Technology transfer models of universities and public research organisations in South Africa: changes before and after the IPR-PFRD Act of 2008

Ramazan Uctu[1], Hassan Essop[2]*

Abstract

Growing recognition exists in developing countries that technology transfer from public research organisations to the private sector should be part of a long-term strategy that encourages a culture of innovation, technological learning, as well as stimulating the commercialisation of technological innovations. With the same aim as the Bayh-Dole Act (1980), almost twenty-eight years later, the South African government published the Intellectual Property Rights from Publicly Financed Research and Development (IPR-PFRD) Act (Act 51 of 2008). The rationale for the IPR-PFRD Act lies in the widely held view that a more frequent and faster rate of transfer of technologies developed in universities or public research organisations (PROs) to the private sector can significantly accelerate national or regional technological innovation. In this regard, the IPR-PFRD Act explicitly requires designated institutions to establish a TTO. However, even prior to the IPR-PFRD Act, some institutions established TTOs, while some institutions established TTOs after the IPR-PFRD Act was enabled. This study, amongst other aspects, provides overview of the TTO models used in South Africa and investigates the successes of TTOs at universities and PROs, emphasising the nature of their activities and their performance after the introduction of the Act in 2008.

Keywords: Technology transfer; technology transfer offices; universities; public research organisations; South Africa

Submitted: April 13th, 2021 / Approved: August 23rd, 2021

1. Introduction

Growing recognition exists in developing countries that technology transfer from public research organisations to the private sector should be part of a long-term strategy that encourages a culture of innovation, technological learning, and the promotion of the commercialisation of technological innovations. This view is partially based on the success of the United States of America's Bayh-Dole Act. In 1980, the Bayh-Dole Act was enacted with the aim of significantly increasing the commercialisation of technologies that were developed from publicly funded research. Almost twenty-eight years later, the South African government published the Intellectual Property Rights from Publicly Financed Research and Development (IPR-PFRD) Act (Act 51 of 2008) with the same aim as the Bayh-Dole Act; i.e. the goal of promoting the commercialisation of publically funded technologies. The rationale for the IPR-PFRD Act lies in the widely held view that a more frequent and faster rate of transfer of technologies developed in universities or public research organisations (PROs) to the private sector can significantly accelerate national or regional technological innovation. Furthermore, such accelerated technological innovation and subsequent commercialisation is likely to have positive effects on economic growth and potentially employment as well.

However, an appropriate vehicle is required to link public research organisations with the private sector. Typically, the latter function is performed by a technology transfer office (TTO). A TTO can be defined as an institutional mechanism created to promote universities' interaction with the private sector and the government. The need to improve the effectiveness of transferring publicly-funded research results to industry underlies the creation of TTOs. In this regard, the IPR-PFRD Act explicitly requires designated institutions to establish a TTO. However, even prior to the IPR-PFRD Act, some institutions established TTOs, while some institutions founded TTOs after the IPR-PFRD Act was enabled.

Although some attempts were made as early as the 1980s to promote TT activities, it was only during the late 1990s that TTOs were founded at a few institutions. There were six universities and science councils with well-established TT activities (Wolson, 2007; Uctu and Jafta, 2014). In 2008 the "Intellectual Property Rights from Publicly Financed Research and Development, 2008" (henceforth referred to as "the Act") was enacted. The purpose of the Act is, *inter alia* (Uctu and Jafta, 2014):

- to ensure the more efficient use of intellectual property resulting from publicly funded research and development;
- to create the National Intellectual Property Management Office (NIPMO) and the Intellectual Property Fund (IPF) and,
- to provide for the establishment of TTOs at institutions and organizations.

Under the Act, each institution receiving public funds must establish a Technology Transfer Office to assist researchers at the institution in any aspect related to the protection and commercialization of their research. Moreover, the TTO must assist researchers in the implementation of the Act, its regulations and any other related matter. Currently, 23 universities and PROs have established TTOs. This study, amongst other aspects, provides overview of the TTO models used in South Africa and investigates the successes of TTOs at universities and PROs, emphasising the nature of their activities and their performance after the introduction of the Act in 2008.

(1) Department of Business Administration, American University of Iraq-Sulaimani, Raparin 46001, KRG, Iraq & Department of Economics, Stellenbosch University, South Africa.
(2) Department of Economics, Stellenbosch University, South Africa
*Corresponding author: ramazan.uctu@auis.edu.krd

Specifically; this paper addresses the following questions[1]:

- Which technology transfer management models do universities and research institutions use in South Africa?
- How did the university TTOs perform after the new legislation?

The paper is structured as follows: The paper begin with a short background of TTOs and the concept of TTs and, followed by a brief overview of the TTO-enabling legislation in South Africa. Then the paper presents the survey results of the TT models used at universities and research organisations in South Africa. The last section summarises and considers pointers for further research.

2. Bayh-Dole Act and TTOs

The history of TTOs dates back to 1924 when Professor Harry Steenbock, who demonstrated that Vitamin D could be boosted in food and drugs through a process of irradiation, wanted income derived from the discovery to be ploughed back into research. With the cooperation of other alumni, he founded the Wisconsin Alumni Research Foundation (WARF) which is the US's oldest known TTO (Sampat and Nelson, 1999; Litan et al,. 2007; Feldman and Breznitz, 2010; Etzkowitz, 2017; Feldman and Clayton, 2017; Hayter and Rooksby, 2020). WARF, as a TTO, could accept patents, licence such patents to third parties, and distribute revenues the discoverer and relevant institution (Sampat and Nelson, 1999; Litan et al., 2007).

After the foundation of the WARF, it took over five decades and several developments to accelerate TTO creation and development. Such developments have been evolving federal policy, shifts in R&D spending, the emergence of knowledge-based industries, a growing emphasis on regional economic growth, rising awareness of commercialisation success stories and a reduction in public support for universities (Litan et al., 2007).

