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The drivers and barriers influencing the commercialization of innovations at research and innovation institutions in Uganda: a systemic, infrastructural, and financial approach

Ronald Jjagwe[1,2*], John Baptist Kirabira[1], Norbert Mukasa[1] and Linda Amanya[2]

*Correspondence:
jagweron@gmail.com

[1] College of Engineering, Design, Art and Technology, Makerere University, Kampala, Uganda
[2] Uganda National Council for Science and Technology, Kampala, Uganda

Abstract

Research and innovation (R&I) institutions must commercialize their innovations to remain competitive in a knowledge-based economy. While R&I institutions in Uganda have the potential to drive socioeconomic development, a clear understanding of the commercialization pathway is lacking. This study aims to bridge this gap by analyzing the systemic, infrastructural, and financial factors that drive and hinder the commercialization of innovations at R&I institutions in Uganda. This study offers the first comprehensive examination of the systemic, infrastructural, and financial dimensions influencing innovation commercialization within Uganda's R&I ecosystem, presenting new empirical evidence on the prioritized barriers and drivers as perceived by key stakeholders. Employing a mixed-method approach, this study uniquely combines quantitative surveys with qualitative case studies and key informant interviews, enabling a nuanced understanding of the multifaceted drivers of and barriers to innovation commercialization in Uganda. The study employed the Delphi technique to identify consensus among key informants. The findings highlight the urgent barriers to address, including fragmented R&I ecosystems, inadequate support infrastructure, such as technology transfer offices, and significant gaps in innovation financing. These issues underscore the urgent need for targeted policy interventions. Based on our findings, we recommend the establishment of a national innovation fund, enhancement of public private partnerships for R&D infrastructure development, and formulation of a cohesive national policy framework to streamline commercialization processes at R&I institutions. This study provides policymakers with a data-driven foundation to craft targeted interventions aimed at removing the identified barriers, thereby catalyzing the commercialization of innovations in Uganda's R&I institutions.

Keywords: Barriers, Commercialization, Drivers, Innovations, Research and innovation institutions, Uganda

Introduction

Innovation is a valuable resource for research and innovation (R&I) institutions, and many developing countries have prioritized its commercialization and utilization (Aktar et al., 2021; Ecuru et al., 2014; Kreiterling, 2023; Kurpayanidi, 2021). Uganda's investment in innovation, technology development, and transfer, expressed as gross expenditure on research and development (GERD), is currently 0.18%, which is below the 1% recommended by the African Union (NPA, 2020; Sithole, 2020). The products of innovation generation, diffusion, and exploitation are crucial to a country's economic growth, competitiveness, and transformation. Many developed countries attribute their success to the knowledge economy, which is characterized by well-established innovation and commercialization systems (Atwine et al., 2023; OECD, 2021; Schwab & Zahidi, 2020).

Innovation and commercialization are two key processes that are vital for converting knowledge and ideas into commercially viable products and services. Research and development (R&D) plays a crucial role in the innovation process, and the availability of adequate support infrastructure, financing mechanisms, and a well-coordinated R&I ecosystem are essential for successful commercialization. These elements facilitate the transfer of knowledge from knowledge generators such as research institutions and universities to knowledge consumers such as techno-business firms and industrial actors. The conversion of innovative products into profits is the primary goal of commercialization, which relies on the creation of market value for novel goods, processes, and services (Bakhtiar et al., 2020; Kruachottikul et al., 2023).

The Government of Uganda (GOU) acknowledges the crucial role of R&I in establishing a competitive and knowledge-based economy that addresses socioeconomic transformation issues (Mulumba et al., 2017; NPA, 2020; Sithole, 2020). Consequently, the GOU has shown political will by positioning science, technology, and innovation (STI) at the forefront of the country's transformation and growth processes. This is exemplified by the creation of the innovation, technology development, and transfer (ITDT) program under the Third National Development Plan (NDP), as well as the development of a supportive regulatory and institutional environment (NPA, 2020) in the country.

The commercialization of innovations has been demonstrated to yield substantial returns, with estimated returns of 30% in the commercial sector and 50% in the social sector (Schwab & Zahidi, 2020). Despite these benefits, Uganda does not invest significantly in innovation and commercialization (Mulumba et al., 2017; NPA, 2020; Sithole, 2020). Research and innovation contribute up to 3% of the Gross Domestic Product (GDP) of developed and emerging industrialized countries (OECD, 2016; Schwab & Zahidi, 2020). As such, Uganda's socioeconomic development plan must prioritize the advancement of scientific and technological innovation (Mulumba et al., 2017; NPA, 2020; World Bank, 2021).

Notwithstanding these observations, there are compelling reasons for researchers and innovators to gain a comprehensive understanding of the process of commercializing their ideas. This is particularly important if the country aims to achieve its transformation agenda. The successful commercialization of innovations is essential to unlock their full potential benefits, as recognized by several scholars

(Bakhtiar et al., 2020; Kruachottikul et al., 2023). Product commercialization is a clear indication of the true value of an invention and serves as a strategic driver of economic growth and development for firms (Bakhtiar et al., 2020; Kruachottikul et al., 2023).

According to Ecuru et al. (2014), the commercialization process in Uganda faces systemic barriers, yet detailed insights into these barriers remain scarce. Our study aims to delve deeper into these systemic issues, providing a nuanced understanding that previous research has overlooked. Inadequate comprehension of the structure and functionality of the country's innovation and commercialization processes hinders investment in R&I (Asad et al., 2023; World Bank, 2021). This lack of understanding adversely affects the learning process and interaction among the various stakeholders in the R&I ecosystem (Abbas et al., 2018; Martins et al., 2023). As a result, policymakers and stakeholders in the R&I ecosystem are constrained in their ability to devise and implement strategies to promote the development of the country's innovation and commercialization systems (Abate & Sheferaw, 2023; Aktar et al., 2021). Consequently, research, innovation, and commercialization programs are at risk of being underutilized, and their value, relevance, and impact are frequently underestimated.

While previous studies have highlighted the role of commercialization in driving economic growth in developing countries (Butnik-Siverskyi et al., 2024; Min et al., 2020; Shcherbachenko & Kotenko, 2022), there remains a limited understanding of the specific systemic, infrastructural, and financial challenges faced by R&I institutions in Uganda. This study seeks to address this knowledge gap by conducting a comprehensive examination of the systemic, infrastructural, and financial dimensions influencing innovation commercialization within Uganda's R&I ecosystem, presenting new empirical evidence on the prioritized barriers and drivers as perceived by key stakeholders. This study is guided by three pivotal research questions: What are the systemic drivers and barriers impacting innovation commercialization in Uganda? How do infrastructure issues influence this process? What financial challenges do R&I institutions face and how can these be addressed?

Unlike previous studies, which have mainly focused on systemic, infrastructural, or financial aspects in isolation (Gong et al., 2021; Loganathan & Subrahmanya, 2022; Shcherbachenko & Kotenko, 2022), our study adopts a comprehensive approach that integrates all three dimensions. This holistic view is crucial for developing targeted interventions that can effectively enhance the commercialization capabilities of R&I institutions in Uganda. The findings underscore the critical importance of a fully integrated R&I ecosystem that requires both institutional and national support mechanisms. This study provides a viable solution that can be utilized to formulate effective policies and foster the creation of a commercialization strategy for the country. This, in turn, leads to increased efficiency and productivity in Uganda's R&I institutions. The study recommends that the government and its partners encourage collaboration and knowledge sharing among the various stakeholders in the R&I ecosystem, enhance R&D infrastructure, and broaden the scope of innovation and commercialization financing channels at Ugandan R&I institutions.

The following sections of this paper will discuss the literature review, research methodology, study findings and discussion, contextual analysis of the systemic,

infrastructural, and financial drivers and barriers, recommended measures and strategies to overcome the systemic, infrastructural, and financial barriers, and the conclusion.

Review of literature

The Triple Helix model's role in innovation commercialization

The Triple Helix model characterizes the connection between creators of knowledge, users of knowledge, and the government as well as their involvement in a knowledge-based economy (Abbas et al., 2019; Cai & Etzkowitz, 2020). This model emphasizes collaboration, cooperation, and co-development among the three institutional spheres of university, industry, and government, with the university playing an enhanced role (Abbas et al., 2019; Cai & Etzkowitz, 2020). In a triple-helix culture, the functions of university, industry, and government change in a manner that enable each institutional sphere to assume the role of others in specific and relevant situations (Abbas et al., 2019; Cai & Etzkowitz, 2020). This means that the Triple Helix concept allows for the overlap of functions and the creation of boundaries or bridging institutions, as collaboration between universities, industry, and the government provides flexibility in institutional boundaries. Entities that generate knowledge include universities, research organizations, science academies, and other science- and technology-related agencies (Abbas et al., 2019; Cai & Etzkowitz, 2020). The government sector comprises science and technology (S&T) policy and legal and regulatory organizations, while knowledge-consuming (industry) entities include manufacturing and services, whether for profit or not.

While Abbas et al. (2019) emphasize the critical role of government support in innovation commercialization, other studies have pointed out instances where excessive government intervention has stifled innovation (Zhang et al., 2023; Zhu et al., 2020;. This discrepancy highlights the complex nature of government involvement in innovative ecosystems and underscores the need for a balanced approach. Despite extensive research on the impact of the Triple Helix model on innovation commercialization, there remains a lack of understanding of how this model interacts with local cultural and economic dynamics in Uganda. This approach directly points to gaps and sets the stage for the relevance of the study.

Systemic drivers and barriers to innovation commercialization

The commercialization of innovations is a critical aspect of transformation and growth in both developed and developing countries (Al-Shammari & Waleed, 2018; Fuentelsaz et al., 2019; Kruachottikul et al., 2023). Researchers and innovators have shown considerable interest in this area because of its positive impact on socioeconomic advancement, including the creation of new job opportunities (Atwine et al., 2023; Omri, 2020; Uyarra et al., 2020). Furthermore, the successful execution of projects that contribute to national competitiveness depends on the appropriate commercialization of ideas (Baláž et al., 2023; Khelfaoui & Bernier, 2023; Teixeira et al., 2021).

The current policy climate and framework conditions for research and innovation in a country are constrained by structural and systemic limitations (Fosci et al., 2019; Mulumba et al., 2017; NPA, 2020). The fragmentation of the R&I ecosystem in Uganda, as noted by Mulumba et al. (2017), not only hinders knowledge transfer, but also leads

to the duplication of efforts and inefficient allocation of resources. A closer look at this fragmentation reveals that it stems from the lack of coordinated policy implementation and inadequate platforms for stakeholder engagement. The national R&I ecosystem in Uganda is characterized by a disjointed network of entities with divergent sectoral alignments in budgeting, planning, and service delivery (Mulumba et al., 2017; NPA, 2020; UNCTAD, 2020).

According to Mulumba et al. (2017) and UNCTAD (2020), R&I endeavors are disjointed and lack intersectoral linkages and synergies between public and private sector entities. The absence of platforms for collaborative planning and implementation of synergistic programs hinders intersectoral collaboration, knowledge transfer, and commercialization (Chane & Atwal, 2023; Kruachottikul et al., 2023). Each R&I system player operates in isolation, disregarding related or complementary efforts from other actors that can be harnessed to achieve better results.

Based on the literature reviewed above, our first research question is as follows: Q1: What are the systemic drivers and barriers that impact the commercialization of innovations at the institutional level in Uganda?

This question aims to identify the factors that either facilitate or hinder the systemic aspects of the commercialization process at the institutional level in Uganda. The answers to this question contribute to a better understanding of the systemic challenges faced by institutions in Uganda when attempting to commercialize their innovations.

Following the discussion on systemic barriers, it is crucial to consider infrastructural challenges, as they are intrinsically linked. While systemic issues create a foundational dilemma, infrastructural inadequacies directly impact the operational capability of R&I institutions to innovate and commercialize effectively.

Infrastructural promoters and challenges to innovation commercialization

In recent years, innovation infrastructure has been recognized as a vital component in addressing societal challenges (Kesselring et al., 2023; Uyarra et al., 2020). Public research and innovation (R&I) institutions are increasingly striving to stimulate and support private sector innovation by developing an R&I infrastructure that fosters creative activities (Arora & Chong, 2018; Fudickar & Hottenrott, 2019). As a result, R&I institutions play a crucial role in driving a country's goals towards commercialization, as well as supporting the efficient execution of government infrastructure plans (Mulumba et al., 2017; NPA, 2020; UNCTAD, 2020).

It can be stated that research and innovation institutions aim to bring about beneficial changes and reshape societal realities through rational resource utilization and the establishment of robust infrastructure initiatives (Baláž et al., 2023; Nuruzzaman et al., 2019; Zhu et al., 2020). These institutions not only demonstrate effectiveness but also play a crucial role in the successful commercialization of innovations. Evaluating institutional efficiency in the public sector involves assessing its capacity to implement impactful infrastructure programs and policies while addressing societal needs and concerns and maximizing public value with limited resources (Chen et al., 2018; Khelfaoui & Bernier, 2023; Rivera & Landahl, 2019).

