COMMERCIALISING INTELLECTUAL PROPERTY EMANATING FROM UNIVERSITIES IN THE WESTERN CAPE, SOUTH AFRICA

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Declaration

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Abstract

University technology transfer and the effective commercialisation of intellectual property emanating from university campuses has become a topic of growing interest. University intellectual property assets have become products generating income streams and competitive advantages for its owners as intellectual property grows in stature in knowledge driven economies. The purpose of this study is to gain a better understanding of the concept of intellectual property and the importance of its effective commercialisation for SA universities. The research objectives were to define intellectual property, technological innovation, and technology transfer within a university setting and to develop a conceptual framework that would identify key dimensions representing the enabling environment for university technology transfer. These dimensions were then applied to multiple case studies conducted at SU, UCT, UWC and CPUT. The main research question inquires how effective these four universities have been in commercialising intellectual property assets via recognised technology transfer practices.

Textual and numeric primary as well as secondary data were used in this study as part of an empirical ethnographic research design. The inquiry strategy uses a mixture of qualitative and quantitative research approaches in the four embedded case studies for describing and analysing existing data. Primary data were collected from the partaking universities by developing a qualitative survey questionnaire as research instrument which was used during in-person interviews to evaluate the effective use of employed technology transfer practices. The resultant overall research design is descriptive and evaluative in nature, using inductive reasoning.

The findings reveal five major internal enablers which comprise the policy environment, institutional commitment, the legal milieu, the funding arena and human resources. Some academic interviewees as respondents in the case studies were critical in stating the support from their superiors were lacking the commitment expected from them when compared to the universities' stated policy documents. A number of respondents to the interviews at the research intensive universities noted that TTO staff are not available to them as they are simply too busy and often overwhelmed by their workload to provide TT services to academic staff and students as inventors. Overall, respondents were satisfied with the level of service they receive from the university TTO.

Although this is not a comparative study, the study discovered that the less research-intensive universities have a much shorter pipeline of new invention disclosures for novel technologies, as they have less funding available to direct to basic or applied research activities. It emerged from the literature and the study that university technology transfer is an intriguing and multi-faceted environment that requires dedicated staff with unique skills and management capabilities.

The study highlights the single biggest factor affecting the rate of new invention disclosures, and ultimately the success rate of technology transfer commercialisation activities, as the total annual research and development spending at SA universities. The researcher found that without significant quality and quantity of research and development being conducted, little or no revenue streams can be expected from new inventions emanating from SA universities.

Opsomming

Tegnologie-oordrag en die effektiewe kommersialisering van intellektuele eiendom wat op universiteitskampusse ontwikkel word het ’n onderwerp geword wat toenemend belangstelling wek. Die intellektuele eiendomsbates van universiteite het produkte geword wat inkomstestrome genereer en mededingende voordele skep vir die eienaars daarvan namate hierdie bateklas in prominensie groei in kennisgedrewe ekonomieë. Die doel van hierdie studie is om ‘n beter begrip te ontwikkel van die term intellektuele eiendom en om die belangrikheid van die effektiewe kommersialisering daarvan vir SA universiteite beter te verstaan. Die navorsingsdoelwitte is om intellektuele eiendom, tegnologiese innovasie, en tegnologie-oordrag binne ’n universiteitsomgewing te definieer en ’n konseptuele raamwerk te ontwikkel wat die dimensies identifiseer wat ‘n ondersteunende omgewing vir tegnologie-oordrag by universiteite skep. Hierdie dimensies word dan toegepas op gevallestudies by die US, UK, UWK en CPUT. Die hoofnavorsingsvraag ondersoek hoe effektief hierdie vier universiteite hul intellektuele eiendomsbates kommersialiseer deur middel van erkende tegnologie-oordrag praktyke.

In hierdie studie is geskrewe en numeriese primêre sowel as sekondêre data gebruik as deel van ’n empiriese etnografiese navorsingsontwerp. Die ondersoekstrategie gebruik ’n samevoeging van kwalitatiewe en kwantitatiewe navorsingsmetodes in die vier ingebedde gevallestudies vir die beskrywing en ontleding van bestaande data. Primêre data is van die deelnemende universiteite ingesamel deur ’n kwalitatief-gebaseerde vraelys te ontwikkel en te gebruik as navorsingsinstrument tydens persoonlike onderhoude om die effektiewe gebruik van tegnologie-oordragpraktyke te evalueer. Die gevolglike algehele navorsingsontwerp is beskrywend en ondersoekend van aard, met behulp van induktiewe redenasie.

Die bevindings lewer vyf belangrike interne ondersteuners wat bestaan uit institusionele toegewydheid, die wetlike omgewing, beleid- en befondsingsomgewings, en menslike hulpbronne. Sommige akademici as respondente in die gevallestudies was van mening dat die ondersteuning van topbestuur nie die institusionele toegewydheid weerspieel wat hulle onderneem het om te doen in die universiteits se beleidsdokumente nie. ‘n Aantal respondente het gedurende die onderhoude opgemerk dat personeel van die tegnologie oordrag kantoor nie beskikbaar is vir hulle nie, aangesien hulle eenvoudig te besig is en dikwels oorweldig word deur

hul werkslading om tegnologie oordrag dienste aan akademiese personeel en studente as uitvinders te lewer. Oorwegend was die respondente gelukkig met die dienste wat hulle ontvang van die universiteit se tegnologie oordrag kantoor.

Alhoewel dit nie ’n vergelykende studie is nie, het die studie ontdek dat die universiteite wat minder navorsingsintensief is ’n baie korter pyplyn het van openbaarmakings van nuwe uitvindings van tegnologieë, aangesien hulle meer beperkte befondsing het vir basiese of toegepaste navorsing. Dit blyk uit die literatuur en die studie dat tegnologie-oordrag vanaf universiteite ’n fassinerende en veelsydige omgewing is wat toegewyde personeel met unieke vaardighede en bestuurskundigheid vereis.

Die studie dui daarop dat die enkele grootste faktor wat die tempo van nuwe openbaarmakings van uitvindings beïnvloed, en uiteindelik ook die sukseskoers van tegnologie-oordrag se kommersialiserings-aktiwiteite bepaal, die totale jaarlikse navorsings- en ontwikkelingsuitgawes aan SA universiteite is. Die navorser het bevind dat sonder ‘n beduidende gehalte en hoeveelheid navorsing en ontwikkeling, min of geen inkomstestrome van nuwe uitvindings aan SA universiteite verwag kan word nie.

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Abbreviations

ACE	Angiotensin Converting Enzyme
AIM	Alternative Investment Market
AMI	African Medical Imaging
AMTS	Advanced Manufacturing Technology Strategy
ARL	Applied Research Lab
ATRE	Adjusted Total Research Expenditure
AUTM	Association of University Technology Transfer Managers
B-BBEE	Broad-Based Black Economic Empowerment
BRICs	Biotechnology Regional Innovation Centres
CAT	Computed Axial Tomography
CBD	Convention on Biological Diversity
CeBER	Centre for Bioprocess Engineering Research
CeSTII	Centre for Science, Technology and Innovation Indicators
CFI	Canadian Foundation for Innovation
CHEC	Cape Higher Education Consortium
CIPC	Companies and Intellectual Property Commission
CiTi	Cape Innovation and Technology Initiative
CoEs	Centres of Excellence
CPUT	Cape Peninsula University of Technology
CRADAs	Cooperative Research and Development Agreements
CREST	Centre for Research on Science and Technology
CVP	Centennial Venture Partners
DAC	Department of Arts and Culture
DACST	Department of Arts, Culture, Science and Technology
DOE	Department of Education
DHET	Department of Higher Education and Training
DST	Department of Science and Technology
DTI	Department of Trade and Industry
DVC	Deputy Vice-Chancellor
ESIL	Energy Storage Innovation Lab
FDI	Foreign Direct Investment

FITT	Foundation for Innovation and Technology Transfer (India)
FRD	Foundation of Research Development
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
GTZ	German Agency for Technical Cooperation
HySA	Hydrogen fuel cell Centre of Competence
HEIs	Higher Education Institutions
HEMIS	Higher Education Management Information System
HSRC	Human Sciences Research Council
IC	Intellectual Capital
ICF	Intellectual Capital Forum
ID	Industrial Design
IDC	Industrial Development Corporation
IES	Industrial Extension Service
IF	Innovation Fund
IFCO	Innovation Fund Commercialisation Office
IIPI	International Intellectual Property Institute
IOP	Institutional Operating Plan
IP	Intellectual property
IPAs	Institutional Patent Agreements
IPAC	IP Advisory Committee
IPCC	Intergovernmental Panel on Climate Change
IPR-PFRD	Intellectual Property Rights from Publicly Financed Research and Development
IPRs	Intellectual Property Rights
IRR	Internal Rate of Return
KAIST	Korea Advanced Institute of Science and Technology
KAT	Karoo Array Telescope
LEAP	License and Entrepreneur Assistance Program
LES	Licensing Executives Society
LOAs	Licensing, Option and Assignment Agreements
M&E	Monitoring and Evaluation