As these trends developed, lawmakers in the USA recognised the need to intervene and to develop appropriate legislation to promote innovation. As a result, the Bayh-Dole Act, also known as the University and Small Business Patent Procedures Act, was approved by the United States Congress under the Enactment of the Bayh-Dole Act (P.L. 96-517) and the "Patent and Trademark Act Amendments of 1980" on 12 December 1980. Specifically, the Bayh-Dole Act regulates intellectual property resulting from research funded by the federal government. In addition, the legislation established a uniform policy on patent among the many federal agencies that fund research, whilst also allowing small businesses and non-profit organisations and universities to retain ownership of materials and products they discover and develop using government resources. Changes to the Act were made to extend the scope of the legislation to all contractors funded by the federal government, and to set standard licensing procedures in place. (AUTM, 2017b; COGR 1993; Tahvanainen and Hermans, 2008)[2].

After the passage of Bayh-Dole, many institutions set up TTOs to manage and protect their intellectual property (Siegel et al., 2003; Phan and Siegel, 2006). The Bayh-Dole Act offers a range of opportunities to universities. In the USA, universities control inventions made using public funds and commercialise them in terms of the Bayh-Dole Act. As a result, core technologies often stem from university patents. This outcome underlies the importance of universities' potential impact on a nation's patent production. In the USA, there are several examples of the impact that universities has had in the development of the economy that range from the biotechnology to the software industry. Some of these examples include:

- The 1980 Cohen and Boyer (Stanford and University of California) patent on recombinant DNA technology is at the heart of the entire biotechnology industry (King, 2007; Srivastava and Chandra, 2012).

- The Axel patents (from Columbia University), presented a new process for inserting genes into mammalian cells to make protein. This invention resulted in a host of new pharmaceutical products (COGR, 1993:1; Srivastava and Chandra, 2012).

- Several companies spun off from Stanford University (such as Google, Sun Microsystems, Silicon Graphics, Netscape, Cisco Systems, and Yahoo). In addition, around 150 new MIT-related companies are set-up on an annual basis, with a minimum of 10% directly linked to university technology transfer undertakings (Palmintera et al., 2005).

As a result of the success of TTOs from USA universities, international universities and research organisations became interested as to the reasons behind the aforementioned success in the USA. The international reaction is clearly visible, with TTOs having been established in many countries other than the USA. Developed economies such as the United Kingdom, Germany, and emerging economies such as South Africa, Brazil, India and China amongst others have developed and adapted their laws and policies to allow universities and faculty members to manage and transfer intellectual property (IP) to the marketplace, following the USA legal model (Nelsen, 2007; Uctu and Jafta, 2014).

In the case of South Africa, the government introduced legislation encouraging the patenting of publicly funded research (So et al., 2008). The main purpose of the Intellectual Property from Publicly Financed Research and Development Act, 2008 ("the Act") is to promote and enable the use and commercialisation of IP generated from publicly financed research for the benefit of society. The Act also seeks to:

a. encourage and reward human ingenuity and creativity;
b. support to grow and develop the private sector, particularly small and medium-sized enterprises and Broad-Based Black Economic Empowered enterprises[3];

[1] A study by Allessandrini, Klose & Pepper (2013) also considers the status quo of TTOs in South Africa, however, their focus was organisational structures and key factors determining successful technology transfer at 13 publicly funded research institutions prior to the ACT 2008.
[2] This legislation was co-sponsored by Senators Birch Bayh of Indiana and Robert Dole of Kansas.
[3]This stems from the legacy of inequitable access to the market under Apartheid by the majority of the population, which has resulted in provision for redress in almost all South African legislation. More information on BBBEE can be found through the South African Department of Trade and Industry (dti, 2017).

c. provide IP protection before research results are published; and
d. provide for State "walk-in" rights – where necessary, the State may use the results of publicly financed research and development – with regard to the IP needed for the health, security and emergency interests of South Africans.

While it is evident from the aims of the Act that there are many similarities with the US Bayh-Dole Act, additional provisions in the South African legislation are also included to address unique local conditions such as a preference for licensing to Broad-Based Black Economic Empowerment (BBBEE) companies.

3. The Nature and Importance of Technology Transfer (TT) and Technology Transfer Offices

Given the history of TT as discussed above, it is important to be clear as to what TT means. However, TT is defined differently by different people and institutions, guided by their purpose. There are overlapping elements, and the differences are often a matter of nuance and emphasis, as is shown below. In general terms, TT is the sharing and application of scientific knowledge between research institutions and society. The participants may include laboratories, universities, industry, research institutes, local and state governments, and facilitators from third parties such as venture capitalists and management firms (Synder et al., 2003). Dos Santos and Rebolledo (2006) describe different ways in which TT occurs, such as oral communication, the physical transfer of a tangible research result or through the licensing of the intellectual property. Focusing on TT as a "process", Friedman and Silberman (2003:18), identify TT as "*…a process whereby invention or intellectual property from academic research is licensed or conveyed through use rights to a for-profit entity and eventually commercialized.*"

Other definitions with overlapping elements abound. Synder et al. (2003:3), for example, presents TT definitions from various sources in their paper, including the following:

- The National Technology Transfer Center (NTTC) regards TT as the process of utilising technology, expertise, know-how or facilities for a function or use different to the initial intention of the institution involved. TTs can result in commercialisation or product/process improvement.
- The Federal Laboratory Co
- nsortium (FLC) considers TT as a process whereby existing knowledge, facilities or capabilities developed under federal R&D funding are utilised to fulfil public and private needs.