Considering the critical role of infrastructure in supporting innovation (Uyarra et al., 2020), Uganda could benefit from targeted investment in R&D facilities and

technological infrastructure. This approach is supported by UNCST's Engineering Development and Innovation Center (EDIC), where similar investments have led to significant improvements in innovation output (Ogwang & Vanclay, 2021). The current state of research, innovation, and commercialization infrastructure in Ugandan R&I institutions is inadequate. This lack of a national research agenda and priorities limits opportunities for coordinated and consolidated national efforts to develop an R&I infrastructure through demand-driven, shared access, and cost-effective models (Ogwang & Vanclay, 2021; Tweheyo et al., 2024). Access to advanced research facilities is limited, and only a few scientific centers of excellence have such capabilities. Research materials are often transferred to foreign laboratories for analysis at high cost (Ogwang & Vanclay, 2021; Pius & Owin, 2024).

Based on the literature review, our second research question is formulated as follows: Q2: What are the infrastructural drivers and barriers that impact the commercialization of innovations at the institutional level in Uganda?

This question aims to identify the factors that either facilitate or hinder the infrastructural aspects of the commercialization process at the institutional level in Uganda. The answers to this question contribute to a better understanding of the infrastructural challenges faced by institutions in Uganda when attempting to commercialize their innovations.

Following the discussion on systemic and infrastructural barriers, it is crucial to consider the associated financial challenges as they are intrinsically linked. While systemic and infrastructural issues create a foundational dilemma, financial inadequacies directly impact the operational capability of R&I institutions to innovate and commercialize effectively.

Financial incentives and constraints to innovation commercialization

The national R&I ecosystem must meticulously evaluate its financial assets and employ the most effective mechanisms to achieve desired outcomes, including fostering public welfare, enhancing public services, and promoting economic growth, leading to increased employment and higher incomes for citizens (Geissinger et al., 2019; Nuruzzaman et al., 2019). Unfortunately, Uganda's GERD is currently at 0.18%, which is below the level of 1% suggested by the African Union (NPA, 2020; Sithole, 2020), resulting in insufficient financial resources for ordinary (non-grant) support of research institutions, infrastructure, human resources, and other development activities. Furthermore, the grant money is also in short supply, and the government-allocated funding for research is less than the demand stated in the research proposals. Many R&I institutions rely heavily on external funding (Hogan et al., 2022; Kurekova et al., 2023).

Furthermore, the funding available for the translation of research discoveries into commercial products is limited in size and scope, requiring significant investment in infrastructure, equipment, and product development. The financial tools available for R&I activities do not align with the financial and innovation sectors of Uganda. In contrast to Uganda's 0.18% GERD, Kenya invests 0.8% of its GDP in R&D (OECD, 2021), which is closer to the African Union's recommended value of 1% (African Union Commission, 2014). This comparison not only highlights Uganda's relative underinvestment but also suggests that increasing R&D expenditure could be a pivotal

driver for enhancing innovation commercialization. Platforms for connecting academia, researchers, and industry, which can attract venture funding from potential scientific entrepreneurs, are still in their early stages (Fosci et al., 2019; Mulumba et al., 2017; UNCTAD, 2020). Consequently, many researchers are left with immature prototypes and must seek financing throughout the various stages of R&D.

The financing arrangements for R&I are untenable. In the absence of a sufficiently capitalized national research fund, R&D funding is allocated through the national budget framework process, which utilizes the medium-term expenditure framework (MTEF) and annual budget framework paper (BFP) (NPA, 2020). To ensure continuity of funding, the mechanism provides short-term support for R&D activities and requires researchers to provide verifiable research outcomes within a specific fiscal year.

It has been noted that many long-term research initiatives encounter financial sustainability issues due to the significant time lag between research funding and the realization of actual findings, particularly those involving longitudinal studies such as vaccine development and climate change studies (Fosci et al., 2019; NPA, 2020; Zhu et al., 2020). To address this issue, the national R&I fund must either be adequately capitalized, or alternative long-term financing mechanisms for R&D must be developed to provide a resolution to short-term finance and allow for the completion of the R&D cycle.

Our third research question, formulated based on the literature reviewed above, is as follows: Q3: What are the financial drivers and barriers that influence the commercialization of innovations at the institutional level in Uganda?

This question aims to identify the factors that either facilitate or hinder the financial aspects of the commercialization process at the institutional level in Uganda. The answers to this question contribute to a better understanding of the financial challenges faced by institutions in Uganda when attempting to commercialize their innovations.

Based on a literature review and formulation of the research questions, the proposed conceptual model (Fig. 1) was established for this study. The literature review shows that various actors are involved in transforming innovation into marketable products or services. When the conditions are conducive, interactions and learning among these actors occur, resulting in innovations that improve the productivity, commercial

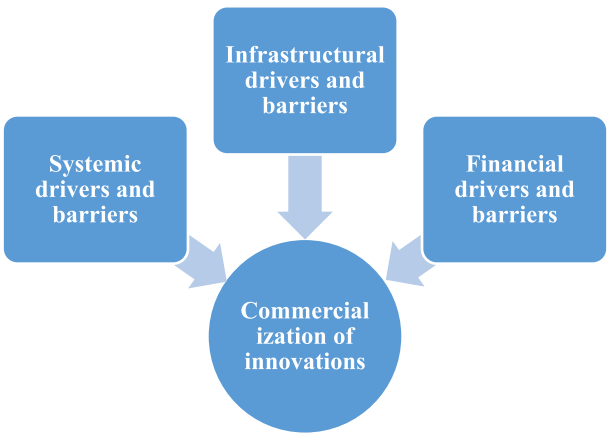

Fig. 1 A proposed conceptual model (Source: Authors)

viability, and profitability of R&I institutions. To achieve this, actors throughout the R&I ecosystem must grasp the processes of commercializing innovations and surmount barriers to technology adoption and commercialization. However, the existing literature is deficient in empirical theory or explanation regarding the systemic, infrastructural, and financial drivers and associated measures that influence the commercialization of innovations at R&I institutions in Uganda.

Method

Study design and approach

To address the multifaceted nature of commercialization barriers and drivers, this study employed a mixed-methods approach. This methodological choice allows for an in-depth exploration of qualitative insights from key informant interviews and case studies while also enabling the validation of these insights through quantitative data from surveys. This approach is particularly suited to uncovering the nuanced interactions between systemic, infrastructural, and financial factors, which the existing literature has not fully explored. Despite the recognition of systemic, infrastructural, and financial factors as critical to the commercialization of innovations, there remains a gap in empirical studies that comprehensively explore these factors in tandem within the context of Uganda. This study aims to bridge this gap by employing a mixed-method approach to identify and analyze these drivers and barriers in a holistic manner.

The Delphi technique utilized in this study, according to Mohannak and Samtani (2014), involves conducting multiple rounds of surveys with a panel of experts. After each round, the aggregated responses were shared with the panel to refine their views in subsequent rounds. This iterative process is designed to converge on a consensus regarding the most significant systemic, infrastructural, and financial barriers and drivers to innovation commercialization in Uganda, thereby addressing a critical gap in existing empirical research.

Given the identified gap in understanding the private sector's role in innovation commercialization in Uganda, this study specifically aims to dissect how private enterprises and financial institutions contribute to or hinder the commercialization process. By leveraging both qualitative insights from key informant interviews and quantitative survey data, this study seeks to elucidate the mechanisms through which the private sector can either facilitate or obstruct the commercialization of innovations, thus offering targeted recommendations for enhancing private sector engagement.

Study population

Participants were selected from R&I institutions, including universities, research institutes, techno-business firms, incubation/innovation hubs, private/consultancy firms, and non-government organizations (NGOs), based on the following inclusion criteria: (a) involvement in at least one commercialization project within the last five years; (b) holding a position that directly influences R&D decisions, such as project managers, principal researchers, or executives of R&I institutions; and (c) willingness to provide a detailed description of the innovation and commercialization process in their respective institutions. These inclusion criteria for participant selection ensured that the study gathered insights from individuals with first-hand experience in Uganda's

innovation and commercialization landscape. R&I institutions can be broadly classified into four categories: knowledge generators, such as research institutions and universities; knowledge consumers, including techno-business firms and industry actors; government bodies; and support systems, such as incubators and innovation hubs.

Sampling method

To ensure a representative sample of R&I institutions in Uganda, we calculated the required sample size using a standard formula based on the expected proportion of innovative firms and a confidence level of 95%. Study participants were selected using purposive sampling to ensure a comprehensive understanding of the drivers and barriers that influence innovation commercialization at the institutional level (Holliday, 2014; Manly, 2015).

The sample size was determined using the following formula (Manly, 2015):

$$n = \frac{Z^2 \times [P \times (1 - P)]}{\alpha^2}$$

where; α is the level of significance; $e = 5\%$ [error]; $P = 0.917$ [% of innovative firms in Uganda (NPA, 2020; Sithole, 2020); and $Z = 1.96$ [*Z-value*].

Taking $\alpha = 5\%$, Thus

$$n = \frac{1.96^2 \times 0.917 \times 0.083}{0.05^2} = 116$$

Therefore, a sample size of 116 participants was used in this study.

Data collection

The study was conducted in 2022, and the investigator administered the questionnaires to the participants. Online questionnaires were available to respondents who preferred to complete them on their own. A total of 95 responses were recorded from 116 participants, with a response rate of 82%. The data collection tool aimed to explore the possible drivers and barriers to the commercialization of innovations by focusing on the linkages between the R&I ecosystem and the private sector, R&I support infrastructure, and mechanisms for innovation and commercialization financing at the institutional level.

Key informant interviews were conducted with a diverse range of stakeholders, including scientists/innovators, chief executive officers, business leaders, and administrators in selected organizations, universities, incubators, and firms. The purpose of these interviews and discussions was to gain a comprehensive understanding of the factors that drive and hinder the commercialization of innovations at R&I institutions in Uganda.

The structure of the interview questions was specifically developed to obtain respondents' experiences, opinions, and expectations (OECD/Eurostat, 2018) regarding a firm's systemic, infrastructural, and financial capabilities and networks. The interview session, which lasted for approximately one hour, was conducted at different times and locations. After each interview session, the data collected were transcribed, and the interpretations derived from them were sent to the participants via email for their

approval. Participants' feedback on the interpretation of the data was sought to verify and confirm their accuracy. The participants were allowed to modify any information they believed did not accurately reflect their perspectives and experiences. These subsequent checks by the participants served to prevent researchers' subjective biases from unduly influencing the findings. Emphasis was placed on ensuring the consistency and reliability of the generated data, following the principles outlined by Holliday (2014).

Data analysis

The process of ensuring the accuracy of the collected data involved verifying the completeness and consistency of the questionnaires. In cases where further clarification was necessary, additional information was requested from respondents. The data were then inputted into Microsoft Excel, organized, and thoroughly cleaned before being analyzed using the Statistical Package for Social Scientists (SPSS) 26.0.

The analysis of the generated data was conducted using a three-pronged approach (Lester et al., 2020; Mihas, 2019) and comprised the following three main phases: (i) data reduction, which involved selecting, clustering, abstracting, and transforming the documented transcriptions (interview data) into a usable and manageable form; (ii) data display, which involved organizing the data in a manner that would facilitate the drawing of conclusions. The data were organized into time-ordered matrices and supplemented with information on roles and inputs. (iii) Drawing conclusions and verification: This phase involved evaluating the key results of the study and, in some cases, re-analyzing the data to verify the findings.

An explanation-building procedure was employed in a cross-case analysis (Lester et al., 2020; Mihas, 2019) to gain further insight into the drivers and barriers affecting the commercialization of innovations in R&I institutions in Uganda. Through a comparison of cases, it was possible to determine the general applicability of the findings and to specify the conditions under which those findings hold.

Results and discussion

Characteristics of participating research and innovation organizations

As highlighted by Muriisa and Rwabyoma (2019), R&I institutions in Uganda play a crucial role in the country's growth, competitiveness, and reform programs. These institutions primarily focus on addressing societal needs such as poverty alleviation, food security, and disease prevention. As shown in Fig. 2, various participants in the R&I landscape were identified, including universities (60%), research institutes (28.7%), private companies (5.3%), NGOs (2%), consultancy firms (2%), and others (2%).

Understanding the linkages between the research and innovation ecosystem and the private sector

According to research, the private sector plays a crucial role in the commercialization of innovations, which is vital to the country's economic growth and development (Abbas et al., 2019; Kruachottikul et al., 2023). As a developing country, Uganda relies heavily on innovation and entrepreneurship to drive economic growth and has proposed initiatives to encourage the private sector to participate in these efforts. In recognition of the significance of the private sector, the GOU has implemented measures to create

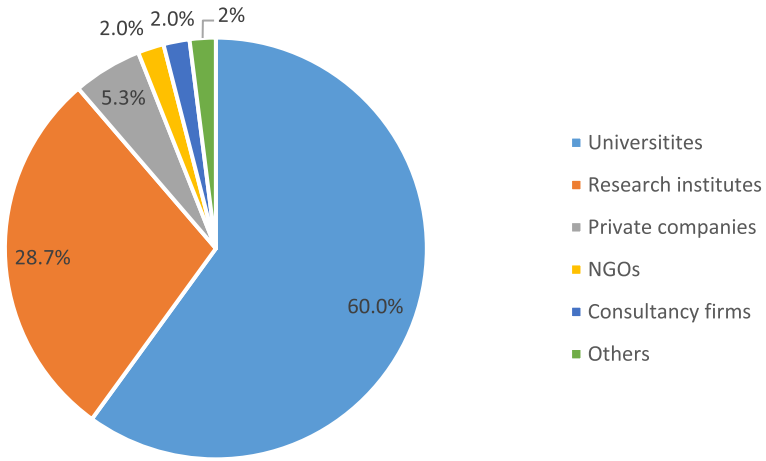

Fig. 2 Organizations as a proportion of the total study participants

a supportive business environment within the country (Okumu & Buyinza, 2020; Sendawula et al., 2023).