MIT	Massachusetts Institute of Technology
MiTech	Missions in Technology
NACI	National Advisory Council on Innovation
NC SBTDC	North Carolina Small Business and Technology Development Centre
NC State	North Carolina State University
NDP	National Development Plan
NIH	National Institute of Health
NIPMO	National Intellectual Property Management Office
NMMU	Nelson Mandela Metropolitan University
NRF	National Research Foundation
NSI	National System of Innovation
NSF	National Science Foundation
NSRC	National Survey of Research Commercialisation
NWU	North West University
OECD	Organisation for Economic Co-operation and Development
OER	Open Educational Resources
OIL	Office of Industry Liaison
OIP	Office for Intellectual Property
OTL	Office for Technology Licensing
OUI	Oxford University Innovation
PCT	Patent Co-operation Treaty
PFROs	Publicly Funded Research Organisations
RC&I	Research Contracts & Innovation
RCIPS	Research Contracts & Intellectual Property Services
R&D	Research and development
RIMS	Research Information Management Systems
RTI	Research & Technology Innovation
SA	South Africa
SAAO	South African Astronomical Observatory
SAIAMC	South African Institute for Advanced Materials Chemistry
SALT	SA Large Telescope
SARChI	South African Research Chairs Initiative

SARIMA	Southern African Research and Innovation Management Association
SAVCA	Southern African Venture Capital and Private Equity Association
SBIR	Small Business Innovation Research
SEDA	Small Enterprise Development Agency
SET	Science, Engineering and Technology
SETA	Sector Education and Training Authority
SETIs	Science, Engineering and Technology Institutions
SKA	Square Kilometre Array
SMME	Small, medium and micro enterprise
SPII	Support Program for Industrial Innovation
S&T	Science and Technology
SU	Stellenbosch University
TAP	Technology Advancement Programme
THRIP	Technology and Human Resources for Industry Programme
TIA	Technology Innovation Agency
TRIPS	Trade Related Aspects of Intellectual Property Rights
TT	Technology transfer
TSP	Technology Station Programme
TTOs	Technology transfer offices
TUT	Tshwane University of Technology
UAVs	Unmanned Aerial Vehicles
UCT	University of Cape Town
UCSD	University of California at San Diego
UFS	University of the Free State
UJ	University of Johannesburg
UK	United Kingdom
UML	Unistel Medical Laboratories (Pty) Ltd
UNISA	University of South Africa
UNNW	University of the North West
UoT	University of Technology
UP	University of Pretoria
USPTO	United States Patent and Trademark Office

USA	United States of America
US	United States
UWC	University of the Western Cape
VC	Venture Capital
WARF	Wisconsin Alumni Research Foundation
WHO	World Health Organisation
WIPO	World Intellectual Property Organisation
WRC	Water Research Commission
WTO	World Trade Organisation

Chapter 1: Introduction

1.1 Background

Authors Gibbons, Limoges, Nowotny, Schwartzman, Scott and Trow (1994) assert that the knowledge economy began evolving in advanced economies during the latter part of the 20th century. Knowledge, which is abstract and intangible (Chartrand, 1995), performs a crucial role in several active markets (Gibbons *et al.*, 1994). Yet, the results of knowledge gained from research efforts often lead to legal protection by securing intellectual property rights (IPRs) and exploitation of it through technology transfer (TT) practices. Once protected, the novel research findings usually contribute to the creation of innovative products in various fields that can penetrate commercial markets across the globe.

University technology transfer and the effective commercialisation of intellectual property (IP) emanating from university campuses has become a topic of growing interest for academic staff and students all over the world. Scholars from fields such as economics, business, science, sociology, and history have studied the topic from different points of view. Technology transfer professionals from universities around the world and lawyers that are experts on matters of IP legislation and IP protection have added impetus to the dialogue. The bulk of the literature on university technology transfer is being written in the United States where university technology transfer activities have blossomed since the enactment of the Bayh-Dole Act of 1980 (Bozeman, 2000; Colyvas, Crow, Geljins, Mazzoleni, Nelson, Rosenberg & Sampat, 2002; Mowery, Nelson, Sampat & Ziedonis, 2001).

Society has progressed from the agricultural age through the industrial age to the information age in less than 200 years (KPMG, 2013). While the agricultural age was constrained by labour and land, today most of the value of an organisation may be in the form of intangible assets and IP. KPMG (2013) asserts that globalisation, combined with the advancement of technology and the consequent acceleration of product life cycles, has increased the importance of IP in organisations and the need to manage it strategically. KPMG (2013) further claims that IP assets have become products unto themselves, capable of generating revenue streams and competitive advantages for their legal owners. IP constitutes the primary product and input of the information age, and is the central resource for creating wealth in almost all industries from which organisations extract maximum value to be competitive (KPMG, 2013).

Knowledge workers are typically managers, entrepreneurs, and businessmen who can use information and the latest technical innovations to their advantage in order to create successful organisations. In the modern economy, companies and countries within which these companies operate are as good as their ability to generate, use, and manage knowledge and knowledge workers.

Bourne (2000:25) refers to the knowledge economy as follows:

> Knowledge requires people, and people, not things, are at the heart of the knowledge economy. In the knowledge economy of today, productivity is based on innovation, requiring a wide range of people with specialised knowledge and experience, who must be able to experiment, respond to change, and work creatively in teams. Education and research are thus at the heart of the new economy, and investment in people should be the central policy of any country's long-term economic strategy.

IP refers specifically to intangible assets that are legally protected in some manner (KPMG, 2013). Depending on the jurisdiction, protection can take varying forms, including patents, copyrights, trademarks, registered designs, and trade secrets. IP is an integral part of Intellectual Capital (IC), which includes human resources, processes, and other forms of know-how. Know-how is the most difficult to exploit commercially, as it does not always enjoy legal protection. While universities in South Africa (SA) generate IP, it may not be converted into value, due to inefficient and ineffective technology transfer practices. Therefore, the potential of IP in making a financial contribution to these universities, which are likely to become more and more financially constrained, needs to be examined. Of importance will be to see if the commercialisation of IP by knowledge workers at these universities can become a catalyst for socio-economic development.

Garduño (2004a), Mowery (2004), and Lehman (2001) note that a number of universities in developed countries have succeeded in commercialising their IP effectively. Most universities in the United States have capitalised on the commercialisation of IP, thanks to the Bayh-Dole Act (PL 96-517, Patent and Trademark Act Amendments of 1980), which shifted the ownership of IP developed by academics using federal funding from government to universities, and encouraged these universities to commercialise their ideas (Mowery *et al.*, 2001; Thursby & Thursby, 2003).

Universities in the United Kingdom (UK) have also been developing a reputation for applying the results of scientific research to new products that can hold their own in commercial markets of the world (Lambert, 2003).

Clearly the potential of IP as generator of economic value has become more important for universities across the globe. Thus, several universities in SA have embarked on a path to unlock the commercial potential of their IP by establishing technology transfer offices (TTOs) and adopting IP policies approved by their university councils. The first universities in SA to claim ownership of IP created by its academic staff and students were Stellenbosch University (SU) and the University of Cape Town (UCT). Starting these initiatives in 1999, both SU and UCT hoped that their policies, offering incentives to academic staff, would lead to disclosures of novel technologies that can be commercialised.

A major challenge for SA universities is to create effective technology transfer mechanisms for assisting academic staff to create innovative technologies. The SA government has stated its intention of becoming actively involved in promoting innovation by effective resource allocation to the National System of Innovation (NSI). It is the aim of various SA national policies (see section 4.5.1) to support interventions that will lead to a reduction of poverty and improvement in the quality of life for all in South Africa (Republic of South Africa: Department of Science and Technology, 2002).

Universities across the globe are changing their focus to become more entrepreneurial in their approach by actively commercialising the IP developed on their campuses (Lambert, 2003). The need for SA universities to follow their example and to increasingly participate in the knowledge economy of today is highlighted in this study. It is also against this background that the research objectives and the main research question of the study were derived.

1.2 Purpose of study

One of the main challenges of university TTOs is to identify suitable and novel inventions that can be protected and for which commercialisation is a real possibility. Academic staff members as researchers are often the source of new technology to be transferred to businesses in commerce and industry. Yet, while valuable ideas emanate from university laboratories, they cannot be exploited if researchers do not disclose them to their university TTO (Thursby & Thursby, 2005).