Moreover, the *Association of University Technology Managers (*AUTM, 2017a), define TT as *"…the process of transferring scientific findings from one organization to another for the purpose of further development and commercialization*." Although these definitions are subtly different and contains nuances not elaborated upon here, it suffices to note for our purposes that TTOs are critical institutions in the development and commercialisation process of technological innovations. In summary, to facilitate and promote TT at universities and other research organisations, an institutional mechanism is required, namely the Technology Transfer Office (TTO). Siegel, Veugelers and Wright (2007: 641) see that TTOs act as an 'intermediary' between two parties namely university scientists (supplier of the innovations) and others who might (help to) commercialize them (i.e. firms, entrepreneurs, and venture capitalists). The establishment of TTOs stems not only from the need to improve the university performance effectiveness but also from the promise to increase university income by transferring research results to industry and licensing of technologies (Dos Santos and Rebolledo, 2006; Siegel, Veugelers and Wright, 2007).

The Association of University Technology Managers (AUTM) has outlined four primary reasons for establishing university TTOs, namely to:

- facilitate the commercialisation of research results for the public good
- reward, retain and recruit high-quality researchers
- develop closer ties with the industry
- generate income for further research and education, and, therefore, to promote the economic growth (Young, 2005:13).

In addition to abovementioned reasons, Siegel, Veugelers and Wright (2007) emphasized that the TTOs activities have significant economic and policy consequences as licensing agreements and university spin-offs will contribute to increase revenue for universities, employment opportunities for researchers and graduate students, and local economic and technological spillovers by encouraging increased R&D investment and job creation.

The mission of TTOs is therefore to transfer the results university research from laboratories to commercial applications for the benefit of society. In general, the TTO seeks and receives reports from authorities on inventions; reports the inventions to sponsors; determines whether to hold title to inventions produced with external funding; files applications for patents; markets those patents to industry and negotiates and administers licence agreements. In addition, TTOs are also responsible for tracking patent litigation, recording of income and disbursements (COGR, 1993: 3). The university's mission statement and its IPR policies will also impact on the internal TTO infrastructure to support research and technology transfer. Globally, there are many different forms of university TTOs, including the following:

(i) an office or department within the university usually referred to a Technology Licensing Office (TLO), an Office of Technology Transfer (OTT), Knowledge Transfer Office (KTO) or some related name;
(ii) an external office, founded either as a for-profit or a not-for-profit organisation;
(iii) both an external organisation and a university office working together; and
(iv) an external company that performs contract services for the university on a project-by-project basis (Young, 2005:14)

Given the discussion above, the importance of TTOs cannot be understated, perhaps even more so in a developing country context. After a short account of the advent of TT and TTOs, we now get to one of the key questions in this paper, namely to investigate which TT models are

employed at South African universities and PROs. The next section will focus on which TT models are utilised in South African universities and public research organisations, with some additional research results.

4. Technology Transfer Models at South African Universities and Public Research Organisations

4.1 Methodology

Apart from consulting relevant secondary sources and official university documentation, a direct survey method was employed to garner the data for this paper. The data collection method entailed, firstly, gathering information on the existence and activities of TTOs via telephone and electronic means over a six-month period. Several variables that are considered to be the standard were identified as output measures and data for those variables were collected. These output measure variables are: invention disclosures, PCTs applications (The Patent Cooperation Treaty), provisional patent applications, licenses or sale of IP and the number of spin-out companies. Moreover, information on the revenues from commercialisation was attained were possible. Measuring the impact of the TTO activities on the economy and society does not fall within the scope of this paper. A recent report released in April 2017 conducted a survey on technology transfer functions at universities and science councils (DST, 2017). However, the survey had a response rate of 24 out of 33, with two universities (Sol Plaatje University and the University of Mpumalanga) not included in the survey, with all the results being aggregated.

In this section the research results are presented, focusing first on the universities and their TTO models, followed by the PROs and their TTOs. An attempt is made to draw out similarities and differences between the two organisational types.

4.2 The Universities and TTO models

South African Technology Transfer Offices (TTOs), like their international counterparts, tend to follow two main models: (1) an internal institutional office, or (2) an external company. Unlike universities in other countries; however, there are currently no South African universities that use an external organisation that is not linked to the university for technology transfer; the external companies, although separately registered entities, are wholly owned by the university itself.

Either model of TTOs will focus on technology transfer *per se* (i.e. intellectual property (IP) management and commercialisation, usually with some IP contract management), or will undertake numerous functions related to technology transfer such as IP management and commercialisation, contract management, short course management, consulting, financial management of grant and contract research, and project management.

The South African public universities[4] (also referred to as Higher Education Institutions (HEI), of which there are 26) current situation with regard to TTO formation are listed in Table 1 below, together with the type of model they follow (Internal/External) and the functions they perform (TT mainly/Numerous). In addition, their funding (Institutional/Self-funding) is also given.

Table 1: TTOs at South African Public Universities

No	University	Type of office	Functions performed	Funding
1	Durban University of Technology (DUT)	Internal	Numerous	Institutional
2	Nelson Mandela Metropolitan University (NMMU)	Internal/External	TT mainly	Institutional
3	North-West University (NWU)	Internal	TT mainly	Institutional
4	Stellenbosch University (SUN)	External	TT mainly	Institutional
5	Tshwane University of Technology (TUT)	Internal	TT mainly	Institutional[2]
6	University of Cape Town (UCT)	Internal	TT mainly	Institutional
7	University of the Free State (UFS)	Internal	TT mainly	Institutional
8	University of Johannesburg (UJ)	Internal	TT mainly	Institutional
9	University of Kwa-Zulu Natal (UKZN)	Internal/External	TT mainly/Numerous	Self-funding
10	University of Pretoria (UP)	Internal	TT mainly	Institutional
11	University of the Witwatersrand (Wits)	External	Numerous	Self-funding
12	Cape Peninsula University of Technology (CPUT)	Internal	TT mainly	Institutional
13	University of the Western Cape (UWC)	Internal	TT mainly	Institutional
14	Central University of Technology (CUT)	Internal	TT mainly	Institutional
15	Vaal University of Technology (VUT)	Internal	TT mainly	Institutional

[4] There are 30 private universities or colleges in South Africa, with most focusing on undergraduate or diploma degrees.

