

RESEARCH ARTICLE:

Benefits and Challenges of Research Commercialisation in South Africa: A Systematic Review

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Abstract

In developing countries, there is an increased emphasis on encouraging the commercialisation of research at universities. This triggers universities to adopt a culture of innovation and technological learning at both undergraduate and postgraduate levels. The focus of this review article is to highlight the benefits and challenges faced by researchers in the field of synthetic biology products, biotechnology, agribusiness, Biofuels and phytomedicine in commercialisation. The methodological approach was informed by a selection of electronic databases with a high chance of the selected field in relation to the commercialisation of the research outputs. Google Scholar, PubMed, and Higher Education and Science Technology South Africa Reports for entrepreneurial universities were searched, focusing on 2007 to 2023. The years proved to have played a role in furthering discussions and policy in research on commercialisation in South Africa, the benefits of research commercialisation, challenges of research commercialisation, its determinants, and its impact on academics, universities, and other stakeholders. The review findings suggest that the commercialisation of research is a challenging and complex task to execute, as there are very few cases in South Africa to have a successful academic intellectual property creation, licensing, academic entrepreneurship, and start-up of research. This is placed into context by the fact that the market for high-end products and processes is highly uncertain.

Keywords: commercialisation; entrepreneurship; innovation; technology; South Africa

Introduction

In South Africa, the government has embarked on a long-term project to intervene to increase the country's economic growth and enhance the participation of universities in the economy through innovation for social development. This hunt for innovative answers will reduce the crises faced by South Africa of joblessness, inequality, and poverty. Commercialisation is considered the universities' third mission; universities should play a socio-economic role (Biranvand and Seif, 2020). Research commercialisation is defined as the transfer of knowledge, products and artefacts from a university to society for social or commercial benefit (Cullen *et al.*, 2020). Implementing research findings, prototype development, and commercialisation are the major goals of science, technology, and innovation under the university's Technology, Transfer, and Innovation (TTI) office (Alessandrini *et al.*, 2013). Universities are recently orienting themselves to focus on innovation and entrepreneurialism driven by highly increased unemployed graduates, developing technological innovation and the knowledge economy (Ho and Lee, 2021). Regarding entrepreneurship education, a focus on maximising value creation is typically expressed as activities related to developing new business ventures (Alves and Lourenço, 2023). For instance, the government of Korea has maintained a leading position in research and development (R&D) for economic development by boldly adopting cutting-edge technologies and advanced technologies from foreign

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countries(Cinar *et al.*, 2024). This approach also fosters assimilation and improvement while promoting the development of domestic capacity for technological capabilities. The Korean government have invested more in funding opportunities for R&D; they have funded the Gyeonggi Research Institute (GRI) to operate and manage many large-scale R&D projects, such as national R&D projects, industrial genetic technology development projects, and advanced national R&D projects Acha and Martin (2011); (Yoon, 2014).

The commercialisation of university research has a wide variety of channels for the knowledge to be transferred, such as licensing of patents, university-industry research collaboration, company spin-offs from academic research, as well as start-up companies from students and recently research-trained alums (Kergroach *et al.*, 2018). According to Ho and Lee (2021), an entrepreneurial university is a university anticipated not only to create intellectual impact but to create socio-economic impact through academic research, industrial and social development through collaboration, and to improve regional and national economic growth through the development of entrepreneurial growth in addition to teaching and research (Siegel and Wright, 2015; Ho and Lee, 2021). The commercialisation of research required multiple transformations within the universities, which gave an innovation culture to address the government's calls for universities to be more proactive in technology transfer and innovation (Miller *et al.*, 2018; Guindalini *et al.*, 2021). Based on the 2020 report by South Africa, Higher Education, Science, Technology, and Innovation Institutional Landscape (HESTIIL, 2020: 112) identified several institutional weaknesses within and between some of the key entities systems that hindered the conversion of valuable research into economic output. A set of National System of Innovation (NSI) institutions are either too small, have little impact, are poorly funded, or their location within the NSI is misplaced. To illustrate, the vitally important Technology Innovation Agency (TIA) needs more leadership stature and financial capacity and has largely failed to pursue and achieve the ambitious goal of facilitating and commercialising hundreds of new ventures in advanced technologies. There is a need to incorporate values that are aligned with entrepreneurship within the country's innovation discourse to support the overall thrust of Science, Technology, and Innovation (STI) policies. The multimodal promotion of entrepreneurial values among all population sectors will help create an enabling environment for technology-based enterprise development initiatives (South Africa, Higher Education, Science, Technology, and Innovation Institutional Landscape, 2020: 112) (Academy of Science of South Africa, 2022).