Moreover, in SA the main problems arising from the commercialisation of IP are due to a lack of an enabling environment, the inexperience of some university academic staff, and the shortage of skilled technology transfer practitioners (Garduño, 2004a). These challenges are obstacles to establishing a technology transfer industry at tertiary institutions. It is imperative that SA universities invest limited resources to facilitate the transfer of new technologies from their research laboratories to other organisations and businesses in commerce and industry.

The purpose of the study was to gain a better understanding of the concept of IP in general, and the importance of its effective commercialisation for SA universities. The commercialisation of IP rights requires a thorough understanding of the issues involved in legal protection and the use of IP to aid economic development. Effective commercialisation strategies at SA universities are evaluated as part of an in-depth analysis using multiple case studies of four universities located in the Western Cape, SA. These universities are Stellenbosch University (SU), Cape Town University (UCT), The University of the Western Cape (UWC), and Cape Peninsula University of Technology (CPUT).

Research objectives

Technology transfer activities are not limited to claiming ownership of IP created by academic staff and protecting the IP by using patents or any other means of protection. Initiatives for promoting technology transfer and increasing the conversion rate of IP from its disclosure (limited in value) to useful technology (high in value) include the establishment of innovation centres or incubators where entrepreneurs can work closely with university academics and scientists. Universities can also provide pilot plants and promote entrepreneurship by facilitating access to venture capital for the formation of university spin-out companies.

The overall objective of this study is to consider the role of universities in the effective commercialisation of IP emanating from their campuses. The specific research objectives are to:

- define intellectual property within the context of universities globally;

- define the terms technological innovation and technology transfer used in describing efforts to commercialise university IP assets;
- develop a conceptual framework consisting of key dimensions that represents the enabling environment for institutional technology transfer at universities; and
- use the key dimensions from the conceptual framework in case studies to evaluate technology transfer practices used at four SA universities located in the Western Cape, SA.

These objectives will inform a discussion of the effective commercialisation of IP assets at the four SA universities, ultimately allowing the researcher to draw valid conclusions.

1.3 Main research question

IP has not been effectively commercialised at SA universities during the first decade following the year 2000. This statement is supported by empirical evidence (Sibanda, 2009; Wolson, 2007) indicating the low number of patents and the small number of new enterprises ("spin-out companies") emanating from SA universities annually.

The main research question is derived from increased activity noted and successes achieved from technology transfer practices employed at SA universities lately. The increased activity is supported by recent empirical evidence indicating the increased number of patents, license agreements concluded, and the starting of new enterprises ("spin-outs") from SA universities, at Western Cape universities in particular. The main research question of this study is addressed by determining how Stellenbosch University (SU), Cape Town University (UCT), The University of the Western Cape (UWC), and Cape Peninsula University of Technology (CPUT), all located in the Western Cape, SA, as a developing country, faired in using enabling factors as dimensions in commercialising their IP assets.

Consequently, the main research question is: ***How effective have four universities in the Western Cape, SA, been in commercialising their intellectual property assets through the use of technology transfer practices?***

It is hoped that the results of this study will lead to increased rates of disclosure of new inventions and better research collaboration amongst university academic staff at all SA universities and their counterparts at other research institutions within geographical regions. If academic staff members co-operate and disclose their novel findings to their university TTOs, they can better contribute to and benefit from the high growth potential of the current knowledge society.

1.4 Significance of the study

Management of SA universities' IP portfolios is increasingly important and requires a wide range of legal, engineering, economic, taxation, and accounting knowledge and capabilities. Valuable IP assets accumulate at SA universities and is not effectively utilised through commercialisation efforts due to inefficient technology transfer practices (Heher, 2006; HESA (Higher Education South Africa), 2007). The problem is not unique to SA and has been experienced at universities around the globe. Until 2006, the absence of a strong legal environment in SA [prior to the enactment of the Intellectual Property Rights from Publicly Financed Research and Development Act 51 of 2008 (IPR-PFRD Act)] and the lack of access to experienced entrepreneurs led to ineffective commercialisation strategies employed by many SA universities (Wolson, 2007).

The significance of this study lies in its contribution to the body of knowledge by highlighting current technology transfer practices used at four SA universities located in close proximity in the same province. Also, the study draws attention to the unique challenges faced by all SA universities in promoting a better understanding of the commercialisation of IP produced by its academic staff and students. The study further indicates the level of commitment required from university top management and the cooperation needed between technology transfer managers at university TTOs and academic staff within universities to effectively commercialise IP.

The target readers are academic staff members and students at SA universities who, as participants in research projects, can be motivated by this study to increase their disclosure of research findings which can lead to successful commercialisation and subsequent benefits flowing back to them, their university, and the SA economy. The target readers also include managers at SA universities' TTOs and managers at various SA governmental and non-governmental institutions who interact with universities and jointly fund research projects with the aim to commercialise novel research findings emanating from such joint research efforts.

1.5 Motivation for the study

The researcher's interest in the commercialisation of IP started at the beginning of 2000 when he was appointed as financial manager of the then newly created Office for Intellectual Property at Stellenbosch University. The magnitude of technology transfer activities at universities across the globe became clear to him when he read IP law at Oxford University in 2000 for a master's degree in Future Studies, awarded by SU in 2001. He also attended the annual conference of the Association of University Technology Managers (AUTM) held in San Antonio, Texas, in the United States in March 2004. This was followed by a longer visit of two months during May and June 2004 to North Carolina State University (NC State) in Raleigh, North Carolina. At the TTO of NC State he gained valuable knowledge regarding the enabling environment required for improving the success rate of university technologies being transferred to commerce and industry.

The motivation for the current study is that the research results should be utilised to increase the pipeline of new inventions emanating from university research, and to improve technology transfer practices at SA universities in other provinces too. If the TTOs at other SA universities succeed in doing so, then valuable IP assets can be commercialised for the public good. The commercialisation of IP rights requires greater understanding of the issues involved in legal protection and the ability of IP rights to add considerable value to its legal owners and its users once it has been commercialised.

1.6 Limitations

As researchers, academic staff need to be reminded that identifying inventions from research findings and disclosing them timeously to their university's TTO may not only benefit them personally, but also promote increased research activities. They should be encouraged by the fact that intellectual exchange and collaboration with industrial partners may attract financial support for additional research activities, as well as unimagined personal wealth.

Although this study focuses on four SA universities in one province, it does not demean efforts exerted by other SA tertiary education institutions in other provinces. The role of all SA tertiary education institutions and private organisations in teaching specific skills is very important to the SA economy and businesses in commerce and industry. The study is not aimed at finding alternative ways of valuing IPRs, but rather highlighting the potential of IPRs as an additional source of income for universities once fully exploited. In particular, the study will indicate how four SA universities have progressed in commercialising IP emanating from their campuses through evaluating key statistics from 2008 to 2015. The study will not distinguish between various IPRs that should or should not remain in the public domain.

1.7 Outline of chapters

This introductory chapter introduces the topic. The sections above comprise background information, the purpose of the study, research objectives, the main research question, significance of the study, and the motivation for undertaking the study. The penultimate section discusses the limitations for this study, whilst this section concludes the chapter with an outline of each of the remaining chapters to follow.

The remaining chapters are structured to best address the research objectives and to answer the main research question. Chapters Two and Three are literature reviews and address the first three research objectives. Chapter Two starts by answering the first research objective and comprises a terminological clarification of IP. The chapter includes definitions of terms for IP assets and addresses the second research objective by offering definitions for technological innovation and technology transfer before the effective measurement of university technology transfer is stated.

Chapter Three examines the changing role of IP emanating from universities globally by considering the history of university technology transfer in developed and developing countries. A conceptual framework is suggested for institutional technology transfer at universities, delivering a number of dimensions that are prevalent enablers for university technology transfer.

Chapter Four addresses the third research objective by discussing trends globally and in SA for university technology transfer, using five key dimensions which form part of an enabling environment.

The fifth chapter is concerned with the research design and methodology used for this study.

The literature reviews, read together with the analysis provided by the multiple case studies from Chapters Six to Nine, assist in answering the fourth research objective, which is to evaluate technology transfer practices used at four SA universities.

The final chapter draws upon the entire study, tying up the various theoretical and empirical strands in order to reach the final conclusions, and ends with recommendations for future research.

Chapter 2: Terminological clarification

This chapter comprises a literature study that introduces the reader to key terms and definitions used throughout this study.

2.1 Introduction

If the 19th century was characterised by a demand for physical capital in the form of buildings and machines, the 20th century saw an increasing demand for intangible capital represented by education and research. Chartrand (1995) contends that knowledge is abstract and thus intangible. He poses the question: “How can knowledge be converted into property?”