16	University of Zululand (UZ)	Internal	TT mainly	Institutional
17	University of South Africa (UNISA)	Internal	TT mainly	Institutional
18	Rhodes University (RU)	Internal	TT mainly (biotech focus)	Institutional
19	University of Fort Hare (UFH)	Internal, but functions with research unit	Unknown	Institutional
20	Walter Sisulu University of Science and Technology (WSU)	Internal, but functions with research unit	Unknown	Institutional
21	Sefako Makgatho Health Sciences University (SMU)	None	N/A	N/A
22	Sol Plaatje University (SPU)	None	N/A	N/A
23	University of Mpumalanga (UMP)	None	N/A	N/A
24	University of Limpopo (UL)	None[5]	N/A	N/A
25	University of Venda (UNIVEN)	Forum	N/A	Institutional
26	Mangosuthu University of Technology	None	N/A	N/A

Source: Authors' own construction 2019

Notes:

i. Note that UKZN has both an internal office focused on technology transfer (established in October 2008) and an external company.

ii. NMMU's TTO, TUT's TTO and UKZN's internal TTO were partially funded by the Innovation Fund[6].

iii. NMMU also has a commercial company called Innovolve. The latter aims to commercialize NNMU innovations by licensing intellectual property, as well as by supporting and forming spinout companies.

iv. The Eastern Cape Regional Technology Transfer Office (ECR-TTO) was supposed to be formed by all four Eastern Cape universities under a Memorandum of Agreement. The ECR-TTO assists institutions to manage and commercialize their Intellectual Property, particularly as Fort Hare University and Walter Sisulu University do not have full-fledged Technology Transfer Offices. Rhodes University's TTO is also focussed on the biotech field. The NMMU's TTO is known as the Department of Innovation Support & Technology Transfer. The ECR-TTO was supposed to be funded by the National Intellectual Property Management Office.

v. The UFH and WSU have units that focus on research and innovation; within these units there are staff that are dedicated to technology transfer.

Out of all the TTOs at universities, only three (SUN, UKZN and Wits) are external companies, although UKZN has an internal office as well, and only three (UKZN, Wits and DUT) perform numerous functions, which include but are not limited to the traditional TT functions. Only two (UKZN and Wits) are self-funded which corresponds to their status as external companies. SUN's TTO migrated from being an internal office to an external office, but it is still funded by the university.

UKZN's internal TTO was funded by the Innovation Fund for a period of three years, after the university became responsible for funding its TTO. Part of the reason for setting up this office is the disconnect between UKZN's research output and its patent portfolio. The external company, UKZN Innovations (Pty) Ltd, undertakes numerous other functions such as consulting work, both with UKZN academic staff and without them, as well as property development. The internal TTO is meant to manage IP and the external company is meant to commercialise IP. Unless there is significant interaction between the two; however, this presumes that there can be a split between these two functions and that a patenting strategy can be developed without commercialisation input.

Wits' TTO is situated within the Wits Commercial Enterprise (Pty) Ltd, which also undertakes all grant and contract management for Wits' academic staff, including financial management of projects. Wits Enterprise staff occasionally undertake consulting work. Wits Enterprise also manages many of Wits' short courses, although there is no consistency in the short course model used across Wits.

Even within those universities which have an institutional office and focus mainly on technology transfer *per se*; there are differences between their reporting lines within the university. NMMU, UCT, NWU and UFS report directly to the most senior person for research (Deputy Vice-Chancellor (DVC) or equivalent), whereas UJ's TTO reports to an Executive Director who reports to the Deputy Vice-Chancellor. The TTO's at UP, TUT and UKZN form part of the Research Office and report to the Director for Research, who then reports to the Deputy Vice-Chancellor. The reporting lines often show the importance placed on TT by the university, and more senior reporting lines can empower the TTO's to operate independently.

At least two other universities (WSU and UFH) have technology transfer officers on their organogram or advertising openings for those posts. These universities typically do not even have a dedicated webpage for their TTO office. This potentially reflects the fact that TTOs are not prioritized at these institutions. Furthermore, five universities (of which two are approximately 2 years old) do not have TTOs.

Globally, access to experienced technology transfer professionals is one of the main barriers to the development of TTOs. As a result, Denmark and Germany, for instance, have invested millions of euros

[5] The university has established the Univen Research and Innovation High Level Stakeholders Forum; however, there is no TTO and the University's strategic plan for 2016-2020 does not reference a TTO (Univen 2015).

[6] The initial aim of the Innovation Fund was to foster South Africa's economic competitiveness by investing in technological innovations and supporting South Africans looking for IP protection . However, the Innovation Fund became part of the TIA. The TIA is involved in several fields, namely in industrial biotech, agriculture, health, mining, energy, advanced manufacturing technologies and information and communication technologies and is a new public entity created by a merger of seven DST-funded organizations, namely, Tshumisano, Lifelab, BioPAD, Plantbio, Cape Biotech, the Innovation Fund and AMTS (Advanced Manufacturing Technology Strategy) (see Uctu and Essop, 2013)

to promote the development of technology transfer office staff. In the same vein, the UK government has raised spending on training in university intellectual property management (Cervantes, 2003). Muscio (2010) also argues that the quality of personnel at the TTOs is very crucial when it comes to collaboration with industry. They found that TTOs managed by professional staff that have industry background and dedicated staff in certain industries (like biotechnology, IT and engineering etc.) close the difficult cultural gap between the industry and university. TTO managers and staff need to understand the academic world and also need to have a good understanding of the business world. Having such suitable qualified staff increases the probability of successful commercialisation.

