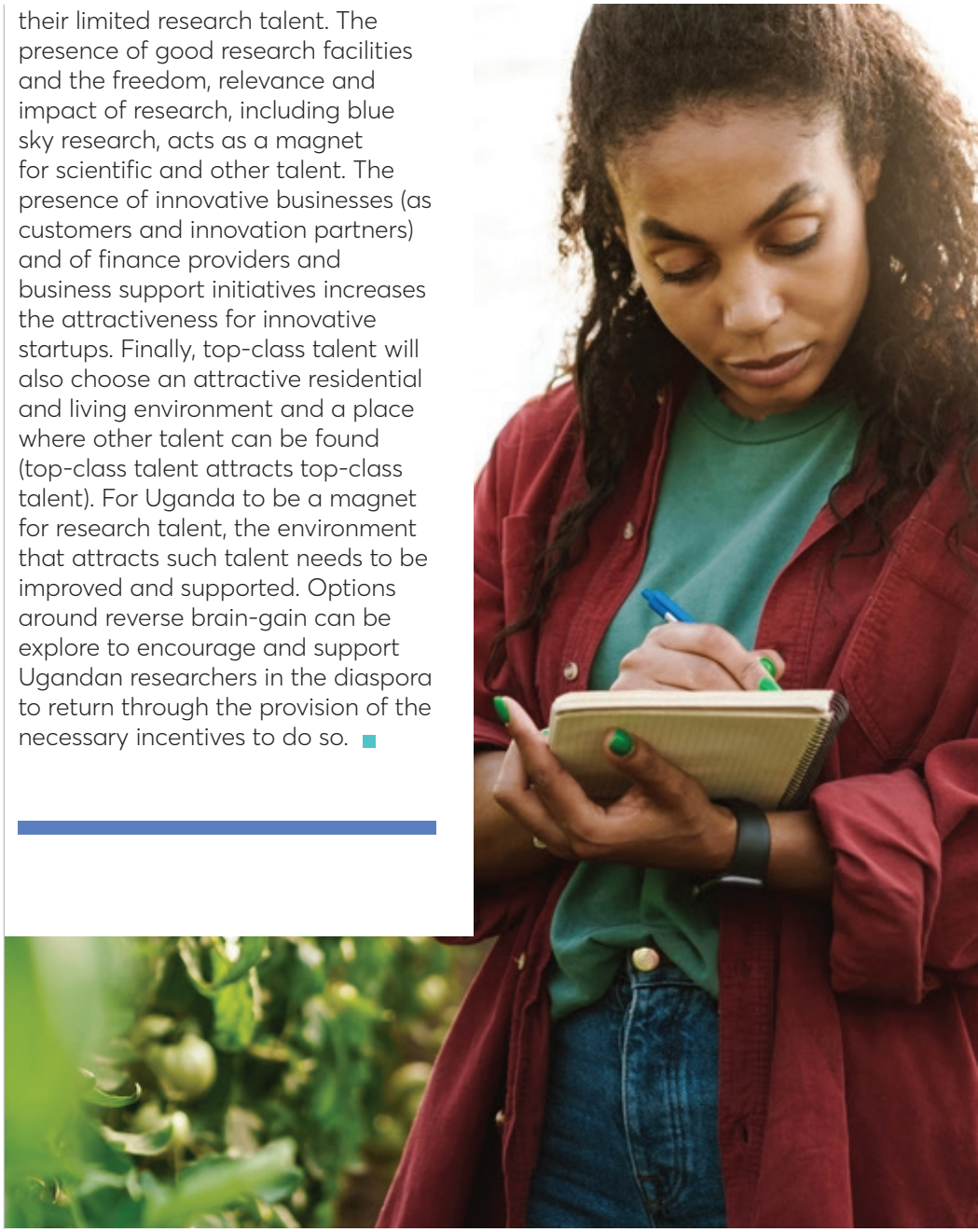
instance, the locus of partnership between research actors and mainstream government programs like the Parish Development Model (PDM), should be highlighted and prioritized.