> It is not like a car or a house, which can be locked and secured against theft. If someone gains knowledge it does not reduce that which is available to others. Essentially there are two ways of turning knowledge into property. One way shared by all cultures is through secrecy, i.e. keeping it confidential. The second is through intellectual property law, including copyright, patent, registered industrial design and trademark legislation... (Chartrand, 1995: 4).

Nelson (2001) maintains that universities are important suppliers of new inventions emanating from technological innovation. TT activities are linked to universities, as they are generators of valuable products that have the potential for commercial exploitation once the IP is secured and protected. The benefits flowing to the broader public, following TT at universities, are new products and services which lead to economic growth.

2.2 Intellectual property – an intangible asset (Key definitions and concepts)

Hughes (1988: 3) refers to IP as the “*propertisation of talent*”, and maintains that IP has similar characteristics to other forms of property, describing it as “*non-physical property...whose value is based upon ideas*” (Hughes, 1988:4). Universities are generally known as organisations that promote the creation and exchange of ideas. When referring to knowledge production leading to useful ideas, Gibbons *et al.*(1994:14) assert that “*Socially distributed knowledge production is tending towards the form of a global web whose numbers of inter-connections are being continually expanded...*” Gibbons *et al.* (1994) further maintain that IP has become a significant matter on university campuses, resulting in changed responsibilities for university lawyers and giving birth to what is called “*academic entrepreneurs*”.

Formal IPRs, such as copyrights and patents, are used to protect and to spur creativity, which could otherwise be used without restraint by others. In reply, society requires that creators publish their work, and provides a market in which their work can be traded. While society desires to promote creativity, it does not want to encourage restrictive market forces. As a result, IP legislation is aimed at limiting the rights afforded to the creator. Such limitations include both the period and the freedom of use, as IPRs are granted for a predetermined length of time, and protect only the concentration of originality once in substantial form (Chartrand, 1995).

Anson (2007) reports that *intangible assets* denote items of worth that are not physical, but can be quantified and controlled and to which a value may be attributed. *Intellectual property* is a subcategory within the broader group of intangible assets. A piece of IP is a distinctive intangible asset, as formal legal protection is available to it. *Intellectual capital*, which also encompasses human resources, characteristically contains a group of various intangible assets such as patents, trademarks, copyrights, brands, logos, and other classes of goodwill that are rarely valued separately and are less likely to be legally protected (Anson, 2007).

Landes and Posner (2003) define IP as "ideas, inventions, discoveries, symbols, images, expressive works (verbal, visual, musical, theatrical), or in short any potentially valuable human product that has an existence separable from a unique physical embodiment". They further contend that there has been "growing enthusiasm" for IPRs in general, as reflected by the increased number of patents registered by the United States Patent and Trademark Office. Idris (2003), refers to IP assets such as patents, trademarks, copyright, designs, traditional knowledge, know-how and trade secrets as "hidden value" when commenting on the increased value and importance of intangible assets that have grown steadily since 1982. In 1982, some 62% of corporate assets in the United States were represented by physical assets. This figure shrunk to only 30% by the year 2000, as intangible assets grew in value and importance (Idris, 2003).

Table 2.1 below lists the various types of intangible assets, grouped into three categories, namely intellectual property, intellectual capital, and goodwill, as classified by Ch'ang & Yastreboff (2003).

TABLE 2.1: TYPES OF INTANGIBLE ASSETS

Intangible Assets

Intellectual Property	**Intellectual Capital**	**Goodwill**
• **Patents** (including processes and inventions) • **Trademarks** (including domain, company and business names) • **Copyright works** (Including designs and circuit layouts) • **Confidential information** • **Plant breeder's rights**	• **Human capital** (Know-how) • **Enterprise knowledge** • **Enterprise innovation** • **Enterprise relation-ships** (including contractual rights, licensing, permits, franchises, distribution rights and non-complete covenants)	• **Future benefits from unidentifiable assets** that are not capable of being individually identified and specially recognised. Such assets can include, market penetration, effective advertising, good labour relations and a superior operating team.

Source: Ch'ang & Yastreboff (2003:33).

Ch'ang and Yastreboff (2003), like Hughes (1988), contend that IP assets, unlike tangible assets such as factory operating plants, vehicles, machinery and equipment, are not physical in nature and are inherently invisible. Often though, it is the unique intellectual (and thus *intangible*) property that organisations own that gives them a competitive advantage and the critical leverage needed to be profitable and sustainable. This is true also for universities as organisations that create and own IP. Both authors mentioned above assert that IP, within the context of universities, should be defined as unique intangible and invisible assets emanating from the intellect of academic staff and students, available to universities for commercial application after it has been legally protected.

Christie and Pryor (2005: 36), after considering the meanings and interpretations of the words "*intellectual*" and "*property*", argue that the term "*intellectual property*" refers to "an innovative or creative emanation of the human intellect in respect of which a legal right of exclusivity may be granted".

The convention that established the World Intellectual Property Organisation (WIPO) determined on 14 July 1967 that intellectual property shall include rights relating to:

- literary, artistic and scientific works;
- performances of performing artists, phonograms and broadcasts;
- inventions in all fields of human endeavour;
- scientific discoveries;
- industrial designs;
- trademarks, service marks, and commercial names and designations;
- protection against unfair competition; and
- and all other rights resulting from intellectual activity in the industrial, scientific, literary or artistic fields (World Intellectual Property Organisation, 2013a).

Similarly, IPRs have been defined by the World Trade Organisation (WTO) (2013) as "rights given to people over the creation of their minds", and include "…ownership of ideas, including literary and artistic works (protected by copyright), invention (protected by patents), signs for distinguishing goods of an enterprise (protected by trademarks) and other elements of industrial property". The following sections (2.2.1 to 2.2.7) describe different IP types, namely patents, trademarks, copyright, industrial designs, know-how, trade secrets, and traditional knowledge in more detail.

2.2.1 Patents

A patent is a time-limited monopoly granted to the legal owner of an invention by the government in return for disclosing information about the said invention. Griliches (1990) maintains that the monopoly granted by patents is justified, as it allows the owner to recoup the investment made in Research and Development (R&D before competitors can enter the market. The author further declares that "...patent statistics remain a unique source for the analysis of the process of technical change. Nothing else even comes close in the quantity of available data, accessibility, and potential industrial, organisational and technological detail" (Griliches, 1990:1702).

Bremer (2001) claims that the patent system was created as an incentive to invent, develop and promote new technologies for the public good. Bremer (2001) also advocates that what is available to everyone is often of value to nobody. One of the conditions for the granting of patent rights is that the subject of the application should be "new" or "novel". Once a patent is granted, the owner of the patent has the right to stop others from selling the invention without his/her consent or adequate compensation for its use for the duration of the monopoly. Patent law administration varies from country to country. In some countries, only an inspection is performed of the submitted documents to determine whether it complies with formal requirements. These countries are referred to as non-examining or registration countries. The South African Patent Office is an example of such a non-examining office, as the only examination performed is on papers submitted and not on the actual substance of the patent. The novelty requirements of South Africa are very similar to those of most of the high income countries world including Europe, Australia, the United States and Japan (Hahn & Hahn, 2005).

Conversely, other countries perform an examination to test the merits of a patent application, based on an extensive search on the current state-of-art. The United States Patent and Trademark Office (USPTO), for instance, examines patents and plays an important role in helping inventors protect their inventions in the United States. Countries with examining offices include both their own patents and foreign patent material in their search files (United States Patent and Trademark Office (USPTO), 2005).

Collins (2017) elaborates on USPTO (2005) by advising that a patent will be granted if the invention:

- is new, and does not form part of the current "state-of-art";
- involves an inventive step that is not obvious to a person skilled in the art;
- is capable of industrial application where it can be used in a number of industries; and

- is not excluded from patentability under the European Patents Act of 1977. An invention is not patentable if it constitutes a discovery, a scientific theory, a method of treatment or diagnosis of human or animal bodies by surgery or therapy (including products used in such methods, hence pharmaceuticals are patentable), or a work protected by copyright.

A patent is defined by the Oslo Manual of the OECD as follows:

> A patent is a legal property right to an invention, which is granted by national patent offices. A patent gives its owner sole rights (for a certain duration) to exploit the patented invention; at the same time it discloses the details of the patent as a way to allow broader social use of the discovery (Organisation for Economic Co-operation and Development (OECD), 2005:22).

When inventors started to produce the stove for the mass market (Figure 2.1), the patent system provided an exclusive benefit for promoting sales. It allowed the stove to be differentiated from similar products of competitors in the market, accumulating value, and protected the creator from competition (mainly on price). Once the protected patent was sold or licensed to another producer as a right to assemble and sell to a specific market, the patent provided the same benefits to the buyer as it did for the original creator.