In South Africa, the qualification and staffing of the TTOs vary widely even amongst those universities whose TTOs perform similar functions. The differences are typically dependent on whether all university research contracts are managed by the TTO and the number of research contracts, as well as by the size of the research output. For example, the North-West University TTO has three staff members; two technical staff members and one administrative staff member; of the technical staff, one has a doctorate and commercial qualification and one has a law degree. UFS's technical staff member has a scientific doctorate while Wits has 19 staff, but only two are dedicated to TT, both with science doctorates. UKZN has two internal and ten external staff; the internal staffs have law degrees while the external staffs have commercial qualifications. Overall, 53% of TTO staff in South Africa's HEI and Science Councils have four or more years of experience (based on a 70% sample, DST, 2017), most likely reflecting a generally moderate level of skill and experience in the field of technology transfer.

If the primary mission of universities is to teach rather than conduct research and commercialise it, the establishment of a TTO may not be justified. Without a strong research focus, the organisation would struggle to find a sufficient demand for TT services. Pouris (2007) found that, based on citations in the international scientific literature, only six South African universities are among the top 1% of the world's institutions, namely, the Universities of Cape Town, Stellenbosch, Pretoria, Witwatersrand, Kwazulu-Natal and the Free State. Lubango and Pouris (2007) investigated the innovation activity at South African universities and found that the Universities of Pretoria, Stellenbosch, Cape Town, Witwatersrand and the North-West are the most patent active. All these universities have TTOs, and none of the universities without TTOs are highly research-intensive.

Some universities are not very efficient in the commercialization of their technology. According to Chapple et al. (2005) this may be attributed to the lower rates of R&D and economic activity in those regions. Regional TTOs may be best suited in such situations to provide additional assistance to both universities and business. A potential advantage for coordinating TTOs on a regional basis is that it will promote the creation of specialized teams for various industry sectors. It might also facilitate the development of a critical mass of expertise and experience. Regional TTOs can also gain from economies of scale, with the TT needs of one institution perhaps not justifying the cost of a TTO at said institution. Furthermore, TTOs require staff with a high level of qualification and skill sets, which implies that such staff may be in limited supply and high demand. This is likely to be the case in South Africa, and regional TTOs may prove to be a more suitable solution.

The Technology Stations at CUT and VUT, funded by the Department of Science and Technology's Tshumisano Trust[7], undertake technology transfer in its broadest sense as they transfer solutions to small businesses with technology problems. These Technology Stations are thought of as the TTO at their universities, as they get involved in TTO workshops, such as SARIMA events. However, there are Technology Stations at other universities, such as at NMMU and CPUT, which are involved in technology transfer to small businesses but do not consider themselves as the TTO for their university. The difference is in the definition of technology transfer as IP management and commercialisation, rather than solving direct small business needs.

The Eastern Cape was supposed to establish a Regional TTO under the leadership of the NMMU, which would have incorporated RU, UFH and WSU. The justifications provided for establishing a Regional TTO in the Eastern Cape were that two of the universities (UFH and WSU) are primarily undergraduate institutions, and that RU is a very small, although research-intensive, university. A single TTO, based at the NMMU, with contact people at the other Research Offices, therefore appears to be a sensible way to manage and commercialise IP from all four universities. For unclear reasons; however, this regional TTO has not yet been established.

Chapple et al. (2005) argue that universities in regions where R&D and GDP are higher appear to be more efficient in technology transfer. In South Africa most universities are located in the Eastern Cape, Western Cape (WP), Gauteng and Kwa-Zulu Natal (KZN). These regions especially WP, Gauteng and KZN also appear with higher levels of GDP and R&D as Chapple et al. argued. The provincial breakdown of TTOs is given in Table 2.

Table 2: Provincial breakdown of TTOs*

Province	Number of universities	Universities with TTOs	Percentage with TTOs
Eastern Cape	4	4	100%
Free State	3	3	100%
Gauteng	5	4	80%
KwaZulu-Natal	4	2	50%
Limpopo	2	0	0%
Mpumalanga	1	0	0%
Northern Cape	1	0	0%
North-West	1	1	100%
Western Cape	4	4	100%
9 provinces	25	18	

Source: Authors own construction 2019

*Excludes UNISA which operates across the country as a distance-learning university

[7] Which is part of the TIA now.

Ignoring the provinces with one university, of the five provinces with 3 or 4 universities, only one, the Western Cape, have a TTO at all universities. Gauteng has TTOs at 80% of universities whilst KwaZulu-Natal has TTOs in half of their universities and the Free State and Eastern Cape have only one TTO. However, the Free State's two universities without TTOs have Technology Stations acting as TTO-type structures, so it could be argued that all the Free State universities have TTOs.

Including the limited TTO structures at WSU and UFH as well as the Free State's Technology Stations as TTOs, then only six universities (excluding UNISA) do not have any form of TTO: UniZul, UNIVEN, UL and MUT. Table 3 lists those institutions which do not have a TTO. Currently there are six universities in South Africa which do not have a TTO.

Table 3: South African Universities without TTOs

University	Status
No TTO but has contact for IP	
Mangosuthu University of Technology (MUT)	None
No contact details	
University of Venda (UNIVEN)	None
University of Limpopo (UL)	None
Sol Plaatje University (SPU)	None
University of Mpumalanga (UMP)	None
Sefako Makgatho Health Sciences University (SMU)	None

Source: Authors own construction 2019

The Public Research Organisations and TTO models

The public research organizations, according to the Department of Science and Technology (www.dst.gov.za) are:

Africa Institute of SA (AISA)
Agricultural Research Council (ARC)
Council for Geoscience (CGS)
Council for Mineral Technology (Mintek)
Council for Scientific and Industrial Research (CSIR)
Human Science Research Council (HSRC)
Medical Research Council (MRC)
National Facilities falling under Management of the NRF:
South African Astronomical Observatory (SAAO)
South African Institute for Aquatic Biodiversity (SAIAB)
HartRao (Hartbeeshoek Radio Astronomy Observatory)
Hermanus Magnetic Observatory (HMO)
Standards South Africa (stanza)
Marine and Coastal Management
National Institute of Virology (NIV)
National Health Laboratory Service (NHLS)
South African National Energy Research Institute (SANERI)
Meraka Institute
South African Environmental Observatory Network (SAEON)
South African Biodiversity Information Facility (SABIF)

It would not be appropriate for many of these organisations to have a TTO as they do not perform the type of research and development that is appropriate for IP protection and commercialisation. A subset of these PROs is the Science Councils, which are established by Acts of Parliament. Two of the Science Councils (NRF and SABS) are not in the list above although Standards South Africa was previously part of the SABS. Table 4 lists the Science Councils, according to the National Advisory Council on Innovation, and their purpose and TTO status.