This paper addresses these gaps by presenting a systematic review of the literature on the benefits and challenges of research commercialisation in South Africa. The research questions guiding this paper are twofold: What are the benefits of research commercialisation in South Africa? What are the challenges of research commercialisation in South Africa, with a particular emphasis on sectors such as synthetic biology products, biotechnology, agribusiness, biofuels, and phytomedicine? The literature will detail the advantages and constraints of commercialising research in South Africa, focusing on economic, social, technological impacts, regulatory, ethical, and technical aspects. It will emphasise the importance of policies, infrastructure, and innovation in successfully bringing research from these specialised fields to the market.

Methodology

This systematic literature review was conducted using the Preferred Reporting Items for Systematic Reviews and Narrative Synthesis guidelines (Siddaway *et al.*, 2019). The aim was to critically assess the benefits and challenges of research commercialisation in South Africa. To achieve this, we consolidated results from a select number of studies, extracting findings that are generally applicable and relevant to the South African context. The review began with a clear formulation of the research question, which aimed to explore the benefits and challenges of research commercialisation in South Africa. After that, a systematic approach to search engines that are most likely to provide adequate datasets about the identified field of study and commercialisation narratives in South Africa was adopted. The literature search spanned 2007 to 2023, focusing on key sources such as Google Scholar, PubMed, and suitable reports on Higher Education and Science Technology for Entrepreneurial Universities in South Africa. This comprehensive approach ensured a robust collection of data to support our analysis. Studies were selected based on the predefined eligibility criteria. The selection process involved screening titles and abstracts, followed by a full-text review to confirm the study's relevance.

Our search strategy employed a broad range of keywords to capture the multifaceted nature of research commercialisation among which include: research commercialisation in South Africa; benefits of research commercialisation; challenges of research commercialisation; determinants of research commercialisation; impact

of research commercialisation on academics and universities; commercialisation of synthetic biology products, biotechnology, agribusiness, biofuels, and phytomedicine; and the importance of intellectual property creation, licensing, and academic entrepreneurship in South Africa. The selection process involved screening titles and abstracts, followed by a full-text review to confirm the literature's relevance with the current study.

Strategic Approaches to Research Commercialization: Insights from South Africa

Commercialisation is a primary means through which products and services reach the market and consumers, to improve on their which advances public health and the socio-economy as well as the national competitiveness in the global space. Research commercialisation initiatives generate interest and investment in emerging areas of research, with consequent gains or improvements in research funding, job creation, quality of innovation, growth of industries and economic sustainability of universities. Furthermore, commercialisation helps build university-industry collaborations that are often necessary for the translation of research findings into beneficial products and therapies for public use (Caulfield and Ogbogu, 2015). The commercialisation efforts can be about something other than making a significant profit. Even the largest universities with international reputations for excellence will have only a small number of spin-outs that make substantial profits (Sløk-Madsen *et al.*, 2017). Most ventures make a modest financial return. Instead, commercialisation activities can be a powerful way to enhance and sustain research impact after funding ends where grant funds are limited. To this end, some organisations recognise and reward research commercialisation and build this into performance evaluation for their academic promotion pathway (O'Kane *et al.*, 2021). It is widely acknowledged that turning research outputs into useful, marketable products or services maximises the return on public investment in research activities in the form of economic, social and environmental benefits (Abereijo and Obisanya, 2019). According to some of the factors contributing to the low research commercialisation rate in South Africa, universities lack a commercialisation framework that integrates an incentive system to provide support for researchers.