FIGURE 2.1: STOVE PRODUCED FOR MASS MARKET
Source Harris (2013)

The buyer generates income from selling the use of the invention, while the creator earns recurring royalty income if the selling price included a running royalty (Harris, 2009). The granting of a patent provides the legal owner with a monopoly for up to twenty years and twenty-five years in the case of plant-breeders' rights (Nguyen, 2010). It is argued that while IP law establishes the market in which IPRs are created, valued and exchanged, competition law ensures that the market assigns a fair and efficient value to this property (Nguyen, 2010:37).

Enacted on 12 December 1980, Public Law 96-517, the Patent and Trademark Law Amendment Act of 1980 (commonly known as the Bayh-Dole Act of 1980) in the United States resulted in a standardised patent policy among the many federal agencies that funded research in that country. Bayh-Dole enabled small businesses and non-profit organisations, such as universities, to retain the title to new inventions that emanated from federally-funded research laboratories (Mowery, 2004).

A patent prevents someone from reproducing the product, whereas a trademark is used to distinguish a product from similar products in the marketplace. A trademark can be developed in support of a patented product.

2.2.2 Trademarks

WIPO (2013b:1) defines a trademark as "a *distinctive sign* which identifies certain goods or services as those produced or provided by a specific person or enterprise ... and helps consumers identify and purchase a product or service because of its nature and quality".

A trademark is different from a patent, as it does not represent an invention. A trademark is a registered sign distinguishing the goods and services of one trader from another. If consumers can identify goods (products) by reference to a trademark, it allows for repeat purchases and the consequent avoidance of (perceived) lower-quality products. Adidas, Apple, Calvin Klein, Nike, Microsoft, Facebook, Twitter, and WhatsApp are examples of household names that have so grown in international prominence that they have become invaluable to their legal owners. Whereas goods like sugar and flour would be scooped out of large, unmarked containers by shopkeepers in the pre-branding, pre-packaging era, the start of mass-produced goods necessitated the naming of products, and corporate logos made their appearance in the late

1800s. Trademarks became an increasingly important element in the marketing of products around the world in the nineteenth century, as indicated by this trademark below for Ivory soap (Figure 2.2), registered in 1879.

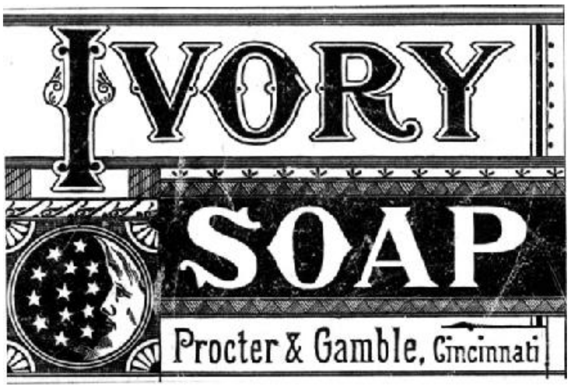


FIGURE 2.2: THE TRADEMARK FOR IVORY SOAP REGISTERED IN 1879
Source: Library of Congress (1879)

The main aim of a trademark is to prevent consumers from becoming confused about the source of a product or service. Trademarks thus assist consumers by indicating who makes the product or who provides the service. WIPO administers a system of international registration of trademarks to avoid the need to register with each country's national or regional office separately. Trademarks add value to the goods and services that they represent, a function commonly known as branding. One of the best examples of a strong South African brand originated in 1987 in a small Johannesburg Portuguese community. Fernando Duarte and Robert Brozin started a fast-food restaurant selling Portuguese-style chicken. They called it Nando's and today Nando's is a global brand, with an extensive international portfolio of registered trademarks. Chains of Nando's stores are situated in thirty countries, including many African countries, Australia, Canada, Egypt, Israel, Malaysia, Saudi Arabia and the United Kingdom (Idris, 2003).

For the registration of a trademark, a graphic representation is required that distinguishes the applicant's goods or services from others in a unique way. Licensees (people or organisations that have been granted the express right to use a trademark) are also protected against infringement, which they can enforce if the trademark owner fails to do so. An example of such an infringement is "passing off" or imitating a well-known brand very closely. Passing off is the practice of making some representation that gives the impression that goods or services of one trader come from another trader who has established goodwill.

Constructing and enforcing specific notions of corporate identity as a property right is one of the functions of trademark law. A good example is that of Nike (http://www.nike.com), as the most important assets the company owns to leverage as productive capital are its logo, brand name, and marketing personnel. Similar to Nike, J.K Rowling, a writer, has gained significant financial benefit from growth in the sales of Harry Potter books and merchandise. Many different companies have secured the rights to use the Harry Potter brand in areas ranging from electronic games, toys, and interactive candy, to video games and the marketing of the film. This is an example where a network of agreements has extended the use of the brand, and co-marketing has helped to reinforce the popularity of the particular character and brand (Idris, 2003).

Good examples of successful South African trademarks come from the late Dr Anton Rupert. While still a lecturer at the University of Pretoria, Dr Rupert conducted a series of searches at the Trademarks Office in Pretoria to see what trademarks might be available, after which he registered a number of trademarks. He first registered the well-known Van Rijn label, and then continued to register brands such as Peter Stuyvesant, Richelieu, Oude Meester, and well-known international brands such as Cartier and Dunhill (Trinitas Consulting, 2013).

Trademark licensing is a lucrative way of extracting value from one’s brand and is fast becoming a significant source of revenue for many universities. All universities promote their name, logo and brand to gain wider recognition and to portray a positive image to their students and the public. Universities issue licensing agreements to control the use of their trademarks in the marketplace and to earn income to support their teaching mission. As academic institutions, universities thrive on their ability to create and uphold a strong reputation, and use distinctive registered trademarks to do this. Examples include NC State University Wolfpack, Washington State University Cougars, Oregon State Beavers, Binghamton University Bearcats, the Miami Redhawk, and UCLA Bruins. Universities often license the right to use one or more of their trademarks to manufacturers, retailers, or vendors for use on their products or services. This may include the right to use the university’s name, seal, logo, crest, sports mascot or any other of its markings. This arrangement, called merchandising, ensures a good source of revenue for universities (WIPO, 2013b). The licensing of university brand names is similar to that of a franchise- franchisee relationship, whereby strict control measures are used to monitor the correct use of the name of the institution on agreed-upon terms. In the United States, collegiate merchandise is a multi-billion dollar industry. Outside of the United States many universities, such as Oxford University in England, also follow similar trademark licensing policies.

Leading universities worldwide have an excellent academic reputation and it makes sense for them (and lesser known universities) to promote and capitalise on their trademarks and brands which have been built and maintained over many years. University sport also contributes to the reputation of universities and attracts a huge following. In SA, for example, Tukssport (Pretoria University) and MatieSport (Stellenbosch University) are examples of departments that are actively embarking on enhancing and promoting the sporting culture of their respective universities.

2.2.3 Copyright

Collins (2017:1) defines copyright as “the exclusive right to produce copies and to control an original literary, musical, or artistic work, granted by law for a specified number of years”.

The cost of reproducing the work of a creator may be low compared to the cost of creating the original work, such as a book, movie, song, etc. Protection by copyright to stop others from reproducing a particular piece of work is aimed at allowing the creator of the work to recover the cost of producing the work and to make profit from it. Significant benefits are often derived by the owners of copyrightable works apart from financial remuneration, for instance when university academic staff publish articles in journals (Landes & Posner, 1989). The ownership of copyrightable works produced by academic staff at universities has been an issue for university administrators since 1970. Lape (1992) examined this issue and considered whether the work produced by an employee (usually an academic staff member) for his employer (the university) was within the scope and course of his/her employment or not. He concluded that ownership issues are best resolved by individual university copyright policies, and that the rights of academic authors to control the dissemination of such work should be protected.

Copyright law, called the *Statute of Queen Anne*, was formally passed in 1710 in the UK and conferred rights upon a work for the first time. However, the owner of copyright was mainly the printing company and bookseller. Only in 1775 did the House of Lords in England change the common law of printing rights in favour of the author. Thus, copyright was first granted to printers, then to booksellers, and finally to individual creators. Copyright is treated as an article of trade that can be bought and sold (Chartrand, 1995; Landes & Posner, 1989). In France and Western European countries, *droits d'auteur* or author's rights have their roots in the republican revolution of the late 18th century. The European perception of the creator's rights rests on two pillars, namely economic rights and moral rights. Economic rights allow the creator to assign or license the use of the work to others and are the means by which a creator earns income from the work. Moral rights, on the other hand, grant the creator lasting control over the work despite its exploitation. In such a system, the creator is the prime benefactor and later exploiters (like publishers, motion picture and recording companies) are less important players (Chartrand, 1995).