One of the critical knowledge gaps identified is understanding the direct impact of R&I ecosystem fragmentation on the efficiency of resource allocation and information dissemination within Uganda's innovation landscape (Okumu & Buyinza, 2020). The study findings indicate that fragmentation of the R&I ecosystem is a significant systemic challenge to the commercialization of innovations in Uganda. This study evaluated the connections and collaborations between knowledge-generating organizations such as universities, research institutes, NGOs, private companies, consulting firms, incubation facilities, innovation hubs, and knowledge users, specifically techno-business firms and the private sector (Abbas et al., 2019; Bakhtiar et al., 2020). To enhance the effectiveness of these linkages and cooperation, sectoral fragmentation measures must be implemented across the R&I system.

Private sector collaboration within the different organizational categories

Several scholars have noted that the connections between R&I institutions and the private sector in Uganda are disjointed and suboptimal despite efforts to strengthen them (Ajer et al., 2023; Okumu & Buyinza, 2020; World Bank, 2021). This is a manifestation of the fragmentation that exists within the R&I ecosystem, which poses a significant obstacle to the commercialization of innovations at the institutional level in Uganda. To foster economic growth and development, the government and other stakeholders are working to create a more favorable environment for collaboration between the R&I ecosystem and the business sector.

Except for limited responses from recently established institutions, all participants reported the presence of private sector participation in the operations of their organizations, as depicted in Fig. 3. Few institutions that did not involve the private sector in their operations are situated upcountry and geographically removed from the country's major business center, which hosts a higher concentration of private firms and corporations. Some of these institutions were new and still in the early stages of

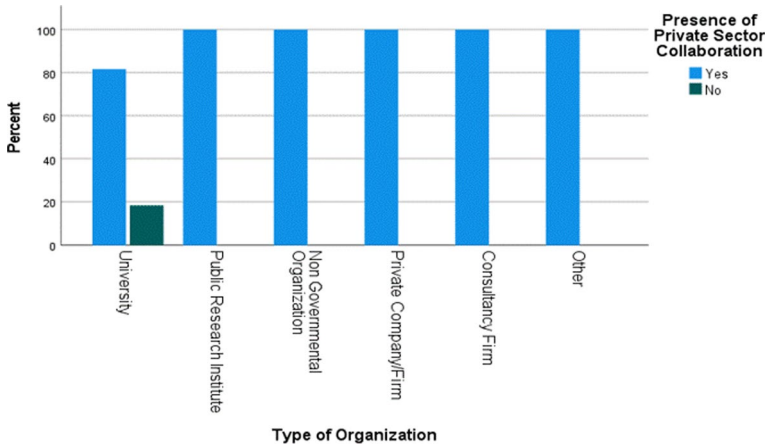

Fig. 3 Private sector collaboration within the different organizational categories

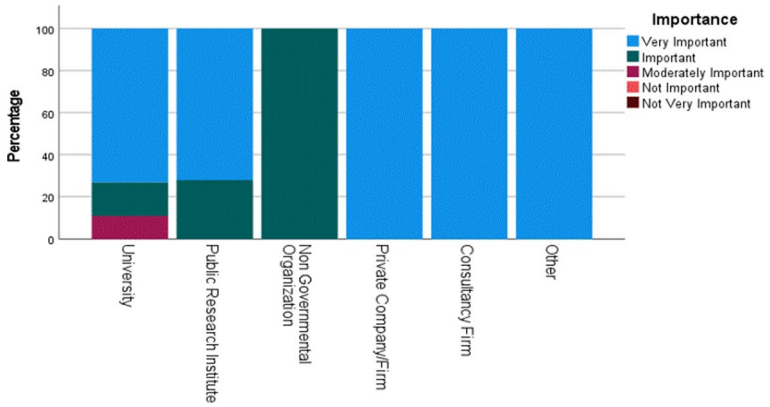

Fig. 4 Importance of collaboration with the private sector

establishing their operations, which hindered their ability to engage in collaborations and interactions with the private sector.

Importance of collaboration with the private sector

It was observed that coordination between the business sector, government, and academia is essential for the effective commercialization of innovations in Uganda. By working together, the private sector, government, and academia can establish an environment that fosters entrepreneurship, promotes innovation, and drives sustainable economic growth (Tweheyo et al., 2024; Wang et al., 2024).

Figure 4 illustrates that most R&I institutions, including public universities that were fully funded by the government, considered private-sector collaboration essential to their operations. In contrast, only a small percentage of universities (10%) perceived private-sector collaboration as a moderately important venture.

Time dedicated to private-sector collaboration

Several scholars have noted the importance of allocating time for collaboration with the private sector to commercialize innovation (Salmon et al., 2020; Stubbs et al.,

2022). The private sector plays a crucial role in economic growth, job creation, and the introduction of new products and services into the market. By working together, public and private sectors can expedite the innovation process, leading to increased productivity, competitiveness, and societal benefits.

According to the study, private sector collaboration was found to be highly valued in the commercialization of R&D, but most R&I institutions did not allocate sufficient time to promote such collaboration. Consultant firms were an exception, as they dedicated sufficient time to private sector collaboration, as demonstrated in Fig. 5. The study also revealed that consultant firms spent the most time collaborating with the private sector, followed by universities, and research institutes. In contrast, NGOs and private corporations were less dedicated to private-sector collaboration. The limited commitment of NGOs to private sector collaboration can be attributed, in part, to their funders, who often have special interests and restrict NGOs' participation in private sector players to a certain extent.

The value attached to strengthening collaborations with the private sector

Cooperation between the private sector and R&I institutions in commercializing innovations is of utmost importance for obtaining resources, market validation, industrial expertise, network expansion, risk reduction, and market access, as supported by Abbas et al. (2019) and Martins et al.(2023). Such collaboration leads to economic development, job creation, and the development of innovative solutions to societal problems by connecting creative ideas with commercial success.

During the study, it was noted that collaboration with the private sector was highly valued by private firms, consulting firms, and NGOs. This was evidenced by the willingness of R&I institutions to encourage staff partnerships with the commercial sector through internships and part-time consultancy as well as by creating opportunities for the corporate sector to participate in events such as public lectures. However, it should be noted that approximately one-fifth of research institutes (20%) placed limited importance on the need to expand private sector partnerships, as shown in Fig. 6.

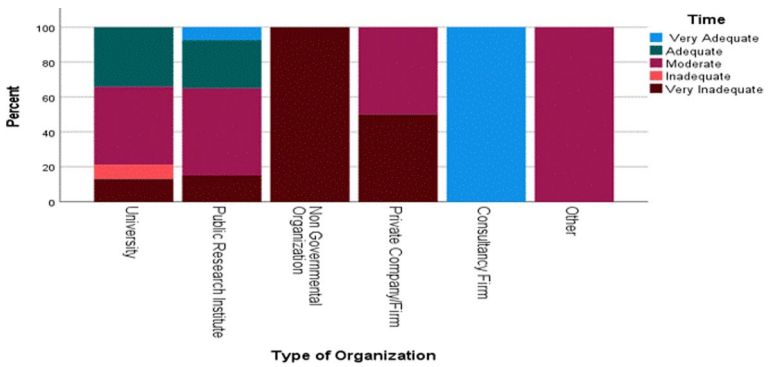

Fig. 5 Time dedicated to private sector collaboration

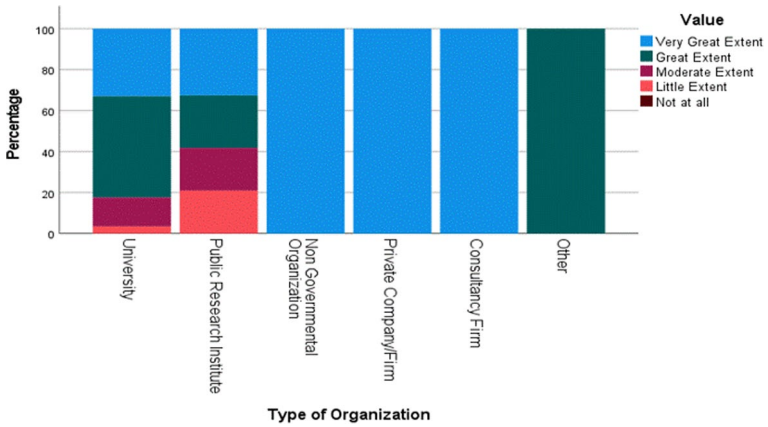

Fig. 6 Value attached to strengthening collaborations with the private sector

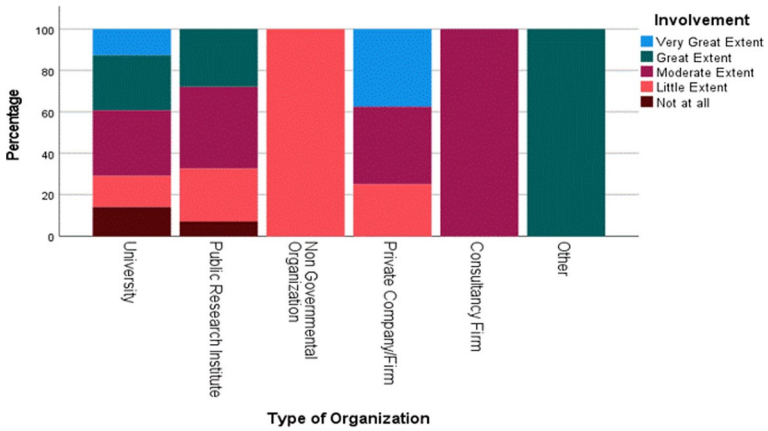

Fig. 7 Involvement of the private sector in the setting of organizational priorities

Involvement of the private sector in the setting of organizational priorities

Based on this research, involvement of the private sector in the formulation of organizational objectives can provide multiple advantages and positively impact an organization's overall performance. According to Baláž et al. (2023) and Kesselring et al. (2023), this collaboration can provide valuable commercial experience, a market-focused approach, opportunities for risk-sharing, and expedited product development and commercialization. Furthermore, it can help firms align their innovation efforts with market demand, enhance their chances of success, and contribute to economic growth.

The results of the study revealed that a significant proportion of respondents from private businesses (38%) and universities (14%) involved the private sector in the establishment of organizational goals (Fig. 7). Conversely, consulting companies engaged only in the private sector to a moderate extent in this process. Notably, NGOs were not involved in the private sector. The university and research institution respondents generally had positive reactions to the business sector's engagement in determining organizational priorities, particularly when the private sector was a key stakeholder or partner, and when joint programs or projects were being implemented in the private sector.

The contribution of institutional research and innovation support infrastructure

The study observed that the country's R&D infrastructure is still in its formative stages, with limited access to laboratories and research facilities. To bridge this gap, a detailed study of the optimal allocation and utilization of R&D resources in Uganda's R&I institutions is recommended. This could inform targeted investments in infrastructure that directly contribute to the commercialization process, such as prototyping facilities and technology transfer offices (Pius & Owin, 2024).

However, Uganda has made noticeable strides in upgrading its innovation infrastructure by establishing innovation centers and incubators (Kwesiga, 2019; Ogwang & Vanclay, 2021). The research and innovation support infrastructure provides academics, entrepreneurs, and businesses with the necessary tools, facilities, and support systems to transform their ideas and inventions into marketable products and services. Such infrastructure facilitates the translation of scientific discoveries and technological advancements into practical applications, which significantly contributes to the commercialization of inventions and promotes economic development and societal impact by providing the necessary resources, skills, and support.

According to Kwesiga (2019) and Pius and Owin (2024), Uganda has demonstrated significant progress in recent years in enhancing its R&I institutions' innovation and commercialization infrastructure. Based on this research, the absence of sufficient R&I infrastructure is a critical issue in Uganda's R&I system. Private enterprises, NGOs, and consultancy firms perceive the existing innovation and commercialization support infrastructure, such as Intellectual Property Management Offices (IPMOs), Technology Transfer Offices (TTOs), and grant management offices (GMOs), to be of less importance due to budgetary constraints, which often hinder their operations.

Availability of institutional R&I infrastructure

This study analyzed the availability and functionality of institutional infrastructure that supports R&D innovation and commercialization. The study scrutinized IPMOs, TTOs, and GMOs as integral components of the infrastructure that foster innovation and commercialization at the institutional level (Pius & Owin, 2024). Additionally, the study evaluated the availability of institutional intellectual property (IP) policy, financing, and the level of skills or abilities of staff working in IPMOs, TTOs, and GMOs as part of the infrastructure.

The research findings indicate that inadequate R&D support infrastructure is a significant obstacle to commercializing innovations at the institutional level in Uganda. The study discovered that many firms participating in the survey lacked adequate R&D infrastructure (Fig. 8), highlighting the need for increased investment in research, innovation, and technology transfer facilities.

Based on the study results, as depicted in Fig. 8, only private enterprises, research institutions, and universities reported having sufficient institutional infrastructure in the form of laboratories, incubation centers, and workshops. The respondents cited reasons such as the lack of funding and resources for development, as well as the obsolescence of some equipment and technologies in innovation and incubation facilities for those where the support infrastructure was deemed insufficient.