Table 4 Science Councils and their TTOs

Science Council	Purpose	TTO Status
Africa Institute of SA (AISA)	Research and policy development support with focus on Africa.	No TTO. Public dissemination of research results more appropriate.
Agricultural Research Council (ARC)	Conduct agricultural research, development and technology transfer to promote agriculture and industry.	Have Executive Director: Technology Transfer but do not have organised approach to IP management; not involved in TTO activities of SARIMA
Council for Geoscience (CGS)	Develop and publish world-class geoscience knowledge products and provide geoscience-related services to the South African public and industry.	Do not appear to have TTO or senior manager responsible for technology transfer. May be more appropriate to disseminate results publicly.
Council for Mineral Technology (Mintek)	Promote mineral technology and foster the establishment and expansion of mineral industries and products.	No TTO but certain staff members involved in TTO activities of SARIMA; feel that TTO should be established.
Council for Scientific and Industrial Research (CSIR)	Undertake directed and multidisciplinary research, technological innovation and industrial and scientific development.	Have TTO reporting to CSIR Group Executive for R&D Outcomes and Strategic Human Capital Development.
Human Science Research Council (HSRC)	Conduct large-scale, policy-relevant, social-scientific projects which support development nationally.	No TTO. Public dissemination of research results more appropriate.
Medical Research Council (MRC)	Promote the improvement of the health and the quality of life of the population of South Africa through research, development and technology transfer.	Have TTO (MRC Innovation Centre) reporting to Executive Director: Technology and Innovation.
National Research Foundation NRF)	Support and promote research through funding, human resource development and the provision of the necessary research facilities.	Not appropriate. Provides funding for universities and other research organisations.
South African Bureau of Standards (SABS)	Promote and maintain standardisation and quality in connection with commodities and the rendering of services.	No TTO.
South African Nuclear Energy Corporation (NECSA)	Primary function is to conduct and initiate R&D in the field of nuclear energy, radiation science and related technologies.	No TTO, but has two subsidiaries through which it conducts business (NTP Radioisotopes SOC Ltd and Pelchem SOC Ltd)
Water Research Commission (WRC)	Amongst others, the WRC stimulates and funds into water research.	The Water "Tech Transfer Office" was established to conduct TT for the WRC.

Source: Authors own construction 2020

Of the nine science councils, three (ARC, CSIR and MRC) have a TTO or related activity and five (AISA, CGS, HSRC, NRF and SABS) do not have a TTO and it is probably not appropriate for them to have one. Mintek is the only science council that undertakes the type of research that requires a TTO for IP protection and commercialisation but does not yet have one.

The TTOs that exist are all institutional offices funded by the relevant organisation itself.

Two other bodies that are part of the National System of Innovation but fall outside of the Science Council system must be mentioned, namely the South African Energy Development Institute (SANEDI, previously known as SANERI), and the Water Research Commission (WRC). SANEDI is listed as a public research organisation by DST but is not a Science Council and exists as a company. However, it is the public entity entrusted with the coordination and undertaking of public interest energy research, development and demonstration. It does not have a TTO, yet owns or shares ownership of IP related to the projects it funds. The WRC, established by the Water Research Act under the Department of Water Affairs and Forestry, supports and funds water research and development as well as the building of a sustainable water research capacity in South Africa. The WRC has a TTO, which aims to protect and commercialise IP funded by the WRC (www.wrc.org.za, accessed on 22 June 2020)

There are some similarities and differences between the universities and PROs in terms of setting, funding and the reporting lines. Only three university TTOs (SUN, UKZN and Wits) are external companies, although UKZN has an internal office as well, and only three (UKZN, Wits and DUT) perform several functions. At the PROs, the TTOs are all internal offices. Furthermore, only two university TTOs are self-funded and others are institutionally funded. The TTOs that exist at PROs are all institutional offices funded by the organization itself.

5. An overview of TTOs' performance in South Africa

In this section, we looked at the TTO performance in South Africa including disclosures, number of technologies managed by TTOs, new patent applications, published PCTs applications and start-up/spin-out companies from the universities in South Africa. All mentioned indicators provide a clear indication of performance and innovation levels of the TTOs in South Africa.

Table 5 presents the total number of disclosures, the number of technologies managed by TTOs and new patent applications in South Africa between 2008 and 2014 for 22 universities as reported by DST (2017). Disclosures increased by 122% from 138 to 306 over this time period, whilst the number of technologies managed by the TTOs increased by 192% from 426 to 1244 and new patent applications improved by 110% from 103 to 216.

Table 5: Disclosures, number of technologies managed by TTOs and new patent applications (between 2008 and 2014)

Year	Disclosures	Number of Technologies managed by TTO	Number of new patent applications
2008	138	426	103
2009	181	507	146
2010	210	600	143
2011	265	962	169
2012	229	1056	205
2013	259	1142	209
2014	306	1244	216
Number of TTOs	22	21 up to 2010; 22 thereafter	22

Source: DST 2017: 29-30

Over this same period (2008-2014), IP transactions and revenue also increased. IP transactions are defined as legal agreements that are reached with third parties whereby the agents involved agree to transfer ownership of certain rights. These third parties are normally able to commercialize the IP in question. The two main ways of transferring these rights are via options where the partner may be granted the right to preferential options in future and licenses, where the third party is given rights to use IP or specified technologies in agreed upon countries or regions.