Copyright protects the expression of an idea, not the idea itself. An idea, story, speech or other communication cannot be protected by copyright, unless it is committed to paper or some other fixed form. Copyright requires no registration and arises automatically upon creation of a work that qualifies for this kind of protection. Copyright also protects the results of artistic, literary and dramatic effort, provided it has been recorded in some form or another, and lasts for fifty years after an author's death. Copyright protection is not confined to the arts, but also includes computer programmes, tables and compilations, maps and architectural plans, sound recordings, broadcasts, and other non-artistic works. Generally, a creation is protected by copyright if it constitutes a work that is (i) original and (ii) recorded in some permanent form (Collins English Dictionary, 2017). Black's Law Dictionary (2014) defines copyright as "*the exclusive right of the owner of an intellectual production to multiply and dispose of copies"*.

Copyright is an important IPR for university staff, as publications and other copyrightable works are being produced daily by millions of academics globally. The income earned from the course content of university study programmes and the publication of new scientific research results is significant for universities.

2.2.4 Industrial designs

A design may be registered in respect of an article or set of articles and is defined by WIPO (2013b) as "*the ornamental or aesthetic aspect of an article*". Designs may comprise three-dimensional features (for instance the shape or surface of an article) or two-dimensional characteristics (for example patterns, lines or colour). Anyone using a registered design without the owner's consent commits an act of infringement. It is a criminal offence to claim that a design has been registered if it has not. IP laws have protected the visual appearance of industrial products for many years. Prior to 1773, Europe had superior craftsmen and industrial designers and the leadership in the United States had to decide to either use them or create their own industry. It took a long time for the United States to become established in the field of industrial design (ID). The Carnegie Institute of Technology was established in 1900 by Andrew Carnegie through a donation of $1m where ID was introduced as a subject in 1934 (Lesko, 1997).

Symons (2002) reported that although designs as ideas are easily copied, there are a number of ways to protect them. The author reported that industrial designs are also protected by copyright. Under copyright law an ID is only protected to the extent that the creative aspect can be separated from its practical role. Designs other than computer programs may also be registered as long as they are original and distinctive. Designs that may be registered include specific types of designs like packaging, graphic signs, and lettering. Unregistered designs originate automatically, but must still be recorded in writing or in sample form, and must also be novel in shape or configuration (Davies & Stone, 2004; Symons, 2002).

Various goods also enjoy protection, such as "household goods, textiles, clothing and footwear, jewellery, industrial equipment and tools, vehicles, and packaging for food and drink" (Davies & Stone, 2004:12). Setliff (2006) claims that ID is a result of the industrial revolution and that practicality may be reduced by new mixed designs in order to improve the sales of a product, and thus the profits for its owners. An example listed by Setliff (2006) includes a vacuum cleaner that was aesthetically improved, even though the new design increased both the weight and cost of the product. Another example is the car that has its visual design changed many times, often without any technological improvements, before the launch of a new model.

The border lines for the protection of ID are often difficult to delineate. ID, claims Afori (2008), is located at the heart of art and technology and its main aim is to gain the attention of consumers. Trademark law is relevant in respect of IDs, as the product needs to be uniquely identifiable from similar products produced by competitors. Apart from trademark law and copyright, patent law is often also applicable where artistic and functional qualities combine to create a new industrial piece of equipment or gadget (Afori, 2008).

The most important new technological breakthrough prior to the establishment of gas and electricity in domestic homes in the United States were stoves (Afori, 2008; Harris, 2009). The stove was the most noteworthy but mundane household article of its time. Production increased rapidly during the first forty years, as the number of producers grew and developed their products in a period of fierce competition. Stoves were both articles of function and style, and producers aimed to differentiate their products in both of these aspects (Harris, 2009).

In the stove industry, design was crucially significant to enhance the end product and to assist in creating a demand for it. Stoves became surprisingly reliant on the patent system, and after 1842, also on industrial design and copyright. Stoves made up close to one tenth of all United States patents and about seventy percent of design patents for new inventions in the late 1830s and mid1840s. Inventors, designers and producers of the stove created, bought and sold and strongly protect their inventions with IPRs (Harris, 2009).

Gutiérrez (2012) claims that there is a rapid increase in the innovative design of electronic products such as computers, digital music players, smart phones and electronic display screens. The author argues that industrial design patents are vitally important to product development and claims that creators of physical products have long relied on innovative designs to distinguish their products from those of competitors. He asserts that there is a “technology-driven shift” from three-dimensional physical designs to two-dimensional electronic screens, which he calls the “virtual migration”. It is claimed that new product designs will be implemented via the use of electronic screen displays, rather than physical structure (Gutiérrez, 2012).

Industrial designs are used for a wide range of products in commerce and industry, including technical and medical instruments, watches, jewellery, and other luxury items and electrical appliances, vehicles, architectural structures, textile designs, and leisure goods. To be protected under most national laws, an industrial design must be new and/or original. Novelty or originality is determined by comparing a design to the existing body of registered designs. An industrial design is visual in nature, and does not protect any of the technical features of the article (World Intellectual Property Organisation (WIPO), 2013c).

2.2.5 Know-how

Gibbons *et al.* (1994:168) provide the following definition for know-how: “knowledge not available as a text and which may conveniently be regarded as residing in the heads of those working on a particular transformation process, or to be embodied in a particular organisational context”. Know-how is held by the employees of an organisation and is part of intellectual *capital,* which is an intangible asset (Table 2.1). Know-how may include laboratories, building layouts, vendor lists, ancillary equipment, information, marketing information and techniques, employee job descriptions, regulatory procedures, and customer listings. Generally, know-how in the workplace is protected by an employment contract and/or a restraint-of-trade agreement that legally binds an employee to secrecy. Nonaka and Takeuchi (1995) point out that “tacit” or “personal” knowledge is very important to the innovation process. While theoretical knowledge is important for establishing a base of information for inventors, it is the know-how gained through personal experience and face-to-face interaction that often leads to innovation.

When referring to TT, Seitzer (1999) claims that TT activities increasingly requires knowledge and the transfer of know-how. The author posits that the collective know-how and experiences of university academic staff, which he refers to as the “pool of know-how”, used in R&D contracts with businesses in commerce and industry should be acknowledged. Keeping the input of know-how and experiences in balance with the output within TT activities is sensitive, as companies paying a hundred percent of the R&D in a contract want to obtain an exclusive licence to use the research findings (Seitzer, 1999:145). Seitzer (1999) also states that the contribution of public funding to the pool of know-how is aimed at making the results freely available and should not lead to a single organisation keeping the results for sole exploitation. Seitzer’s conclusions are appropriate for this study, as he correctly argues that the TT process requires increasingly more knowledge and know-how transfer. The know-how is often provided by university academic staff who develop a particular technology using funding provided by both government and businesses in commerce and industry. Figure 2.3 below illustrates input-output flow of know-how into a pool of an organisation, including various sources of funding.

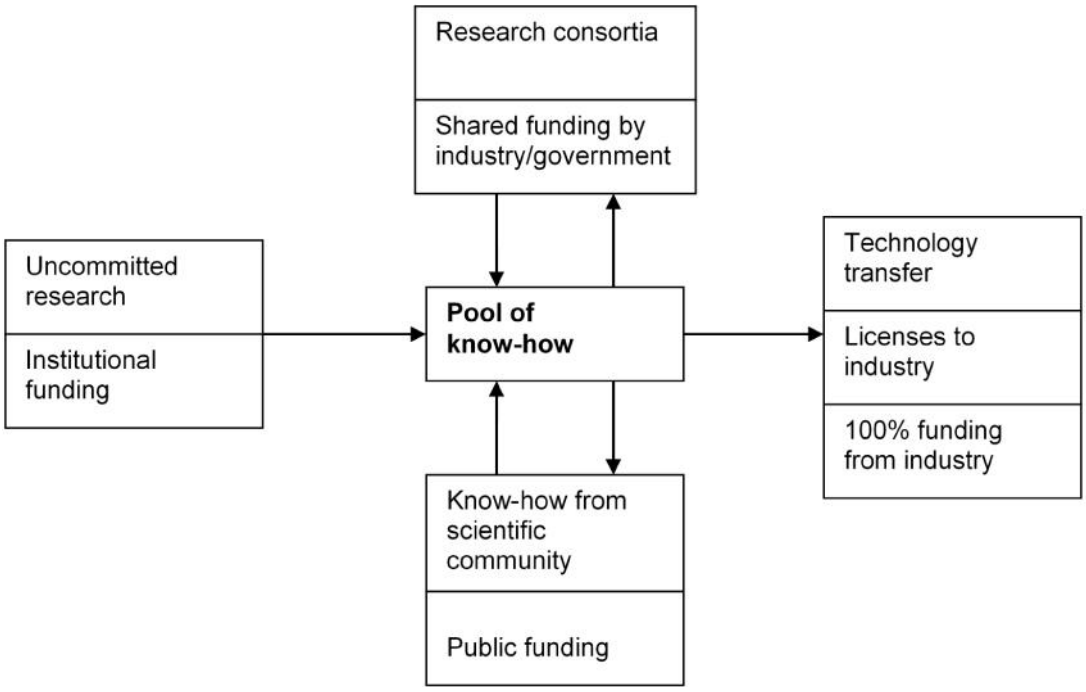


FIGURE 2.3: INPUT/OUTPUT FLOW OF KNOW-HOW INTO A POOL OF AN ORGANISATION
Source: (Seitzer, 1999:145)

Goldfarb and Henrekson (2003) concurred with Seitzer (1999) in asserting that early stage technologies, when knowledge is largely tacit, requires significant effort from academic staff of universities, until it become successfully commercialised. Adequate incentives in the form of monetary compensation are required to keep academic staff motivated throughout the process of development and commercialisation of their inventions.