The HESTILL report indicated that there were several institutional weaknesses both within and between some of the key entities. A set of NSI institutions either needs to be bigger, have little impact, need to be better funded, or have a misplaced location within the NSI. The vitally important TIA is short on leadership stature and financial capacity and has largely failed to pursue and achieve the ambitious goal of facilitating and commercialising hundreds of new ventures in advanced technologies (South Africa, Higher Education, Science, Technology, and Innovation Institutional Landscape, 2020: 112). Although true, the characterisation may be unfair considering the budget that TIA gets allocated. As such, more is needed to enable research commercialisation in universities. The amount of financial support for public universities is still limited because the funding provided by the government and private sectors is focused more on fundamental research (Ramli *et al.*, 2021). The private sector tends to finance research linked to their problems in the industry. Stakeholders within the National Systems of Innovation widely acknowledge the difficulties in accessing funding, which often involves a rigorous and competitive process to secure necessary resources. The sources of financing are mainly from the government, international donors, private sector businesses/industries, banks, and Venture Capital (VC). Currently, the main funders with a sustained impact on the Gross Expenditure on Research and Development (GERD) are the government and businesses. Our VC networks need to be functional enough to help commercialise disruptive innovations. Banks, on the other hand, are too risk-averse (Manzini, 2012; Datta, Saad and Sarpong, 2019; Alexander, 2021). The South African Treasury in 2021 discontinued the Section 12J funding scheme, which was introduced in 2008. Section 12J was a tax deduction scheme for encouraging private entity investments into the establishment of VCs. The minister of finance had pointed out that the scheme had not "sufficiently" achieved its objectives of developing small businesses, generating economic activity, and creating jobs. While it may have been justified to discontinue the scheme, the problem remains that the South African innovation ecosystem needs a thriving VC community to help more start-ups succeed in getting funding (Zuccollo, 2021: 1).

The most recent RandD statistics on the researcher capacity of the country suggest a positive picture. The number of researchers has increased over the past five years. However, a closer inspection of these numbers shows that most of this increase is an output of articles and review articles, none on commercialisation (Pillay and Qhobela, 2019; Wenham *et al.*, 2021). The wording by Mouton needs to be clarified as to whether the finding is that none of the published articles were commercialised or none of them were addressing commercialisation as a topic. Research institutions must support commercialisation efforts for the various innovation types with the correct approach. In the literature, there are multiple descriptions of the types of innovations to consider in the commercialisation effort. Peter Drucker was one of the first to describe seven types of innovations that have

implications on how they can be commercialised (Drucker, 2019). There are several more conceptual listings and mappings for different kinds of innovations. The types of innovation for consideration for the report are best-suited descriptions defined as the Innovation Management Matrix. This mapping is a framework to say how well-defined the innovation is used in research commercialisation and who is best placed to help the process come to fruition. Find the appropriate industry partners for the right innovation approach. If the industry needs breakthrough solutions, then form partnerships like those formed in the Mandela Mining Precinct and its forerunner, the Chamber of Mines Research Organization (COMRO) (Meissner and Kotsemir, 2016; Morad *et al.*, 2021; Hartley *et al.*, 2022). COMRO used RandD to solve the mining challenges in South Africa between the 1960s and 1990s [HESTIL Report 2020] (Academy of Science of South Africa, 2022). Furthermore, the appropriate funding strategies must be used for the different types of innovations used in research commercialisation.

University researchers require technical and entrepreneurial skills. Both skills can also lead to difficulties in commercialising university research findings. Besides, unfamiliarity with commercialisation and experience with issues in commercialising activities would be disadvantageous and lead to difficulty in successful marketing research findings (Ramli *et al.*, 2021). According to Bansi (2018), most South African universities' cultures need to catch up in creating IP culture by reflecting low disclosure rates (Bansi and Reddy, 2015). The enabler of academic entrepreneurship is fostered through a multi-level approach that encourages the commercialisation of research. At the national policy level, incentives such as the Patent Incentive Fund (IPF) are guided by the IPR Act of 2008. Institutional policies communicate core values and offer both monetary incentives, like revenue shares for inventors, and non-monetary benefits, including patent recognition in academic evaluations. Lastly, at the individual level, researchers are motivated by monetary rewards from government funds for their publications and inventions, which encompass payments for patents and profits from the commercialisation of research (Olupot, 2009; Wood, 2011; Bansi and Reddy, 2015).

Commercialisation Challenges of Biotechnology, Synthetic Biology, Agribusiness, and Phytomedicine in South Africa

In this section, we present a discussion on constraints in the commercialisation of research products in South Africa within the field of synthetic biology products, biotechnology, agribusiness and phytomedicine. All these sectors share a common constraint: the need for more institutional frameworks and regulatory clarity. This includes sub-optimal linkages between research, industry, and government, as well as the absence of formal definitions and cohesive legislative structures that can lead to regulatory discrepancies and uncertainties (Manzini, 2012; Ndhlovu *et al.*, 2021; Wakweya, 2023). Financial barriers also span across these industries, with inadequate investment from both public and private restricting innovation and development. The nature of venture capital within the sector is risk-averse due to high production costs and limited resources for product development, which are significant barriers that affect growth and commercialisation. Additionally, sustainability and ethical considerations are paramount across the board, especially in the responsible use of biotechnology and the conservation of biodiversity (Harfouche *et al.*, 2021). However, Agribusiness and biofuels sectors both need more infrastructure inefficiencies. Improved logistical infrastructure, such as ports, rail, and roads, is necessary for better market access and performance. (Sinyolo *et al.*, 2019; Terblanche, 2020).