Moreover, DST (2017: 36-38) found that the total number of IP licenses between 2008 and 2014 amounted to 144, or approximately 20 IP transactions per year. In revenue terms, this amounted to R229,8 million over the 2008-2014 period, or nearly R33 million per year. Two points worth noting, however, is that four institutions consistently accounted for 88% or more of the total IP revenue annually. This could be due to a variety of factors such as maturity and capacity of the TTO, research focus of institution, or other issues which needs further investigation. In addition, the actual current TT operational and IP expenditure far exceed actual revenues earned. If one considers the data for the latest year available, 2014, the TT operation costs amounted to R109 million whereas the actual revenues amounted to R35.6 million. Whilst the total net benefit of TT may exceed the revenue data shown here, it is clear that even though disclosures, number of patents, licenses issued has improved, more needs to be done to increase revenue for TTOs to be sustainable at the aggregate level based on the available data.

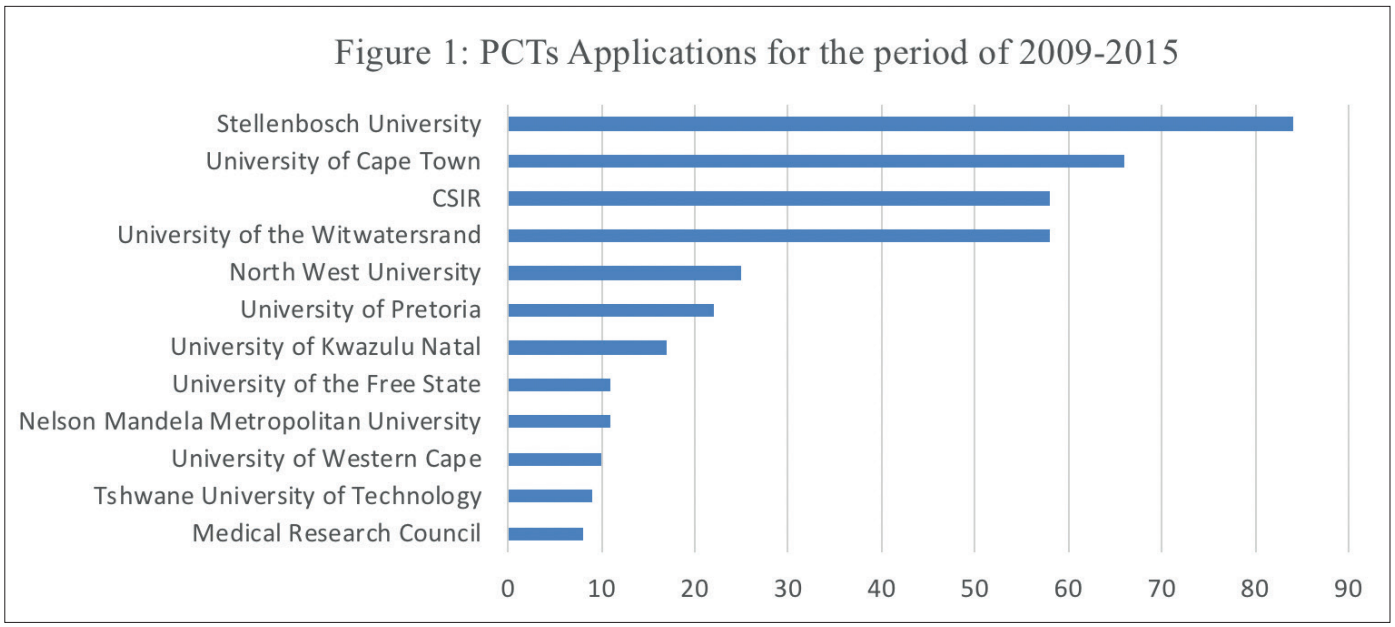
The aforementioned conclusions are endorsed when one considers the Patent Cooperation Treaty (PCT), an international patent law treaty signed in 1970. It provides a unified procedure for the filing patent applications for the protection of inventions in each of its contracting states. A patent application filed under the PCT is referred to as a PCT application. This is a powerful, comparable indicator of innovation activity at an institution. Table 6, Table 7 and Figure 1 shows the published PCT applications done by university and public research institutions between 2009 to 2015 and 2017 to 2019. Most of the applications were made by Stellenbosch University, followed by UCT, the CSIR and the University of Witwatersrand.

Table 6: Published PCTs Applications for the period of 2009-2015

Institutions/Public Research Organisations	Applications
Medical Research Council	8
Tshwane University of Technology	9
University of Western Cape	10
Nelson Mandela Metropolitan University	11
University of the Free State	11
University of KwaZulu-Natal	17
University of Pretoria	22
North West University	25
University of the Witwatersrand	58
CSIR	58
University of Cape Town	66
Stellenbosch University	84

Source: Developed by the authors based on https://www.innovus.co.za/media/documents/The_University_Technology_Fund_2016-5.pdf, accessed on 8 April 2020.

Figures



Source: Developed by the authors based on https://www.innovus.co.za/media/documents/The_University_Technology_Fund_2016-5.pdf, accessed on 8 April 2020.

Table 7: PCT Top Applicants (Only Public Research Organizations and Higher Educations) after 2016

Applicants	2017	2018	2019
University of Cape Town	10	11	18
Stellenbosch University	10	2	17
CSIR	7	8	9
University of Pretoria	8	4	5
University of the Witwatersrand	10	4	4
University of Johannesburg	-	1	3

Source: Developed by the authors based on https://www.wipo.int/ipstats/en/statistics/country_profile/profile.jsp?code=ZA, accessed on 9 April 2020.

Another important indicators is to look at the number of start-ups created by the universities. University spin-offs (also called university entrepreneurship, academic spin-offs and academic entrepreneurship) has been studied by many researchers in South Africa (see for instance Jafta and Uctu, 2013; Rorwana and Tengeh, 2015; Urban and Chanston, 2019) and is seen as an important factor that promotes innovation.