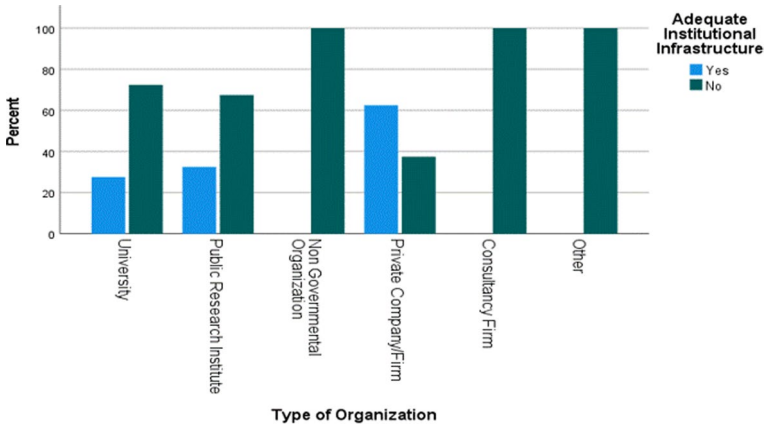

Fig. 8 Adequacy of institutional infrastructure in the organizations

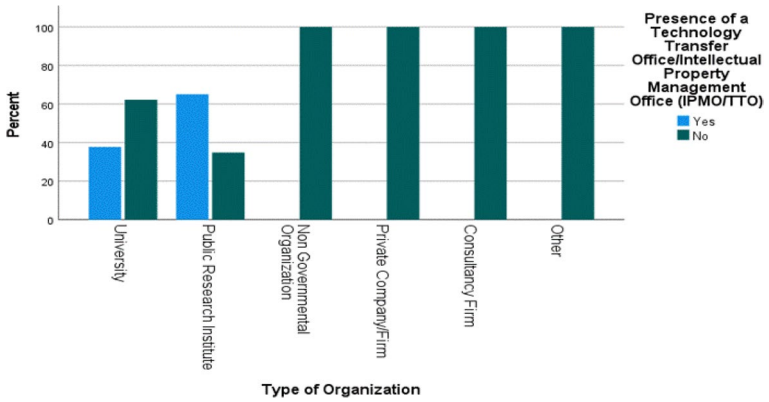

Fig. 9 Presence of intellectual property management offices (IMPO) and technology transfer offices (TTO)

Presence of intellectual property management and technology transfer offices

Intellectual property management offices (IPMOs) and technology transfer offices (TTOs) play pivotal roles in the commercialization of inventions (Min et al., 2020; Sapah et al., 2022). IPMOs are responsible for safeguarding and managing intellectual property assets, such as patents, trademarks, copyrights, and trade secrets. TTOs facilitate the transfer of technology and knowledge from the academic and research settings to the business sector.

IPMOs and TTOs work together to safeguard and promote new ideas. TTOs facilitate collaboration between academia, research, and the business sector, enabling the exchange of technology and knowledge. IPMOs specialize in the legal aspects of IP protection and licensing, and their cooperation is essential for the successful commercialization of discoveries and their transformation into practical products, services, and economic value (Butnik-Siverskyi et al., 2024; Sapah et al., 2022). As depicted in Fig. 9, TTOs and IPMOs were primarily observed at universities (38%) and public research institutions (63%). This deficiency in the promotion of innovation and commercialization has been identified in private corporations, consulting firms, and NGOs.

Presence of intellectual property policies

According to Pererva et al. (2024), intellectual property (IP) policies play a crucial role in the commercialization of innovations at R&D institutions. It establishes a legal framework to protect creators' rights and provides incentives for R&D investment by granting exclusive rights to those who develop or produce something new. The design and execution of institutional IP policies must be geared towards achieving the effective identification, development, protection, and utilization of IP assets. Intellectual property rights (IPRs) promote innovation and creativity by ensuring that R&D findings, discoveries, inventions, and creative work are used to benefit society.

Figure 10 shows that most universities (78%) and public research institutions (80%) with technology transfer offices (TTOs) and intellectual property management offices (IPMOs) have implemented intellectual property (IP) policies. This is because of the critical need for universities and research organizations to have a structured approach to managing the IP assets generated by their R&D outputs (Tahir et al., 2022). To promote innovation and commercialization, all institutions must embrace the development of IP policies. Furthermore, ongoing professional development is vital to enhancing the knowledge and skills of individuals in executing their duties, and the facilitation of mobility between the public and commercial sectors within the R&I ecosystem is crucial.

Availability of resources to intellectual property management and technology transfer offices

Figures 11 and 12 depict the results of the study on the proficiency levels of IPMOs and TTOs, along with the availability of resources in universities and research institutions. Enterprises are responsible for allocating resources to IPMOs and TTOs to safeguard, manage, and capitalize on their IP assets. This approach fosters innovation, encourages collaboration, enhances the value of IP, and supports R&D (Min et al., 2020).

Assessment of IPMOs and TTOs revealed that both universities (40%) and public research institutes (80%) had sufficient resources. However, the capacity of these organizations to facilitate R&D collaboration with the business sector was found to be inadequate. Specifically, up to 20% of university respondents reported that the capacity of IPMOs and TTOs was very limited.

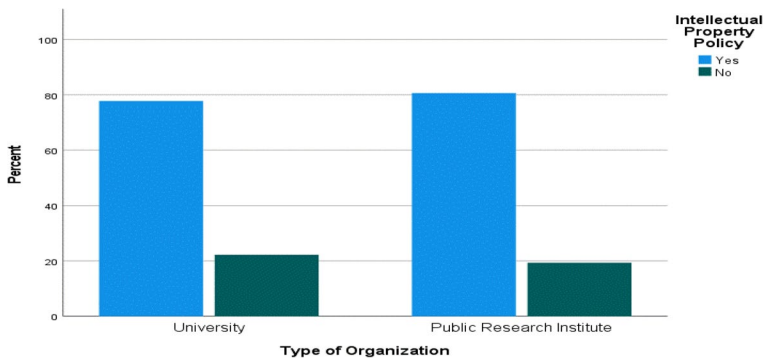

Fig. 10 Presence of intellectual property policy at universities and research institutes

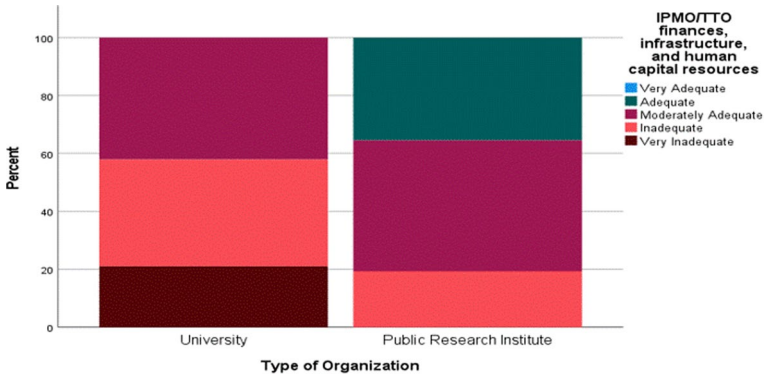

Fig. 11 Availability of resources to IPMO/TTO at universities and research institutes

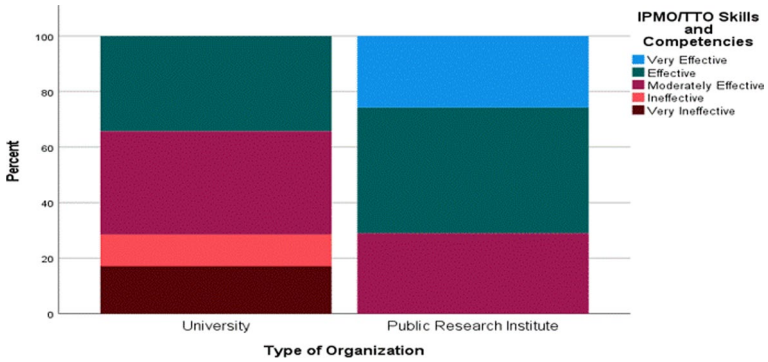

Fig. 12 IPMO/TTO skills and competencies at universities and research institutes

Level of skills and competencies in intellectual property management and technology transfer offices

Adequate skills and abilities are required for IPMOs and TTOs to work effectively. According to Butnik-Siverskyi et al. (2024), these offices play a crucial role in administering and preserving intellectual property assets as well as facilitating the transfer of technology from academic institutions to the business sector. To fulfill their responsibilities successfully, IPMOs and TTOs must possess adequate abilities and competencies. With the necessary competencies, these offices can preserve and utilize intellectual property assets, facilitate technology transfer, and contribute to innovation and economic progress (Min et al., 2020).

In terms of abilities and competencies, IPMOs and TTOs were more prevalent in research institutes (70%) than in universities (34%) (Fig. 12). This phenomenon can be attributed to the fact that certain universities prioritize the advancement of knowledge over the prototyping and commercialization of their research outputs.

The existing institutional mechanisms for innovation and commercialization financing

The financial viewpoint examines the financial resources available for innovation and commercialization at R&I institutions in Uganda. Obtaining funding remains a significant challenge for inventors and entrepreneurs in Uganda, particularly during

the early stages of growth. According to Sendawula et al. (2023) and the World Bank (2021), the financial sector in Uganda is underdeveloped with limited access to venture capital and investors. Moreover, many entrepreneurs lack the financial literacy and business acumen required to secure funding and effectively manage their resources. A comparative study with Kenya's mobile technology sector could reveal innovative financing models, such as public private partnership models for funding R&D, that Uganda might emulate to improve its innovation commercialization of finance channels (Atwine et al., 2023).

Idea commercialization often demands significant capital investment and necessitates the establishment of financing mechanisms for innovation and commercialization (Butnik-Siverskyi et al., 2024; Shcherbachenko & Kotenko, 2022). The evaluation of these mechanisms in various organizations was conducted using factors such as the effectiveness of GMOs, the institutional allocation of resources, accessibility to innovation and commercialization resources, and the competencies and skills of GMOs. The study found that the lack of dependable institutional finance systems for research, innovation, and commercialization is a major obstacle hindering the commercialization of innovations in Uganda.

According to this survey, insufficient financing is a significant impediment to the growth of Uganda's research and innovation (R&I) ecosystem. This study analyzed the allocation and availability of financial resources for innovation and commercialization within Ugandan R&I institutions. The successful implementation of innovation and commercialization initiatives is vital for the country's economic development, and financial sustainability is a crucial factor in determining its success (Ajer et al., 2023). To address the existing funding gaps in R&I institutions, this study recommends exploring options, such as pooling resources or establishing joint ventures.

The presence of grants management offices

Grants Management Offices (GMOs) are crucial in the process of commercializing innovative ideas and provide support for securing grant financing and administration, thus facilitating the growth of innovative ventures (Acebo & Miguel-Dávila, 2024; Zhu et al., 2020). With their guidance, inventors can navigate the complexities of commercialization, increase their chances of obtaining funding, and expedite the process. GMOs contribute to the successful transformation of ideas to commercial products by maintaining compliance, tracking progress, and promoting strategic alliances.

Figure 13 illustrates that all consulting businesses (100%), certain colleges (76%), and research institutions (62%) have established grant management offices (GMOs) to manage their funding resources. By contrast, NGOs are less likely to have GMOs, as they frequently receive financing from parties whose agendas they advocate. Consequently, having a GMO may not be a priority for these organizations, as they do not require funding from external sources to support their activities.

Allocation of resources for institutional innovation and commercialization

Institutional innovation and commercialization require significant resources to promote economic growth, job creation, technological transfer, and cooperation;

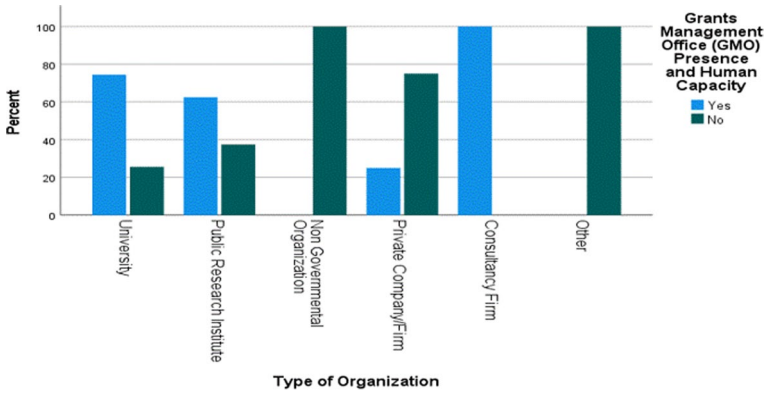

Fig. 13 Presence of grants management offices in organizations

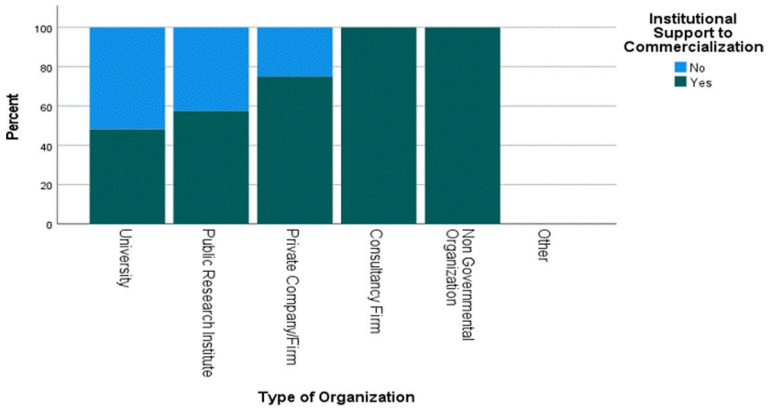

Fig. 14 Institutional allocation of resources for commercialization

address social concerns; generate income; and enhance institutional reputation (World Bank, 2021; Zhu et al., 2020). By fostering an innovative culture and encouraging entrepreneurship, these efforts contribute to society's general prosperity and advancement.