Diverging from these commonalities, each sector faces its own set of challenges. The development of synthetic biology products is not translated immediately outside the lab due to challenges such as enabling long-term storage stability, genetic stability, economics, feasibility, and other technical challenges and operation in resource limit the off-grid scenarios using an autonomous function (Sinyolo *et al.*, 2019; Terblanche, 2020; Brooks and Alper, 2021; Alves and Lourenço, 2023). Biotechnology in South Africa faces significant commercialisation challenges, including inadequate institutional support, insufficient linkages between research entities and industry, a limited skill base due to brain drain, and low investment in RandD (Wolson, 2007: 433). In agribusiness, high transaction costs are identified as the key factor curtailing agricultural commercialisation of smallholder market participation due to liquidity constraints, poor asset endowments, and inadequate access to government support services (Sinyolo *et al.*, 2019). The growth of phytomedicines research commercialisation and related industries has been constrained by a lack of limited resources for product development, a lack of trade networks and limited knowledge about the cultivation of indigenous medicinal plants (Van Wyk, 2011; Street and Prinsloo, 2013; Docrat *et al.*, 2024). For instance, in 2008, the bioprospecting law was adopted in South Africa. The law requires airing a research permit

for anyone conducting applied research and commercial trading involving medicinal plants. The bioprocess laws apply to all medicinal plants (Crouch *et al.*, 2008; Chen *et al.*, 2012).

The commercialisation of biofuels in Africa, particularly in South Africa, is confronted with a series of challenges that span economic and technological domains. The high cost of raw materials, which can constitute up to 80% of production costs, is a significant financial barrier. Technologically, the production of biofuels, especially algal fuels, demands substantial resources such as water and nutrients and faces hurdles in achieving a positive net energy ratio (NER) and energy return on investment (EROI). For algal biodiesel to be viable, it must have a NER greater than 1.0 and an EROI that ideally exceeds 3. Regulatory challenges include outdated governance regarding biomass handling and a need for more focused research on bioenergy, despite some efforts by institutions like the University of KwaZulu-Natal and the CSIR. Addressing these constraints is essential for the successful commercialisation of biofuels, which hold promise as a sustainable energy source (Chisti, 2013; Sheth and Parvatiyar, 2021; Singh and Moodley, 2021).

Implications for Policy and Practice towards the Enhancement of Research Commercialisation in South African Universities

Establishing knowledge-based enterprises, science and technology parks, and entrepreneurship centres in universities will be effective if the commercialised product or knowledge is in demand in South Africa and international markets (Sheth and Parvatiyar, 2021). The idea of granting universities the title to ownership of IP from publicly funded research was brought about with the expectation of increasing commercialisation and affording the country opportunities to participate in global trade and industry activities. For Universities to be successful in research commercialisation, their technology transfer offices (TTOs) need to not only collect, screen, and protect inventions but also develop relationships with industry and understand the many issues affecting inventions within the fields of research in which they are dealing; inventors may thus be a relevant resource in this process given their networks in and knowledge of the appropriate fields and industries (Holgersson and Aaboen, 2019). It would make sense to have TTOs assisting potential start-ups with excess to a bigger consumer base and multiple markets for their innovation.

The entrepreneurial capability of claiming and protecting IP may be challenging in some universities as they may need help to provide funding to support extensive patenting activities. Government grants may also need to be sufficient to support patenting activities (Thomas *et al.*, 2020; Grimaldi *et al.*, 2021). Some scholars have cast doubts on whether scientists should play a leading role in the commercialisation of science through spin-off formation (Thomas *et al.*, 2020). Science-based university spin-offs require significant resources and capabilities in their pre-formation and early post-formation stages. Such endowments result in most university spin-offs failing within a decade of their founding. This paper highlighted the impacts and challenges faced by academic researchers to commercialise their scientific research. The research commercialisation is usually riskier as the markets for taking up the solution tend to need to be clarified. Hence, the innovators will need to pivot several times to find the right solution for the right market. Usually, the domain is clear, and there would be a highly skilled researcher coming up with technology that shows capabilities that can potentially solve consumer problems or even create new industries altogether (Inayah *et al.*, 2011; Putit *et al.*, 2014; Caulfield and Ogbogu, 2015). The support for research commercialisation in this type of innovation would require a setup of Innovation labs, which are hubs, incubators, and accelerators. Beneficial enhancing capacities and quality of service of participating InnoLabs and enabling businesses to seek complete innovation support in a single place (Memon *et al.*, 2022). Some of the researchers as lecturers already have a lot in their laps in terms of schedule requirements for teaching, research work, and supervision of master's and PhD students. As such, it may not be realistic to expect them to commercialise their research successfully.