2.2.6 Trade secrets

Trade secrets are defined in Section 1(4) of the United States Uniform Trade Secrets Act as:

> …information, including a formula, pattern, compilation, program, device, method, technique or process that: (i) derives independent economic value, actual or potential, from not being generally known to, and not being readily ascertainable by ... other persons who can obtain economic value from its disclosure or use, and (ii) is the subject of efforts that are reasonable under the circumstances to maintain its secrecy (National Conference of Commissioners on Uniform State Laws, 1985:5).

According to Chartrand (1995), secrecy is used to protect three types of information, namely trade secrets, know-how, and ritual. Electronic data is protected by encryption and password techniques to safeguard information. When an organisation finds its secrets have been stolen or made known, legal recourse is available through court action. Certain rituals practised by societies throughout the world have traditionally been kept secret, such as oaths of allegiance, traditional legal systems, and traditional healing methods. These may also include a wide variety of expressions, be it special gestures and words, recitations, songs or dances, and special clothing. Knowledge of rituals allows entry into a secret society. Secrecy is also achieved by restricting knowledge to only one individual in each generation (Chartrand, 1995).

Bone (1998) contends that information should adhere to the following three conditions in order to satisfy the criteria of a trade secret:

- it must confer a competitive advantage when kept secret;
- it must be secret in fact; and
- it must be protected by reasonable secrecy safeguards (Bone, 1998:248).

Often, trade secrets comprise a technological aspect, for example the formula for the Coca-Cola soft drink. Virtually anything can be eligible for protection as a trade secret if commercial value is likely to flow from it. In contrast with patent law that protects only novel inventions, trade secret law protects all inventions that bestow a competitive advantage, even if they are not new (Bone, 1998). Bone (1998) further maintains that secrecy needs not be absolute. Organisations can impart secret information to employees and others when needed to develop the commercial potential of the information, if the organisation takes steps to prevent unauthorised use and disclosure. However, information does not qualify as a trade secret if it is commonly known by an organisation’s rivals, or if it can easily be exposed. Steps to prevent unauthorised use may comprise disclosing the secret under a confidentiality agreement, or some other appropriate measure. Trade secret law protects information that is both not patentable and patentable (Bone, 1998; Smith & Parr, 2004).

Lemley (2008) acknowledges Bone’s (1998) proposal that trade secret law can be accommodated by common law doctrines. Nevertheless, Lemley (2008) claims that trade secrets may also be protected as a form of IP. A trade secret offers additional meaningful benefits for inventors over patent protection, because it is cheaper and faster to acquire as it does not necessitate government approval. Trade secrets also provide protection for certain categories of business information and processes that would probably not be patentable. Lemley further maintains that trade-secret law provides an alternative for the contractual constraints that organisations would have to enforce to stop opponents from obtaining their information. He also asserts that inventions which are naturally self-disclosing (like the wheel) cannot be kept secret and that trade-secret law is not required to promote disclosure of intrinsically self-disclosing inventions, but instead patent protection should be used, or nothing at all. Thus, secrecy performs a gatekeeper role by making sure that the law actually promotes disclosure of information that would have been kept secret, while diverting inventors of self-disclosing inventions to the patent system (Lemley, 2008).

The value of secret information is dependent on it being kept strictly confidential. Examples of information that are kept as trade secrets include tender prices, bid estimates, computer software, production processes, know-how, production schedules, computer software, customer lists, and credit records (Water Research Commission (WRC), 2013). Where a staff member of an organisation divulges the trade secrets of the entity to others, he or she is in breach of his/her fiduciary duties as employee. It is an established principle of the law in SA that protection is granted for information or know-how that an employer divulges in confidence to an employee in a contractual relationship, or which the employee gathers during the course of his/her employment. Similarly, academic staff at universities are expected to treat their research activities and research results as highly confidential (WRC, 2013).

Information that may comprise trade secrets for universities includes both research results and unpublished research reports. Universities globally have therefore included trade secrets in their IP policies.

2.2.7 Traditional knowledge

Knowledge can be considered a communal inheritance that directs the evolution of human society and is conveyed from one generation to another (Chartrand, 1995). In the post-modern world, knowledge is embodied in books, recordings, computer software, and other contemporary ways of transmitting know-how to future generations. In tribal or traditional communities, the oral tradition remains the dominant form of inter-generational and intra-generational transfer of knowledge. Chartrand (1995) maintains that such knowledge, when converted into property, should receive the same recognition and respect from other cultures as would other forms of IP. He claims that, while some in the developed world recognise the ownership rights of tribal peoples to their own cultural knowledge, others believe that all of humanity is deprived by restricting access to such knowledge to one culture only.

Traditional knowledge, also called indigenous knowledge, refers to knowledge compiled by a group of people through generations. Indigenous technologies have emanated from some of the world's oldest communities, and Western cultures have in recent years appropriated such traditional knowledge for highly sophisticated biotechnological, pharmaceutical, and industrial applications. Indigenous knowledge is defined by UNESCO as "… the knowledge that people in a given community have developed over time, and continue to develop. It is based on experience, often tested over centuries of use, adapted to local culture and environment, dynamic and changing" (United Nations Educational Scientific and Cultural Organisation (UNESCO), 2013).

The most important international instrument for the protection of indigenous knowledge is the 1992 United Nations Convention on Biological Diversity (CBD), which was signed by 169 nations. It was agreed at the convention that countries should retain the ownership of the natural biological resources in their territories, including their genetic resources. The articles of the convention impose obligations with regard to the conservation of bio-diversity, recognises the value of IPRs, and seeks to address the needs of developing countries by promoting TT and equitable sharing in the results of R&D. Some of the main provisions include Article 8(j), which encourages member countries to "respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities", and recommends the establishment of measures for conserving biological diversity and the sustainable use of its components (United Nations (UN), 1992).

Indigenous people have for millennia played a crucial role in maintaining the diversity of environments that are important to ecologically sustainable global development. For indigenous peoples, heritage is a bundle of relationships, rather than a bundle of economic rights (Puri, 2000). Puri used the Australian aborigines as an example and claimed that they are the bearers of the world's oldest culture. He states that culture represents "expressions, products, knowledge and practices that make up the collective heritage of indigenous peoples", and that it "embraces the intangible ideas and knowledge associated with artistic works, designs or other forms of cultural expression such as music, dance, song and story". According to Puri (2000:23), the word "traditional" means "untouched, untainted and pure", and the concept is "entwined with primitive people who lacked materialism and were unimpressed by the commodities and conveniences that European society has to offer".

The discussion in this section 2.2 included definitions for a number of intellectual property categories as intangible assets. Table 2.2 below summarises the various IP types, the degree of protection afforded, the method of protection, and the time afforded by the protection (if any).

TABLE 2.2: VARIOUS IP TYPES, PROTECTION AFFORDED, METHOD OF PROTECTION AND THE TIME AFFORDED

Intellectual Property Type	Protection afforded	Method of protection	Time Afforded
Patent	Yes	Registration	20 years
Plant Breeders Right	Yes	Registration	25 years
Trademark	Yes	Registration	10 years (Renewable)
Copyright	Yes	Printed on work	50 years after death of author
Registered Design	Yes	Registration	10 years (Renewable)
Know-how	Limited	Legal contract	Duration of contract
Trade Secrets	Limited	Kept confidential, Fiduciary reponsibility	Unlimited
Traditional Knowledge	Limited	Secrecy	Generational / Unlimited

The main differences between the various IP types are the method and the time of protection, which varies from 10 to 50 years for most types. Both trade secrets and traditional knowledge enjoy indefinite protection.