Reinforcing TVET to deliver digital skills

The provision of solid digital skills can be easily adapted to rapidly changing needs through the provision of relevant demand-driven TVET. ICT-specialist training is a growing area within the TVET sector, offering new degrees and programs. The skills acquired through such programs can advance a career at least as much as the acquisition of a university degree. By providing not only theoretical education but also on-the-job training, they can be particularly rewarding. Dual apprenticeship systems, centered on the idea of acquiring both relevant skills and experience, can be particularly useful. More generally, in view of the digital skills that become obsolete too quickly, TVET institutions should strive to teach broader specializations and adaptable skills for fast changing jobs; provide tools on how to manage one's own career and compose one's own qualification; and prepare for the market and for life rather than for a lifetime job. Aligning curriculum to industry and employer needs, and mapping curricula to learning outcomes relevant to labour market needs are keys to the successful delivery of skills that are in great demand and also to improving worker employability. The TVET system should take advantage of existing digital learning tools and resources, and explore options for innovative, digital pedagogical approaches such as simulators and augmented or virtual reality. The development and regular review and update of qualification frameworks can provide relevant support to validation and recognition of prior learning, including digital informal learning. For example, recognizing competencies that have been acquired through online coding courses may contribute to resolving coding skills shortages in Uganda.

Attracting Research Talent

Top-class research talent contributes to many activities in the ecosystem, including agenda-setting and leadership, inspiring and convincing investors with novel approach to challenges. The COVID-19 pandemic demonstrated Uganda's latent research talent that often goes either undeployed and underutilized. The competition to secure top-class talent is highly globalized. Whereas many countries in the Global North are looking at strategies of maintaining and retaining their research talent, by contrast countries like Uganda in the Global South have not been deliberate on protecting, preserving, supporting and nurturing their limited research talent. The presence of good research facilities and the freedom, relevance and impact of research, including blue sky research, acts as a magnet for scientific and other talent. The presence of innovative businesses (as customers and innovation partners) and of finance providers and business support initiatives increases the attractiveness for innovative startups. Finally, top-class talent will also choose an attractive residential and living environment and a place where other talent can be found (top-class talent attracts top-class talent). For Uganda to be a magnet for research talent, the environment that attracts such talent needs to be improved and supported. Options around reverse brain-gain can be explore to encourage and support Ugandan researchers in the diaspora to return through the provision of the necessary incentives to do so. ■



Annexure:

Technology Creation Index	**Patents Granted Index** $=\frac{9^{Uganda}-3^{Samoa}}{1{,}400{,}661^{China}-3^{Samoa}}=0.0000043$ **Royalties and Licence Fees Index** $=\frac{4{,}110{,}505^{Uganda}-13^{SaoTome\ \&\ Principe}}{13{,}779{,}000{,}000^{China}-13^{Sao\ Tome\ \&\ Principe}}=0.00003613$	0.000020215
Diffusion of Recent Innovation Index	**Internet Index** $=\frac{1573^{Uganda}-2^{North\ Korea}}{46{,}678{,}108^{USA}-2^{North\ Korea}}=0.000033656$ **High Tech Exports Index** $=\frac{11{,}771{,}659^{Uganda}-1274^{Gambia}}{757{,}682{,}663{,}756^{China}-1274^{Gambia}}=0.000015535$	0.0000245953
Diffusion of Old Innovation Index	**Telephones per capita Index** $=\frac{Log\ 90774^{Uganda}-Log\ 33^{Kiribati}}{Log\ 181{,}908{,}000^{China}-Log\ 33^{Kiribati}}=0.51$ **Electricity Consumption Per capita Index** $=\frac{Log\ 109.981^{Uganda}-Log\ 12.752^{Benin}}{Log\ 57486.35^{Iceland}-Log\ 12.752^{Benin}}=0.256$	0.383
Development of Human skills	**Mean Years of Schooling Index** $=\frac{6.1^{Uganda}-1.5^{Burkina\ Faso}}{14^{Germany}-1.5^{Burkina\ Faso}}=0.368$ **Gross Enrolment Ratio** $=\frac{14.21^{Uganda}-4.37343974^{Niger}}{757{,}682{,}663{,}75686.5969315^{Belarus}-4.37343974^{Niger}}=0.1221$	0.24505
Technology Achievement Index	(0.000020215+0.0000245953+0.383+0.24505)／4	0.157

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