Most participating R&I institutions, except for certain universities (52%), research institutes (42%), and private enterprises (25%), reported committing resources to support commercialization efforts (Fig. 14). These institutions primarily consisted of private and research organizations that aimed to generate revenue through education and training by committing resources to support commercialization efforts.

Accessibility to the available resources for innovation and commercialization

According to Hogan et al. (2022) and Zhu et al. (2020), the availability of accessible resources is of the utmost importance for securing finance, acquiring knowledge, utilizing infrastructure, developing connections, protecting intellectual property, validating market viability, and adhering to regulatory guidelines. These resources are vital for ensuring the successful commercialization of inventions.

Based on the survey results, access to financing was generally robust at universities, research institutes, consulting firms, and non-governmental organizations (Fig. 15).

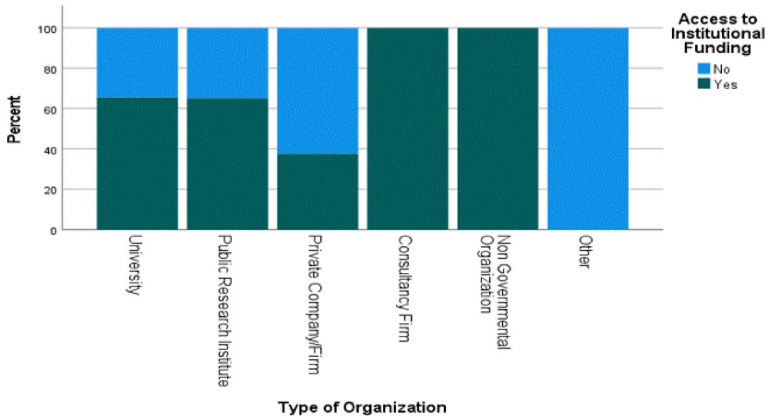

Fig. 15 Presence of institutional funding mechanisms for research and innovation

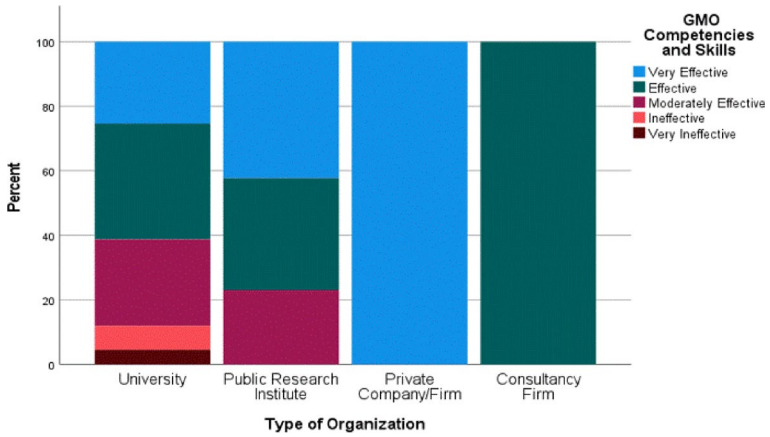

Fig. 16 Grants management office competencies and skills

Additionally, private firms reported more negative than positive responses regarding access to institutional funding for R&I.

Level of skills and competencies at grants management offices

The efficacy of the grants management office (GMO) depends on the possession of adequate abilities and competencies. Grant management encompasses the administration and control of grant programs, including application processing, fund disbursements, project monitoring, and compliance with grant criteria (Agostino et al., 2020; Zhu et al., 2020). It ensures efficient administration, regulatory compliance, effective risk management, project result evaluation, stakeholder participation, financial management, understanding of the financing landscape, and continuous development. The presence of competent experts in grant programs can lead to more significant impacts and better social, economic, and environmental outcomes.

Figure 16 illustrates the proficiencies and abilities of grants management offices (GMOs) in aiding institutions with research and commercialization support. The survey results indicated that GMOs in private enterprises were highly effective, followed by research organizations (43%) and universities (24%). Private firms' effectiveness

with GMOs is attributed to their strong emphasis on maximizing revenue in their commercialization efforts.

Contextual analysis of the systemic, infrastructural, and financial drivers and barriers

Innovation and commercialization play crucial roles in driving economic growth and development (Abbas et al., 2019; Kruachottikul et al., 2023). However, several factors can either support (drivers) or impede (barriers) innovation and commercialization at the institutional level, as highlighted by Perry (2020), which are explored in the systemic, infrastructural, and financial contexts (Fig. 17).

Systemic drivers and barriers to innovation commercialization in Uganda

Systemic drivers are significant elements within the broader research and innovation ecosystem that exert a profound influence on commercializing breakthroughs. According to Fashina et al. (2018) and Yang et al. (2022), these factors can impact the overall market conditions and either facilitate or impede the successful introduction and acceptance of new products, services, or technologies. Addressing and overcoming these systemic drivers and obstacles is crucial for organizations and policymakers seeking to create an environment that fosters the successful commercialization of innovations. By comprehending and leveraging these drivers and obstacles, stakeholders may enhance their prospects of bringing revolutionary ideas to the market and reaping associated economic and societal benefits. These include the following.

Government support

The Government of Uganda (GOU) plays a critical role in promoting innovation and commercialization by crafting regulations and policies that create a conducive business environment (Nahikiriza, 2023). The GOU implemented various programs and initiatives aimed at encouraging innovation and entrepreneurship, including financial incentives, supportive business climates, and the establishment of innovation hubs

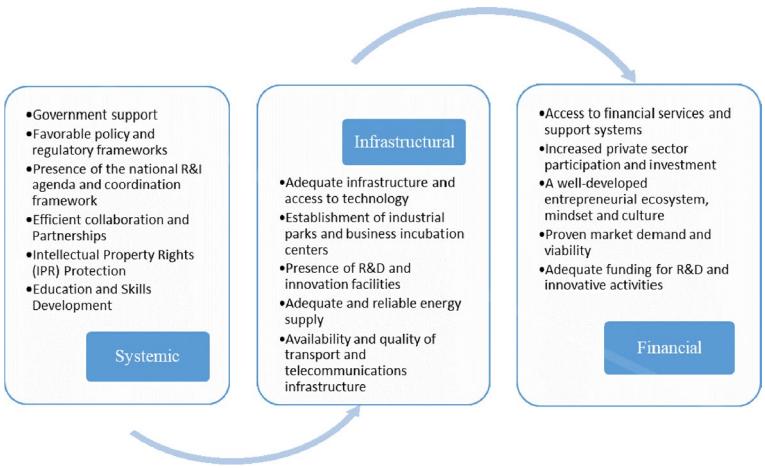

Fig. 17 Systemic, infrastructural, and financial drivers that influence the commercialization of innovations (Source: Authors)

and incubators. The government provides financial and technical support to creative companies through grants, subsidies, tax breaks, and R&D financing (Atwine et al., 2023). Public organizations in Uganda, such as the Uganda Development Bank (UDB) and the Uganda National Council for Science and Technology (UNCST), offer financial and technical assistance to support commercialization efforts, as indicated by (NPA, 2020). The GOU needs to foster an environment that nurtures the success of innovators and entrepreneurs by offering incentives, such as tax cuts, grants, and subsidies.

Favorable policy and regulatory frameworks

It is of utmost importance that policy and legal frameworks be established to promote the commercialization of groundbreaking innovations. This requires the implementation of comprehensive and supportive legislation, robust intellectual property protection, streamlined business registration processes, and R&D incentives. According to Nahikiriza (2023), such measures are essential to enable innovators to bring their ideas to fruition. Governments can further encourage the commercialization of breakthroughs through initiatives such as offering tax breaks for R&D, providing innovation grants, and implementing public procurement programs that prioritize innovative solutions. Governments play a crucial role in fostering an environment that encourages investment, risk-taking, and entrepreneurship.

Presence of the national R&I agenda and coordination framework

The allocation of resources for R&D is a crucial component in determining the success of innovation and is shaped by a country's national R&I agenda and coordination structure (Schwab & Zahidi, 2020; Sithole, 2020). Both government and corporate sectors must prioritize R&D to encourage the development of innovative ideas, products, and services (Hogan et al., 2022). The availability of funding for experimental R&D is a critical factor in determining the success of innovation; therefore, the Ugandan government, in collaboration with development partners, should invest more resources in R&D to foster innovation and commercialization.

Efficient collaboration and partnerships

Collaboration among various stakeholders, including the government, academia, business, and international organizations, is crucial for fostering the commercialization of innovations. Partnerships enhance the likelihood of successful commercialization by facilitating information exchange, resource mobilization, and market access. Public private partnerships (PPPs) are vital in boosting innovation, productivity acceleration, and commercialization in Uganda by leveraging the capabilities and links between the public and private sectors (Salmon et al., 2020; Sendawula et al., 2023). The government can collaborate with private sector enterprises to fund and provide expertise for new initiatives involving partnerships between existing corporations and startups, as well as investments from both domestic and foreign companies. The private sector's involvement not only provides financial resources, but also knowledge, networks, and market access, which accelerates the commercialization process. To support R&D, the private sector can provide funds and investments, whereas the government can offer grants and subsidies. This contributes to an environment that fosters both creativity and

entrepreneurship. Uganda's engagement in regional and international trade agreements and partnerships enables access to larger markets, attracts foreign investment, and promotes knowledge transfer, resulting in the commercialization of innovations.

Intellectual property rights (IPR) protection

Intellectual property rights (IPR) play a crucial role in encouraging innovation and creativity by protecting inventors' ideas and innovations against unlawful use or replication (Pererva et al., 2024). A strong legal framework for patents, trademarks, copyrights, and other forms of intellectual property protection fosters an environment conducive to the commercialization of inventions, thereby promoting economic growth and development. Uganda has been striding to strengthen its intellectual property rules and regulations, which has helped build confidence among inventors and attract investment. The national IP policy addresses various essential issues, including IPR enforcement and IP commercialization, and the implementation of the IP strategy requires increased human and financial resources (MOJCA, 2019). Policymakers must continue to emphasize the importance of IPR in driving innovation, transformation, and growth.

Education and skills development

Uganda's education and research systems play a pivotal role in fostering innovation and commercialization (Tweheyo et al., 2024). The development of a skilled workforce and the cultivation of entrepreneurial talent are of utmost importance for the commercialization of innovations. The Government of Uganda (GoU) and educational institutions are making concerted efforts to enhance science, technology, engineering, and mathematics (STEM) education and establish training programs for entrepreneurship. By investing in R&D, the country may uncover new technologies, develop new products and services, and create new commercialized business models (Lenihan et al., 2023). Collaboration among the government, universities, and other research organizations is essential for creating an environment that promotes innovation and commercialization.

Infrastructural promoters and challenges to innovation commercialization in Uganda

Infrastructure drivers who contribute to the successful commercialization of innovations are fundamental elements of a supportive infrastructure. These drivers play a crucial role in creating an environment that fosters the growth, adoption, and diffusion of innovative technologies, goods, and services in the market. R&I infrastructure is essential for facilitating the entire process of transforming an idea into a commercial product (Kwesiga, 2019; Ogwang & Vanclay, 2021; Pius & Owin, 2024). These infrastructure components are interrelated and mutually reinforcing, promoting an environment conducive to innovation and supporting the successful commercialization of innovative ideas, technologies, and products in the marketplace. These include the following:

Adequate infrastructure and access to technology

Infrastructure is a crucial element of innovation and commercialization in any country. In Uganda, transportation and energy infrastructure are of utmost importance in facilitating innovation and commercialization. Uganda has made commendable progress

in modernizing its infrastructure, including transportation, communication networks, and electrical availability (Ogwang & Vanclay, 2021; Pius & Owin, 2024). The increasing use of mobile phones and Internet access has also opened opportunities for technological advancement. However, the country's transportation infrastructure remains insufficient with limited rail links and inadequate road networks. Enhancing transportation and logistics can help businesses operate more efficiently by facilitating the movement of goods and services across the country, thereby lowering costs and improving efficiency.

Establishment of industrial parks and business incubation centers

The establishment of industrial parks and business incubators has a positive impact on the commercialization of ideas. Studies by Kwesiga (2019) and Atwine et al. (2023) indicate that these facilities offer shared infrastructure, including cost-effective office spaces, labs, testing facilities, and manufacturing units, which can aid entrepreneurs and innovators in reducing expenses. A robust technical infrastructure is crucial for the commercialization of inventions, encompassing access to advanced technologies, ICT systems, high-speed Internet connectivity, and digital platforms that support multiple stages of the innovation process, including research, development, manufacturing, marketing, and sales.

The presence of R&D and innovation facilities

The existence of R&D facilities, universities, and research institutes supports the commercialization of innovations by fostering an environment of information sharing and technological growth through collaboration among academics, inventors, and entrepreneurs (Bowman, 2019; Pius & Owin, 2024). Academic institutions, research groups, and private enterprises are all actively engaged in R&D, resulting in the creation of new technologies and solutions that can be commercialized. The support and resources provided by institutions and organizations that support inventors and entrepreneurs, such as company incubators, technology transfer offices, innovation centers, research institutes, industry associations, and networks that offer mentorship, training, market information, and business development services, are crucial for commercialization success.