The commercialisation of research is a challenging and complex task to execute, as there is a rare finding in South Africa to have a successful academic start-up or commercialisation of research. This is placed into context by the fact that the market for high-end products and processes is highly uncertain (Barnard and Rensleigh, 2015; Cullen *et al.*, 2020). The existing market structures and regulatory frameworks hinder the deployment of new products. Therefore, consistent long-term support from the public sector, improved managerial oversight, and superior levels of coordination are crucial to the success of commercialisation (Chimwani *et al.*, 2014; Nepelski and Van Roy, 2021). Thus, this paper recommends that policymakers, practitioners, universities, and researchers increase support from the relative stakeholders in the innovation ecosystem for researcher involvement in commercialisation

activities at an institutional and national level. Central to the discourse on commercialisation within South African Higher Education Institutions is the need for a structural framework for commercialisation that can outline the process steps so that the correct strategy can be followed for different innovations to be pursued. That will give guidance on the necessary discussion on the types of innovation to be commercialised. Drucker (2019: 212) was among the pioneers who described the seven types of innovations that have implications on how they can be commercialised.

Re-establishment of a national patent incentive fund to reward and incentivise researchers for patents granted, like that of a research publication article incentive fund. McMahon and Doyles (2020: 2), in their article about potential European patent law, indicated that patent protection could also act as an incentive for some researchers as this will give them considerable financial benefit (McMahon and Doyle, 2020; Ouellette and Tutt, 2020). Universities face challenges in funding extensive patenting activities. Government grants should adequately support patenting efforts. Scientists' involvement in commercialisation remains a topic of debate. Researchers must have access to basic incubator facilities and services. Successful research commercialisation relies on demand-driven innovation, ensuring that the commercialised product or knowledge addresses specific market needs in South Africa and globally (National Academy of Sciences *et al.*, 2009; Brinn *et al.*, 2022). Researchers are encouraged to collaborate with industrial institutes to identify market applications and patents' commercial value. Long-term public sector support, entrepreneurial skills, and coordination are essential for successful commercialisation. Stakeholders should collaborate at institutional and national levels. Fostering a cross-sectoral by engaging in international collaborations to learn from successful models of commercialisation, such as Brazil's phytomedicine industry and India's Ayurveda research (Palhares *et al.*, 2021). South Africa could foster partnerships between government, academia, and industry to drive the growth commercialisation of their university researchers, as Brazil and India have done.

To effectively commercialise research, universities should leverage the entrepreneurial skills of researchers who have the necessary resources and networks, potentially foregoing the need for incubation support. A feedback mechanism is essential to assess and enhance the support system for commercialisation. Universities must also focus on hiring staff with entrepreneurial and technical expertise to streamline the commercialisation process. Advocacy for increased funding for start-up support agencies and engaging banks for comprehensive start-up assistance is crucial. Lastly, establishing specialised channels for research commercialisation and pairing technically skilled researchers with entrepreneurial minds can drive successful innovation to market.

Conclusion

This review analyses the challenges and strategies enhancing research commercialisation within South African universities in synthetic biology products, biotechnology, agribusiness, biofuel and phytomedicine sectors. To have successful research, commercialisation is multifaceted, and it requires a harmonious blend of policy, practice, and entrepreneurial spirit. Universities within SA need to establish a support ecosystem for patent incentives, incubator facilities, and industrial collaboration and foster international learning model essentials to be successful in commercialisation for the economy of the country. They must foster an innovative environment through adequate funding, strategic partnerships, and recruitment of entrepreneurial skills personnel. By addressing these areas, South Africa can create a thriving landscape for research commercialisation that not only meets local and global market demands but also positions the country at the forefront of scientific and technological advancement. For future researchers in the field, the paper recommends exploring the impact of innovation types on commercialisation processes, the role of international collaborations, the effectiveness of support structures, the sustainability of commercialised projects, and the balance between academic responsibilities and commercialisation efforts. These areas of focus are poised to contribute significantly to the advancement of research commercialisation strategies in higher education institutions.

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