According to the FIN24 (2015), 59% of South African start-ups are based in the Western Cape, with Gauteng hosting 29% of start-ups in the country in second place. This data may well be linked to the effectiveness of the TTOs at Stellenbosch University and UCT in the Western Cape, and Wits in Gauteng.

Table 8 lists the number of spin-out companies from selected universities, namely Stellenbosch University, University of Cape Town, and Nelson Mandela Metropolitan University. These universities were selected as the relevant websites for other universities did not clearly identify their spin-out companies. From Table 8 it is clear that UCT and Stellenbosch University's early start to their TTOs has played itself into a crucial advantage. This is likely one of the reasons why they have the highest number of spin-off companies created in South Africa, with an apparent specialty in the fields of biotechnology, IT, and biomedical start-ups

Table 8: Spin-Out Companies from selected universities

University	TTO	Spin-Out Companies
Stellenbosch University	Innovus[8]	1. AFRICAN SUN MeDIA 2. AxioVR (Pty) Ltd 3. Bridgiot (Pty) Ltd 4. Cargo Telematics 5. CubeSpace (Pty) Ltd 6. CUSTOS Technologies (Pty) Ltd 7. GeoSmart 8. GeoSUN Africa 9. Maties Gymnasium 10. SEIN Media (Pty) Ltd 11. Sharksafe Barrier 12. Stellenbosch University Executive Development (Pty) Ltd (USB ED) 13. LaunchLab[9] 14. Sun Magnetics (Pty) Ltd 15. The Stellenbosch Nanofiber Company (SNC) 16. Unistel Medical Laboratories (UML) (Pty) Ltd
University of Cape Town	Research Contracts and Innovation[10,11]	1. Antrum Biotech 2. Cape Carotene 3. CapeRay 4. Cell - Life 5. Elemental Numerics (Pty) Ltd (previously Elemental Technologies IP Holdings) 6. Hot Platinum 7. NRI (Nurture Restore Innovate) 8. PST Sensors 9. Seraptix CC 10. Tuluntulu 11. CURIT Biotech South Africa (Pty) Ltd 12. Abalobi NPC 13. AngioDesign 14. Cape Catalytix (Pty) Ltd 15. DroneSAR 16. HyPlat (Pty) Ltd 17. Nautilus Technologies Inc. 18. Nisonic AS 19. Lumkani (Pty) Ltd 20. Attri Orthopedics (Pty) Ltd 21. Dream Haven (Pty) Ltd 22. Cape Bio Pharms (Pty) Ltd 23. Impulse Biomedical 24. Strait Access Technologies (Pty) Ltd 25. Isiqu Orthopedics (Pty) Ltd
Nelson Mandela Metropolitan University	the Innovation Office[12]	1. Kelly Mae Dillon 2. MaXhosa 3. MooiMooii 4. Roses 5. Rubber Nano Products 6. SunTestLab™ 7. Twerly® 8. WeldCore®

Source: Developed by the authors based on https://www.innovus.co.za/, www.rci.uct.ac.za and http://innovolve.co.za, April 2020

[8] https://www.innovus.co.za/spin-out-companies.html, accessed on 8 April 2020

[9] LaunchLab act as an accelerator and promotes on-campus entrepreneurship by offering networking opportunities, mentoring and competitive rental rates in a business-friendly environment. The LaunchLab acts as a platform for spin-out companies from universities, as well as student and external (non-university) entrepreneurs. LaunchLab has 19 orbit companies (companies in orbit have graduated from the Launchlab's programmes and facilities into their own space) and 26 current companies (http://www.launchlab.co.za/, accessed on 8 April 2020).

[10] http://www.rci.uct.ac.za/rcips/innovation_achievements/spinout_companies, accessed on 8 April 2020

[11] Seraptix CC, Cape Carotene (Pty) Ltd and Isiqu Orthopedics (Pty) Ltd (Ceased operation). Of 22 companies, UCT has Equity on 13 companies.

[12] University created a company called Innovolve which is the commercialization company of the Nelson Mandela University. Working closely with the Innovation Office, Innovolve drives commercialization of the University's innovations through the licensing of IP and the establishment of spin-out companies (http://innovolve.co.za/about-us/, accessed on 9 April 2020).

6. Conclusion and recommendation

Given the heightened interest in TT activities and public research organisations, this paper set out to describe the state of play with respect to the existence of TTOs in the South African context. In particular, the focus was on the models of TT employed by TTOs at universities and public research organisations. The legislation that enables and encourages TTOs is still fairly new to South Africa and it is therefore prudent to consider the section on the performance of the TTOs as a pre-legislation state of affairs.

After the legislation in South Africa, more technology transfer activities at universities and PROs are expected, with little empirical evidence to support this view currently. As such, it is necessary to point out that the legislation alone is not enough. Governmental policies will only reach their objectives if accompanied by mechanisms that stimulate cultural changes in the universities and the PROs environment and to the deepening of their understanding on the role of the universities and PROs in the innovation process.

Moreover, given the gap between TT operational expenditures and IP revenues, government and universities will need to carefully consider the funding models currently in place. So far twenty universities and three PROs have a TTO in South Africa. Out of the twenty TTOs at universities, only three (SUN, UKZN and Wits) are external, self-funded companies, although UKZN has an internal office as well, and only three (UKZN, Wits and DUT) perform numerous functions. At the PROs, the TTOs are all internal offices. TTOs that exist at PROs are all institutional offices funded by the organization itself.

Notwithstanding the challenges and newness of the legislation, the data collected from the universities' TTOs shows that technology transfer activity has increased significantly, with invention disclosures increasing from 138 in 2008 to 306 in 2014 and PCT applications filed increasing from 45 (in 2017) to 56 (in 2019). Additionally, there were significant increases in the creation of spin-out companies as well. This is mainly due to a newly formed TTO commercialising IP that had been developed in universities for a number of years.

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