Adequate and reliable energy supply

Reliable power availability is of the utmost importance for businesses, particularly those that rely on technology and industry (Bakhtiar et al., 2020). Access to dependable and affordable electricity enables developers to test innovative technology, power critical machinery, equipment, and technological devices utilized in many companies and minimize operating expenses while enhancing productivity. Although Uganda has made significant progress in expanding its access to electricity in recent years, more effort is necessary to ensure a continuous and affordable power supply (Fashina et al., 2018).

Availability and quality of transport and telecommunications infrastructure

Transport infrastructure plays a vital role in the delivery of goods and services, and well-developed road networks, trains, ports, and airports are critical for product transportation to local and global markets (Bakhtiar et al., 2020; World Bank, 2018). An

improved transportation infrastructure can minimize logistical obstacles, reduce costs, and improve market access to new products. A study by Bowman (2019) indicated that communication technology is also essential for both invention and commercialization, and access to information about new ideas, goods, and services is made possible through communication technology. Dependable and economical communication networks are necessary to support e-commerce platforms, digital transactions, and distribution of information. Entrepreneurs and innovators may use the internet to learn about global trends, R&D, and best practices. While Uganda has made considerable progress in expanding its mobile and Internet networks, more work needs to be done to ensure that these technologies are available to all Ugandans, particularly those living in rural regions.

Financial incentives and constraints to innovation commercialization in Uganda

According to the World Bank (2021), financial incentives for innovation commercialization are crucial elements that determine the success or failure of transforming creative ideas or technologies into profitable products or services. These components are integral to the financial aspects of commercialization and are inseparable from the process. The interaction between financial drivers and non-financial elements, such as technical readiness, market demand, regulatory environment, and organizational skills, significantly impacts the success of innovation commercialization initiatives. These include the following.

Access to financial services and support systems

Entrepreneurs and innovators require funding from well-functioning banking systems, venture capital firms, investors, and microfinance organizations. Adequate financing is necessary for entrepreneurs and inventors to convert their ideas into commercially viable goods and services (Omri, 2020; Varaksa et al., 2021). Financial institutions, venture capitalists, investors, and crowdsourcing platforms can finance R&D, prototype development, scaling-up manufacturing, marketing, and other commercialization operations. The financial industry in Uganda is underdeveloped, with limited access to loans and a low degree of financial literacy (NPA, 2020; World Bank, 2021). A strong financial system that fosters startups and small businesses is necessary in Uganda. The government can help by enacting regulations that make it easier for entrepreneurs to obtain funding as well as by providing grants and loans to promote new ideas and encourage venture capitalists and investors to invest in local firms.

Increased private sector participation and investment

Typically, investors and stakeholders are concerned with the prospective return on their investments. The capacity of an innovation to produce a financial return and provide a competitive advantage significantly impacts its chances of commercialization. A comprehensive business plan accompanied by a compelling financial projection outlining the predicted return on investment (ROI) can attract investors and facilitate the commercialization process. Entrepreneurs and inventors require access to venture capital to commercialize their ideas (Stubbs et al., 2022; World Bank, 2021). To foster an environment that encourages venture capital firms to participate in Ugandan

start-ups and techno-business ventures, Uganda's government and the private sector should collaborate. To encourage investors to invest in innovative ventures in Uganda, the government can offer tax incentives such as breaks, holidays, and reduced tax rates. These incentives encourage investors to engage in creative initiatives.

A well-developed entrepreneurial ecosystem, mindset, and culture

It can be stated that Uganda's social and cultural structures have the potential to foster innovation and commercialization. Uganda's entrepreneurial attitude and culture are growing and providing a supportive climate for the commercialization of ideas (Okumu & Buyinza, 2020; Salmon et al., 2020). Many individuals embrace entrepreneurship and take risks in creating and promoting novel products and services. Entrepreneurship should be recognized as a legitimate career option, and society should acknowledge and reward inventors and entrepreneurs who generate employment and drive economic progress. The commercialization of ideas can be facilitated by a well-developed entrepreneurial ecosystem, which includes incubators, accelerators, mentorship programs, and networking platforms. These mechanisms can connect entrepreneurs to expertise, business development resources, and potential investors, helping them navigate the financial challenges of commercialization.

Proven market demand and viability

The commercial success of an innovation is predicated on its market demand and feasibility. Innovators must demonstrate the economic viability of their goods and services, including market size, consumer preferences, competitive advantages, and revenue generation potential. Studies show that it is imperative to understand the target market's demands and preferences to achieve successful commercialization of inventions (Ajer et al., 2023; Sendawula et al., 2023). Ugandan entrepreneurs are increasingly focusing on developing products and services that cater to the local market. The size of the target market and its potential for expansion are critical considerations for investors and organizations seeking to commercialize inventions. A larger market with strong growth potential provides an attractive proposition for commercialization, offering opportunities for better profits and increased scalability.

Adequate funding for R&D and innovative activities

Adequate financing for R&D activities is crucial for creating commercially viable ideas and prototypes. R&D activities can be supported by funding from government agencies, research institutes, universities, and international organizations, enabling inventors to produce commercially viable solutions. Uganda has seen an increase in both local and foreign investment prospects, with the government and private investors providing financial support to startups and innovative initiatives (Sendawula et al., 2023; World Bank, 2021). To further encourage these activities, the government, in collaboration with the private sector, should support R&D, establish a favorable climate for venture capital, provide tax breaks, promote public private partnerships (PPP), and guarantee that appropriate rules and regulations protecting intellectual property rights (IPRs) are in place.

Recommended strategies to overcome the systemic, infrastructural, and financial barriers

Improving systemic coordination within the R&I ecosystem can not only reduce ecosystem fragmentation, but also enhance the efficiency of infrastructural investments and financial resource allocation. A holistic policy approach that simultaneously addresses systemic coordination, infrastructure development, and financial support mechanisms is crucial for closing the existing gaps.

Strategies to overcome systemic barriers to innovation commercialization

Firms and policymakers must recognize and tackle systemic obstacles that hinder the commercialization of innovations to foster an environment that encourages the application of creative ideas. To address the fundamental challenges faced by the research and innovation sector, a comprehensive strategy encompassing multiple policies and approaches must be employed to overcome the interrelated systemic hurdles, as highlighted by Fashina et al. (2018) and Perry (2020). The following measures and actions are recommended to overcome these systemic gaps.

Develop regulatory frameworks

It is imperative that the government establish regulatory structures that foster research and innovation, including regulations that encourage public private partnerships, protect intellectual property rights, and support inventors by providing a conducive operating environment.

Enhancing collaboration between academia and industry

The connection between academia and industry must be reinforced to promote innovation and technology transfer. This can be achieved by inviting industry to participate in R&D, creating technology transfer offices within universities and research institutes, and promoting collaborative research initiatives between academia and industry. These collaborative efforts may take the form of joint research projects, internships, and exchange programmes. By fostering these relationships, technology and knowledge can be more effectively transferred between the two sectors, leading to increased innovation and commercialization.

Strengthening Intellectual Property Rights (IPRs) protection

The enactment of more stringent rules and regulations by the government can significantly enhance the protection of Intellectual Property Rights (IPR). This measure will help safeguard the intellectual property of creative startups and small enterprises, which, in turn, will attract additional investors to the industry in the long run. The implementation of laws that promote the creation, protection, and commercialization of intellectual property as well as the establishment of an effective patent registration and enforcement system will facilitate this process.

Skills development and capacity building

Uganda must invest in capacity-building initiatives to equip researchers and innovators with the requisite skills and knowledge to thrive in an innovation ecosystem. This

can be achieved through training and mentorship programs, encouragement of international collaboration, and support for the development of professional networks. The curricula for such programs may encompass training in research methods, scientific communication, grant proposal writing, intellectual property rights, and entrepreneurship, among others.

Providing training and mentorship

The utilization of formal training and mentorship programs by government entities may be advantageous for startups and small businesses because it allows students to acquire the expertise and information necessary to effectively promote their innovative notions. The removal of structural barriers in Uganda necessitates a protracted dedication to policies and processes that foster collaboration, creativity, and technology transfer.

Strategies to overcome infrastructural challenges to innovation commercialization

An effective support infrastructure is imperative for the transition of innovative ideas to market-ready solutions. To address the infrastructural challenges in Uganda, a thorough strategy comprising of diversified tactics and policies must be implemented (Kwesiga, 2019; Pius & Owin, 2024). To address the infrastructure gaps in the commercialization of inventions at research and innovation institutions, the following methods and actions are proposed:

Improved access to advanced technology

The government must forge partnerships with developed nations to acquire cutting-edge technologies that can contribute to R&I. In addition, the creation of scientific parks and technology centers can foster an environment that encourages innovators to utilize these new technologies.

Strengthening R&D and innovation institutions

Uganda must prioritize the establishment of well-equipped R&D institutions that can engage in effective collaboration and knowledge sharing. To achieve this, a country should increase its investment in R&D, forge partnerships across institutions, and promote interdisciplinary research.

Enhancing infrastructure and technology transfer

Uganda must allocate resources to improve the infrastructure necessary to promote innovation and technology transfers. This includes the creation of data- and information-sharing networks, the establishment of technological parks and centers of excellence, and the implementation of platforms for knowledge exchange and cooperation.

Improving communication and dissemination of research

The promotion of open-access repositories for the dissemination of research and innovation findings is a matter of great importance. Such repositories, in conjunction with forums for the exchange of information between academics and innovators, can enhance communication and foster cooperation. Therefore, the government must support the establishment and maintenance of these resources.

Strategies to overcome financial constraints to innovation commercialization

The correlation between financial obstacles and the financial aspects of the commercialization process is substantial and has a significant impact on the market outcome of innovation. Studies indicate that overcoming financial challenges necessitates the implementation of a range of initiatives and policies that address a country's core issues (Sendawula et al., 2023; World Bank, 2021). The following policies and approaches are recommended to overcome financial gaps.

Establishment of specialized innovation financing institutions

To provide financial support to creative startups and small enterprises, the government can establish specialized innovation financing entities such as venture capital firms, angel investor networks, and innovation funds. These organizations can offer various forms of financing, including seed investment and venture capital, to assist businesses in commercializing their unique ideas.

Promoting entrepreneurship and innovation

Uganda must create an enabling environment for entrepreneurship and innovation by ensuring access to finance, providing support for incubation centers and innovation hubs, and implementing regulations that foster entrepreneurship and innovation.

Increased funding for research and innovation

The government of Uganda must augment its financial support for research and innovation to foster the development of critical infrastructure, establish centers of excellence for research, and provide grants to innovators. Given the critical barrier to insufficient innovation financing identified in our findings, we propose the establishment of a national innovation fund as a direct countermeasure to enhance the availability of financial resources for R&I institutions.

Providing tax incentives

The government should offer tax incentives to investors who invest in innovative startups and small enterprises. This initiative would encourage greater private investment in research and commercialization, thereby fostering the growth of Uganda's innovation ecosystem.

Promoting access to finance

Through the implementation of credit guarantee schemes, reduced collateral requirements, and simplified loan application processes, governments may enhance access to capital for startups and small businesses. This could result in more startups and small businesses obtaining financing, leading to increased innovation and commercialization.

The findings provide valuable insights into the systemic, infrastructural, and financial drivers and barriers that impact the successful commercialization of innovations at R&I institutions in Uganda. Such knowledge is essential for the formulation and implementation of inclusive innovation and commercialization policies (Fashina et al., 2018; Nahikiriza, 2023). Moreover, R&I institutions can utilize the study's results to

establish and enhance connections and collaborations with one another. Additionally, the study adds to the existing body of knowledge on the commercialization of innovations using an integrated systemic, infrastructural, and financial approach in developing countries, particularly in Africa, where limited research has been conducted in this area.

Conclusion

Theoretical implications

While the Triple Helix model emphasizes the role of university-industry-government collaborations in fostering innovation ecosystems (Noya & Taneo, 2023; Zhuang et al., 2021), this study's findings on the fragmentation of the R&I ecosystem in Uganda and inadequate support infrastructure highlight a critical gap in the model's applicability to developing countries. Specifically, the study reveals a disconnection between policy intentions and on-the-ground realities, suggesting that the Triple Helix model may need adjustments to reflect the challenges faced in these contexts more accurately.

Moreover, findings on financial barriers, including reliance on external funding and the lack of a national research fund, point to a significant gap in the literature on financing innovation in developing countries (Moon, 2022; Salmon et al., 2020). This study contributes to theoretical understanding by illustrating the complexities and challenges of securing sustainable financing for innovation in environments where government support may be inconsistent and external funding sources play a dominant role. These insights could inform the development of new theoretical frameworks or the refinement of existing models to better account for the financial realities of innovation commercialization in similar settings. Currently, there is no formal mechanism for funding long-term research and innovation because of the government's shifting priorities and absence of an approved framework for innovation and research.

Tweheyo et al. (2024) indicate that institutional elements play a crucial role in university commercialization processes, with an emphasis on patent policies, revenue distribution systems, and entrepreneurial education for researchers. This perspective aligns with the work of Min et al. (2020), which emphasizes the significance of TTOs in enhancing commercialization success rates at research universities through appropriate organizational structures and entrepreneurial initiatives. Namugenyi et al. (2023) presents an alternative viewpoint by examining the potential adverse effects of innovation, specifically how the implementation of biomass technology innovations may lead to the erosion of traditional cooking practices, thereby affecting the subjective well-being of households. This insight underscores the necessity of considering socio-cultural contexts in the commercialization process, as innovations may have unanticipated consequences on societal norms and customs.

The conceptual implications suggest that the effective commercialization of innovations within Uganda's research and innovation sectors necessitates a comprehensive strategy. Critical factors contributing to success include institutional elements, such as conducive policies and frameworks, entrepreneurship education, and the role of TTOs (Tweheyo et al., 2024). Furthermore, it is imperative to assess the societal and cultural implications of innovation, as these factors can influence public acceptance and overall well-being (Namugenyi et al., 2023). These findings enhance

our understanding of the commercialization process and identify areas for further investigation and policy development (Namugenyi et al., 2023; Tweheyo et al., 2024).

Policy implications

Policies must address knowledge gaps in understanding the specific regulatory barriers that most significantly impede the commercialization process, such as stringent intellectual property laws that deter rather than encourage innovation. There is a critical knowledge gap in identifying which R&D infrastructural elements most significantly enhance commercialization outcomes, necessitating targeted studies to inform infrastructure development policies (Nahikiriza, 2023; Pius & Owin, 2024). Policies must be informed by a deeper understanding of the factors that motivate or deter private sector investment in R&I, particularly in developing countries, such as Uganda, where economic conditions differ significantly from those in developed economies.

A significant knowledge gap exists in identifying effective and sustainable financing models for innovation that combine government funding, private investment, and international partnerships (Salmon et al., 2020; Sendawula et al., 2023). Future policies should be informed by research into successful models in similar economies. There is a need for empirical research on the most effective mechanisms for implementing innovation policies in Uganda, including stakeholder engagement strategies, policy communication, and the role of intermediaries in bridging the gap between policymakers and R&I institutions. Policymakers and stakeholders must strengthen the legal and regulatory framework for innovation, intellectual property protection, and commercialization and ensure effective enforcement of existing restrictions to enhance the R&I ecosystem in Uganda.

The research conducted by Tweheyo et al. (2024) emphasizes the importance of institutional factors, including patent policies, revenue-sharing frameworks, and the necessity of developing entrepreneurial skills among researchers. These elements play a crucial role in enhancing the commercialization of university research outputs. Similarly, Onapa et al. (2020) and Nahikiriza (2023) highlight the significance of well-coordinated STI policies among various stakeholders. They suggest that political commitment and initiatives such as the Millennium Science Initiative can foster innovation. However, challenges have been identified, including the absence of a cohesive system for STI policy coordination and the underdeveloped state of technology advancement and commercialization within academic institutions.

Namugenyi et al. (2023) elucidated the unanticipated negative consequences of biomass technology innovation on the perceived well-being of Ugandan households. This finding underscores the significance of policymakers, considering both the advantages of bioenergy advancements and the welfare of those utilizing technology. This further emphasizes the necessity for policies that achieve equilibrium between technological progress and sociocultural values. For efficient innovation commercialization in Uganda, policymakers should prioritize establishing supportive institutional structures, enhancing researchers' entrepreneurial capabilities, and ensuring well-coordinated STI policies (Onapa et al., 2020; Tweheyo et al., 2024). Moreover, policies should aim to foster an environment that facilitates collaboration between the public and private

sectors, while addressing the specific requirements and challenges encountered by research and innovation institutions within the country.

Ideas for future research

Future research should focus on developing an empirical framework for measuring the direct impact of private sector collaboration on innovation commercialization success in Uganda. This could help in designing targeted interventions that leverage private sector strengths for R&I commercialization (Stubbs et al., 2022). Future research could focus on identifying effective models for public private partnerships in the R&I ecosystem that enhance commercialization outcomes in Uganda. This would not only highlight a knowledge gap but also direct future research towards a critical area that could support the commercialization process.

Based on the noted challenge of financing long-term research and innovation due to shifting government priorities, future research could investigate how fluctuations in government support impact the sustainability of long-term research and innovation projects in Uganda, and what alternative financing models can ensure their continuity (Ali et al., 2023; Varaksa et al., 2021). The role of digital transformation in enhancing the commercialization process at R&I institutions in Uganda, and a comparative analysis of the commercialization process in R&I institutions across East African countries could potentially be explored. While Uganda has made notable progress in fostering an R&I environment that promotes innovation and commercialization, there is still room for improvement. Uganda offers numerous opportunities for enhanced research and innovation. The growing demand from stakeholders necessitates the fortification of institutional capacity through the implementation of novel models of institutional transformation and growth, which requires further research.

Research suggests that the commercialization process is significantly influenced by a combination of internal and external elements, as well as the specific innovation context (Musabayana et al., 2023; Palinkas et al., 2023; Shcherbachenko & Kotenko, 2022). Several studies have identified broad obstacles, such as transaction expenses, institutional management, and uncertainties related to innovation (Kavaarpuo, 2022). Conversely, others have focused on sector-specific factors, including the impact of social influences and behavioral regulation in healthcare (van der Zanden et al., 2024), and environmental and organizational challenges in the mining industry (Ediriweera & Wiewiora, 2021). Furthermore, researchers have emphasized the importance of examining the interplay between obstacles, facilitators, and various innovation outcomes (Stornelli et al., 2021).

Future research endeavors should focus on developing a comprehensive model that integrates diverse perspectives and addresses the specific challenges faced by Ugandan research and innovation entities. This model should encompass industry-specific barriers and facilitators, the influence of organizational leadership, and the impact of societal and psychological factors on innovation adoption (Pius & Owin, 2024). Furthermore, the role of technological advancements in the commercialization of innovations such as Cloud ERP merits further investigation (Ali et al., 2023). Research methodologies can be enhanced through the application of theoretical frameworks, including the theoretical domain framework (van der Zanden et al.,

2024), to systematically examine the relevant factors. Ultimately, the research findings should inform the development of targeted strategies to overcome identified barriers and leverage enablers for successful innovation commercialization in Uganda.

Limitations of the study

While this study provides in-depth insights into the Ugandan context, it acknowledges the limitations in its applicability to other developing countries without considering their unique socio-economic, regulatory, and technological landscapes. Future research could expand this study's framework to other contexts to validate the universality of identified drivers and barriers. This study's cross-sectional design limits its ability to capture the dynamic nature of innovation commercialization barriers and drivers over time. Longitudinal research is recommended to understand how these factors evolve in response to changes in the national and global economic conditions.

Despite utilizing a mixed-methods approach, this study recognizes the limitations in the depth of the qualitative insights obtained. Future research could employ ethnographic or detailed case studies to delve deeper into the personal experiences and challenges faced by innovators and policymakers in Uganda. This research acknowledges the limitation of capturing the full spectrum of stakeholder perspectives within Uganda's innovation ecosystem, particularly from end-users and the informal sector. Future studies should aim to include these voices to provide a more comprehensive view of the commercialization landscape.

Abbreviations

BFP	Budget framework paper
GERD	Gross expenditure on research and development
EDIC	Engineering Development and Innovation Center
GDP	Gross Domestic Product
GMO	Grants Management Office
GoU	Government of Uganda
ICT	Information and Communication Technology
IP	Intellectual property
IPMO	Intellectual Property Management Office
IPR	Intellectual property rights
ITDT	Innovation, technology development, and transfer
MDAs	Ministries, Departments and Agencies
MTEF	Medium-term expenditure framework
NDP	National Development Plan
NGO	Non-Government Organization
NIS	National innovation system
PPP	Public Private Partnership
R&D	Research and development
R&I	Research and innovation
RoI	Return on investment
SPSS	Statistical Package for Social Scientists
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
STI-OP	Science, Technology and Innovation Secretariat-Office of the President
TT	Technology transfer
TTO	Technology transfer office

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Author contributions

All authors contributed to writing the manuscript and read and approved the final manuscript. RJ and LA analyzed the datasets used for the study and drafted the manuscript, while JBK and NM reviewed and revised the manuscript.

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Data availability
The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Competing interests
The authors declare no conflicts of interest.

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References

Abate, T. W., & Sheferaw, H. E. (2023). Micro, small and medium enterprises and their linkage with key actors in Ethiopia: Developing entrepreneurial ecosystem mapping. *Journal of Innovation and Entrepreneurship, 12*(1), 71.
Abbas, A., Avdic, A., Barker, K. C., & Xiaobao, P. (2018). *Knowledge transfer from universities to industry through university technology transfer offices*.
Abbas, A., Avdic, A., Xiaobao, P., Hasan, M. M., & Ming, W. (2019). University-government collaboration for the generation and commercialization of new knowledge for use in industry. *Journal of Innovation and Knowledge, 4*(1), 23–31. https://doi.org/10.1016/j.jik.2018.03.002
Acebo, E., & Miguel-Dávila, J. -Á. (2024). Multilevel innovation policy mix: Impact of regional, national, and European R&D grants. *Science and Public Policy, 51*(2), 218–235.
African Union Commission. (2014). *STISA-2024 Science, Technology and Innovation Strategy for Africa 2024*. https://au.int/
Agostino, M., Di Tommaso, M. R., Nifo, A., Rubini, L., & Trivieri, F. (2020). Institutional quality and firms' productivity in European regions. *Regional Studies, 54*(9), 1275–1288.
Ajer, B., Ngare, L., & Macharia, I. (2023). Drivers of innovation in the agro-food micro, small and medium enterprises of Uganda. *Journal of Agribusiness in Developing and Emerging Economies*. https://doi.org/10.1108/JADEE-09-2022-0206
Aktar, Most. A., Harun, M. B., & Alam, Md. M. (2021). *Science, Technology, and Innovation (STI) Policy for Sustainable Development* (pp. 1145–1156). https://doi.org/10.1007/978-3-319-95864-4_59
Ali, I., Nguyen, N. D. K., & Gupta, S. (2023). A multi-disciplinary review of enablers and barriers to Cloud ERP implementation and innovation outcomes. *Journal of Enterprise Information Management, 36*(5), 1209–1239.
Al-Shammari, M., & Waleed, R. (2018). Entrepreneurial intentions of private university students in the kingdom of Bahrain. *International Journal of Innovation Science, 10*(1), 43–57.
Arora, P., & Chong, A. (2018). Government effectiveness in the provision of public goods: The role of institutional quality. *Journal of Applied Economics, 21*(1), 175–196.
Asad, M., Asif, M. U., Sulaiman, M. A. B. A., Satar, M. S., & Alarifi, G. (2023). Open innovation: The missing nexus between entrepreneurial orientation, total quality management, and performance of SMEs. *Journal of Innovation and Entrepreneurship, 12*(1), 79.
Atwine, B., Okumu, I. M., & Nnyanzi, J. B. (2023). What drives the dynamics of employment growth in firms? Evidence from East Africa. *Journal of Innovation and Entrepreneurship, 12*(1), 33.
Bakhtiar, A., Aslani, A., & Hosseini, S. M. (2020). Challenges of diffusion and commercialization of bioenergy in developing countries. *Renewable Energy, 145*, 1780–1798. https://doi.org/10.1016/j.renene.2019.06.126
Baláž, V., Jeck, T., & Balog, M. (2023). Firm performance over innovation cycle: Evidence from a small European economy. *Journal of Innovation and Entrepreneurship, 12*(1), 1–23.
Bowman, W. M. (2019). Technological Distribution in Uganda: Information and Communications Technology and the State in an Eastern African Nation. *Review of Policy Research, 36*(6), 835–865.
Butnik-Siverskyi, O., Kirin, R., Doroshenko, O., & Dorozhko, H. (2024). Devising An Economic legal Approach To The Viability Of Innovative Technology Transfer In The Process Of Its Commercialization. *Eastern-European Journal of Enterprise Technologies*.
Cai, Y., & Etzkowitz, H. (2020). Theorizing the triple helix model: Past, present, and future. *Triple Helix, 7*(2–3), 189–226.
Chane, M., & Atwal, H. (2023). The entrepreneurial ecosystem and the performance of micro and small enterprises (MSES) In Amhara Region, Ethiopia: The Political-Legal Perspective. *Journal of Developmental Entrepreneurship, 28*, 2350020.
Chen, J., Yin, X., & Mei, L. (2018). Holistic innovation: An emerging innovation paradigm. *International Journal of Innovation Studies, 2*(1), 1–13.
Ecuru, J., Lating, P. O., & Trojer, L. (2014). Innovation characteristics of formal manufacturing firms in Uganda. *African Journal of Science, Technology, Innovation and Development, 6*(5), 415–423.
Ediriweera, A., & Wiewiora, A. (2021). Barriers and enablers of technology adoption in the mining industry. *Resources Policy, 73*, 102188.
Fashina, A., Mundu, M., Akiyode, O., Abdullah, L., Sanni, D., & Ounyesiga, L. (2018). The drivers and barriers of renewable energy applications and development in Uganda: A review. *Clean Technologies, 1*(1), 9–39.
Fosci, M., Lucia Loffreda, A. C., & Naidoo, N. (2019). *Assessing the needs of the research system in Uganda. October*.

Fudickar, R., & Hottenrott, H. (2019). Public research and the innovation performance of new technology based firms. *The Journal of Technology Transfer, 44*(2), 326–358.
Fuentelsaz, L., González, C., & Maicas, J. P. (2019). Formal institutions and opportunity entrepreneurship. The contingent role of informal institutions. *BRQ Business Research Quarterly, 22*(1), 5–24.
Geissinger, A., Laurell, C., Sandström, C., Eriksson, K., & Nykvist, R. (2019). Digital entrepreneurship and field conditions for institutional change–Investigating the enabling role of cities. *Technological Forecasting and Social Change, 146*, 877–886.
Gong, T., Sullivan, B. N., & Tang, Y. (2021). Internal power dynamics: Impact of government innovation policies on firm commercialization. *Academy of Management Proceedings, 2021*(1), 14524.
Hogan, T., Humphery-Jenner, M., Huong, T. T. L., & Powell, R. (2022). Market dominance, R&D grant funding, and innovation outcomes. *R&D Management, 52*(4), 768–796.
Holliday, A. (2014). *Doing and writing qualitative research*. Sage. https://doi.org/10.4135/9781446287958
Kavaarpuo, G. (2022). Institutional governance of innovation adoption in residential developments: future research directions. *A Research Agenda for Real Estate*, 245–262.
Kesselring, M., Kirsch, M., Wagner, F., & Gloaguen, R. (2023). Knowledge and technology transfer in and beyond mineral exploration. *Journal of Innovation and Entrepreneurship, 12*(1), 74.
Khelfaoui, M., & Bernier, L. (2023). Research and technology organizations as entrepreneurship instruments: The case of the Institut National d'Optique in the Canadian optics and photonics industry. *Journal of Innovation and Entrepreneurship, 12*(1), 52.
Kreiterling, C. (2023). Digital innovation and entrepreneurship: A review of challenges in competitive markets. *Journal of Innovation and Entrepreneurship, 12*(1), 49.
Kruachottikul, P., Dumrongvute, P., Tea-makorn, P., Kittikowit, S., & Amrapala, A. (2023). New product development process and case studies for deep-tech academic research to commercialization. *Journal of Innovation and Entrepreneurship, 12*(1), 48.
Kurekova, L., Cermakova, K., Hromada, E., & Kaderabkova, B. (2023). Public funding in R&D and R&D outcome sustainable development: Analysis of Member States EU. *International Journal of Economic Sciences, 12*(2), 40–62.
Kurpayanidi, K. (2021). National innovation system as a key factor in the sustainable development of the economy of Uzbekistan. *E3S Web of Conferences, 258*, 5026. https://doi.org/10.1051/e3sconf/202125805026
Kwesiga, G. C. (2019). Business incubation–Uganda's experience: the interface between industrial and agribusiness incubation. *Guidelines for Authors Agriculture for Development*, 41.
Lenihan, H., Mulligan, K., Doran, J., Rammer, C., & Ipinnaiye, O. (2023). R&D grants and R&D tax credits to foreign-owned subsidiaries: Does supporting multinational enterprises' R&D pay off in terms of firm performance improvements for the host economy? *The Journal of Technology Transfer, 49*, 1–42.
Lester, J. N., Cho, Y., & Lochmiller, C. R. (2020). Learning to do qualitative data analysis: A starting point. *Human Resource Development Review, 19*(1), 94–106.
Loganathan, M., & Subrahmanya, M. H. B. (2022). *Agricultural Technology Commercialization to Entrepreneurial Startups: Case study on Networking*.
Manly, B. F. J. (2015). *The design and analysis of research studies*. Cambridge University Press. https://doi.org/10.1017/CBO9780511608384
Martins, J. M., Shahzad, M. F., & Xu, S. (2023). Factors influencing entrepreneurial intention to initiate new ventures: Evidence from university students. *Journal of Innovation and Entrepreneurship, 12*(1), 63.
Mihas, P. (2019). Qualitative data analysis. In *Oxford research encyclopedia of education*.
Min, J.-W., Kim, Y., & Vonortas, N. S. (2020). Public technology transfer, commercialization and business growth. *European Economic Review, 124*, 103407.
Mohannak, K., & Samtani, L. (2014). A Criteria-based Approach for Evaluating Innovation Commercialisation. *DRUID Society Conference 2014*, June 16–18.
MOJCA. (2019). *National Intellectual Property Policy* (Issue May). https://ursb.go.ug/wp-content/uploads/2019/09/National-IP-Policy-Uganda-May-2019.pdf
Moon, B. (2022). Unleash liquidity constraints or competitiveness potential: The impact of R&D grant on external financing on innovation. *European Research on Management and Business Economics, 28*(3), 100195.
Mulumba, O., Kinengyere, A. A., Rugambwa, O. N., Okullo, I., Okaka, D. O., Ojulong, A., Ogwang, J., Eron, L., & Emong, P. (2017). *Analysis of the National Innovation System in Uganda*.
Muriisa, R. K., & Rwabyoma, A. S. (2019). Globalisation and knowledge production in higher education: The impact of internationalisation and liberalisation on university education in Rwanda and Uganda. *Africa Journal of Public Sector Development and Governance, 2*(1), 25–48.
Musabayana, G. T., Mutambara, E., & Ngwenya, T. (2023). Establishment of a Zimbabwe National SME sector: A major priority to enhance the performance of the national economy. *Journal of Innovation and Entrepreneurship, 12*(1), 65.
Nahikiriza, D. (2023). Policy implementation performance in developing countries: The Study of Uganda among East African Countries. *East African Journal of Interdisciplinary Studies, 6*(1), 162–169.
Namugenyi, I., Navrud, S., Scholderer, J., & Tione, S. E. (2023). Do biomass technology innovations improve subjective well-being? Traditional versus improved Cookstoves in Uganda. *Sustainability, 15*(4), 3487.
Noya, S., & Taneo, S. Y. M. (2023). Triple helix innovation ecosystem: The role of small and medium enterprises community in enhancing performance. *Quality Innovation Prosperity/kvalita Inovácia Prosperita, 27*(1), 46–61.
NPA. (2020). National Development Plan III (NDP III). In *National Planning Authority* (Issue January). National Planning Authority.
Nuruzzaman, N., Singh, D., & Pattnaik, C. (2019). Competing to be innovative: Foreign competition and imitative innovation of emerging economy firms. *International Business Review, 28*(5), 101490.
OECD. (2021). *OECD Science, Technology and Innovation Outlook 2021*. OECD Publishing Paris. Retrieved from https://www.oecd.org/sti/science-technology-innovation-outlook/crisis-and-opportunity/STIO-Brochure-FINAL-UDP.pdf
OECD/Eurostat. (2018). Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition, The Measurement of Scientific, Technological and Innovation Activities. *Handbook of Innovation Indicators and Measurement*, *22*, 254. https://doi.org/10.1787/9789264304604-en
Ogwang, T., & Vanclay, F. (2021). Resource-financed infrastructure: Thoughts on four Chinese-financed projects in Uganda. *Sustainability, 13*(6), 3259.

Okumu, I. M., & Buyinza, F. (2020). *Performance of Small and Medium-sized Enterprises in Uganda: the Role of Innovation*. AERC.
Omri, A. (2020). Formal versus informal entrepreneurship in emerging economies: The roles of governance and the financial sector. *Journal of Business Research, 108*, 277–290.
Onapa, M. O., Sebbale, S., & Aguirre-Bastos, C. (2020). *Harnessing science and technology knowledge for sustainability in Uganda*.
Palinkas, L. A., Belanger, R., Newton, S., Saldana, L., Landsverk, J., & Dubowitz, H. (2023). Assessment of adoption and early implementation barriers and facilitators of the Safe Environment for Every Kid (SEEK) model. *Academic Pediatrics, 23*(7), 1434–1445.
Pererva, P., Ievsieiev, A., Maslak, M., Tkachov, M., & Tkachova, N. (2024). Formation of intellectual property commercialization strategies. *Eastern-European Journal of Enterprise Technologies., 1*, 80–91.
Perry, K. K. (2020). Innovation, institutions and development: A critical review and grounded heterodox economic analysis of late-industrialising contexts. *Cambridge Journal of Economics, 44*(2), 391–415.
Pius, N., & Owin, O. L. O. (2024). Integration of Artificial Intelligence in supply chain management: Challenges and opportunities in Uganda. *World Journal of Advanced Engineering Technology and Sciences, 12*(2), 9–12.
Rivera, J. D., & Landahl, M. R. (2019). An environment conducive to bureaucratic innovation?: Exploring the potential for public entrepreneurship within FEMA. *Journal of Urban Management, 8*(2), 272–281.
Salmon, M., Stephen, E., Rose, K. N., & Edward, B. (2020). *The portrait of Uganda's informal sector: What main obstacles do the sector face?*
Sapah, R. M., Ali, M. H., & Ibrahim, R. (2022). Critical Factors in Technology Transfer Office (TTO) Process That Support Successful Technology Transfer Within Research Universities (RUs). *International Journal of Advanced Research in Education and Society, 4*(3), 42–50.
Schwab, K., & Zahidi, S. (2020). *Global competitiveness report: special edition 2020*. Retrieved from https://www.weforum.org/publications/the-global-competitiveness-report-2020/
Sendawula, K., Kisubi, M. K., Najjinda, S., Nantale, H., & Kabbera, S. (2023). The efficacy of entrepreneurial networking and innovation in fostering the performance of small businesses in Uganda. *Journal of Innovation and Entrepreneurship, 12*(1), 88.
Shcherbachenko, V. O., & Kotenko, S. I. (2022). *Analysis of obstacles and success factors of innovation commercialization*.
Sithole, M. (2020). *The African Innovation Outlook III*. Retrieved from https://au.int/en/documents/20200213/african-innovation-outlook-iii
Stornelli, A., Ozcan, S., & Simms, C. (2021). Advanced manufacturing technology adoption and innovation: A systematic literature review on barriers, enablers, and innovation types. *Research Policy, 50*(6), 104229.
Stubbs, W., Dahlmann, F., & Raven, R. (2022). The purpose ecosystem and the United Nations sustainable development goals: Interactions among private sector actors and stakeholders. *Journal of Business Ethics, 180*(4), 1097–1112.
Tahir, M., Gen, L. L., Ali, M., & Asif, M. (2022). A Comparative analysis on the protection of property rights and the intellectual property rights: A Pak-Chinese legal perspective. *International Journal of Law and Politics Studies, 4*(1), 59–64.
Teixeira, S. J., Ferreira, J. J., Wanke, P., & Moreira Antunes, J. J. (2021). Evaluation model of competitive and innovative tourism practices based on information entropy and alternative criteria weight. *Tourism Economics, 27*(1), 23–44.
Tweheyo, G., Abaho, E., Verma, A. M., & Musenze, I. A. (2024). Institutional factors and commercialisation of university research outputs and innovations In Uganda. *International Journal of Social Science & Economic Research, 9*, 385–407.
UNCTAD. (2020). *Policy Review* (Vol. 9, Issue 4). Retrieved from https://unctad.org/publication/science-technology-and-innovation-policy-review-uganda
Uyarra, E., Zabala-Iturriagagoitia, J. M., Flanagan, K., & Magro, E. (2020). Public procurement, innovation and industrial policy: Rationales, roles, capabilities and implementation. *Research Policy, 49*(1), 103844.
van der Zanden, M., Helder, O., Westland, H., & Ista, E. (2024). Barriers and facilitators for the implementation of co-created nursing innovations in a Dutch university hospital. *JBI Evidence Implementation*. https://doi.org/10.1097/XEB.0000000000000444
Varaksa, N. G., Alimova, M. S., Alimov, S. A., Rozhdestvenskaia, E. S., & Konstantinov, V. A. (2021). Mechanisms of Financial Support for the Development of Innovative Entrepreneurship in the Digital Economy. *Economic Issues of Social Entrepreneurship*, 151–160.
Wang, L., Ni, Y., Zhao, Y., & Chen, Y. (2024). The triple helix collaboration: Lessons from a Chinese provincial innovation ecosystem. *Chinese Management Studies., 18*, 1276–1289.
World Bank. (2018). Reforming to Create Jobs. *World Bank Group, Washington*, 1–312. Retrieved from http://www.ngbusiness.org/~/media/WBG/ngBusiness/Documents/Annual-Reports/English/DB2018-Full-Report.pdf
World Bank. (2021). *Uganda Economic Update, 17th Edition, June 2021*. Retrieved from https://documents1.worldbank.org/curated/en/265371623083730798/pdf/Uganda-Economic-Update-17th-Edition-From-Crisis-to-Green-Resilient-Growth-Investing-in-Sustainable-Land-Management-and-Climate-Smart-Agriculture.pdf
Yang, Q., Wang, C., & Jiang, H. (2022). Barriers and drivers of university-industry collaborative innovation based on stakeholder theory. *Academy of Management Proceedings, 2022*(1), 10584.
Zhang, Y., Huang, M., Kim, Y., & Wang, Q. (2023). Government innovation subsidy, monetary policy, and corporate R&D investment: Evidence from China. *Asian Journal of Technology Innovation, 31*(2), 356–374.
Zhu, H., Zhao, S., & Abbas, A. (2020). Relationship between R&D grants, R&D investment, and innovation performance: The moderating effect of absorptive capacity. *Journal of Public Affairs, 20*(1), e1973.
Zhuang, T., Zhou, Z., & Li, Q. (2021). University-industry-government triple helix relationship and regional innovation efficiency in China. *Growth and Change, 52*(1), 349–370.

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