Forero-Pineda (2006) agrees with Puri (2000) that traditional knowledge developed by indigenous people over centuries is increasingly being used for commercial application in the agriculture and pharmaceutical industries, and that there are conflicting legal systems in the Western regime compared to indigenous people. The Western legal system focuses on individual ownership of IP rights, whereas indigenous customary law emphasises group ownership and community involvement, rendering the two systems incompatible. Traditional knowledge is relevant to this study, as some universities in SA engage in research activities involving plant and other genetic materials which may be subject to ownership by tribal communities in rural districts.

The next section 2.3 more fully describes the terms technological innovation and technology transfer. Both the terms are important within the context of this study as it relates to universities in particular.

2.3 Technological innovation and technology transfer

Over the past fifty years, developments in technology have improved crop yields, profoundly transformed the way we think of and treat diseases, and created economic growth and development on a scale unimaginable to those living at the turn of the 19th century. Examples include manufacturing through automated processes and the vast improvement in the speed of communication. Innovators have created phenomenally successful and profitable organisations, employing thousands of people. Pavitt (2003) concludes that innovation processes are untidy and not easy to describe despite improvements in the know-how within organisations. In particular, Pavitt contends that large organisations have difficulty in dealing with radical change and the implementation of new products and ideas.

Heinzl, Kor, Orange & Kaufmann (2012) point out that innovation and technological change contribute to economic growth. They argue that innovation and technological change are not facilitated by trade and industry, but within networks conducting joint research, and that at least one of the institutions in these networks has a strong science base (such as universities).

2.3.1 Technological innovation

Of all the influences in an organisation's external environment, technology is the change factor most responsive to creative management action. Technology encapsulates a broad idea, namely the creation of capabilities by the systemic application of knowledge, through a process of invention, innovation, and diffusion. (Schumpeter, 1934:66) argues that the motivation for economic growth is innovation, which he defines as:

- the introduction of a new good;
- the introduction of new method of production;
- the opening of a new market;
- the conquest of a new source of supply of raw materials; and
- the carrying out (formation) of the new organisation.

Schumpeter (1934) further suggests that innovation has many challenges. Firstly, he notes that the know-how needed for entrepreneurial choices are covered in uncertainty. Secondly, the uncertainty is influenced by the unwillingness of individuals to venture into the unknown. Thirdly, innovators face the inhibition of non-innovators in the form of legal and political barriers, habits, and many more.

> It takes a special kind of person to overcome these difficulties…the entrepreneur must be a man of vision, of daring, willing to take chances, to strike out, largely on the basis of intuition, on courses of action in direct opposition to the established…he must have the will to conquer, to fight for the sake of the fight rather than simply the financial gains of the combat; the desire to create new things - even at the expense of destroying old patterns of thought and action. In any society, including capitalism…such people are in the minority (Schumpeter, 1934:xxi).

Price (1984) indicates a link between scientific occurrences and technological innovation. He points out that both scientific and technological innovation may progress from the same valuable discovery of a new device. In science, the standard effect of such a significant modification is an advance or change in science concept. In technology, one finds a major improvement and the opportunity for new technology products.

The historian, James Burke (1985), comments that innovation is often unanticipated, as the process by which new ideas emerge is serendipitous and interactive. Interlocking threads of ideas, networks of people and events are woven into a web of knowledge which comprises science and technology as we know it today. The creation of knowledge improves the competencies and skills of the labour force and contributes to the commercialisation of new technologies (Roberts, 1991).

Powell, Koput & Smith-Doerr (1996) argue that the "locus of innovation" moves to inter-organisational relationships when knowledge is rapidly changing, dispersed, and fragmented among different parties. In addition, the Oslo Manual (Organisation for Economic Co-operation and Development (OECD), 2005:32) distinguishes between *product innovation* and *process innovation*. Product innovation comprises technologically *new* products or *improved* products. Process innovation is "the adoption of technologically new or significantly improved production *methods".* Lundvall and Borrás (1997) add that the process of innovation is difficult to manage, as it is essentially social in nature and involves many interactions between different departments within the same organisation.

Technology innovation takes place in an incremental way, as shown in a proposed model by Winston (1998) which he calls "ideation" (Figure 2.4). The model embodies creativity and intuition. Technologists use it to envisage new products or services. The result is usually a prototype, which could lead to an invention and its diffusion into markets.

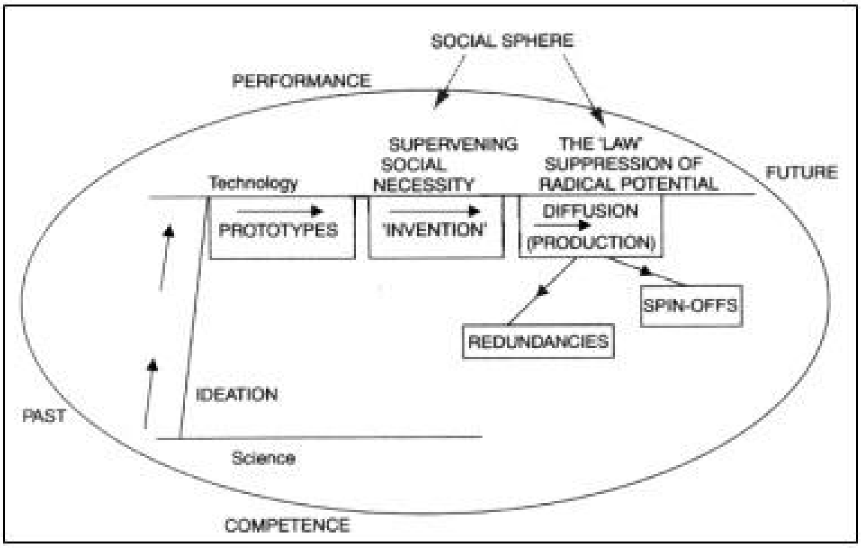


FIGURE 2.4: A MODEL OF TECHNOLOGICAL EVOLUTION
Source: (Winston, 1998:14).

Parallel to Winston (1998), Lundvall and Borrás (1997) and Salter *et al* (2000) assert that innovation by organisations does not occur in isolation. Instead, the authors argue that innovation occurs within chains of activities, making the process difficult to manage. Often, new technologies created through the process of "ideation" leads to new IPRs. This is particularly true for academic staff at universities, as they are the primary creators of new ideas which lead to new inventions on their campuses. The Frascati Manual refers to technological innovation as follows:

> Technological innovation activities are all of the scientific, technological, organisational, financial and commercial steps, including investments in new knowledge, which actually, or are intended to, lead to the implementation of technologically new or improved products and processes (Organisation for Economic Co-operation and Development (OECD), 2002: 18).

In the same vein, Lundvall and Borrás (1997) support the views of Winston (1998), and Salter *et al.* (2000) that innovation is an interactive process that does not occur in a straight line or chain-link fashion from research laboratories to development, and finally to commercialisation. Innovation rarely occurs because a single individual or organisation takes an idea to the market. Rather, *"…*it involves many people playing many roles in a dynamic collaborative process built around creative teams and face-to-face interaction" (Henton *et al.*, 2002:13). Pérez and Sánchez (2003) as well as Debackere and Veugelers (2005) support this view by stating that a myriad of informal contacts and personal industry-science networks support the multitude of formal relationships in the innovation process.

Innovation leading to new and marketable products is necessary for universities to be successful in TT activities through which scientific knowledge is transferred and utilised. Heinzl *et al.* (2012) conclude that universities, representing the science base, contribute to economic growth through TT. The primary competitive edge of universities in the knowledge arena is their ability to create new and novel discoveries and new methods. Therefore, it is crucial for research teams who are engaged in shared R&D activities to make their research results accessible, through TT processes, to other organisations.

2.3.2 Technology transfer

The concept of technology transfer is said to have had its origin in a report called "Science - The Endless Frontier", written by Dr Vannevar Bush and presented to the then United States president in 1945. Bush (1945) recognised the value of research, applying the new knowledge to businesses in commerce and industry, for economic growth. The report by Dr Bush was instrumental in promoting a steady support from the United States government to fund basic research in that country, and led to the formation of the National Institute of Health (NIH) and the National Science Foundation (NSF), among others. The report by Bush suggested the use of public funds to promote basic research at US universities and to foster the training and development of scientists (Bush, 1945).

The transfer of innovations in machine technology was noted by Rosenberg (1976) as an example of a TT between industries when organisations became focussed on processes rather than products only. When the transfer of technology occurred between different countries in the late 1800s, it was common to also transfer skilled staff to facilitate such transfer. Rosenberg (1976) drew attention to the large quantity of gun-making equipment that Britain bought from the United States in the 1850s, and the fact that many American machinists were then subsequently employed by Britain as a critical step in the transfer of skilled knowledge.

Uchida (1990) reports that the discussions on TT mainly focus on how policies can facilitate the transfer of technologies from developed countries to developing countries. He also notes that Japan was the single example in history where technologies were successfully transferred from the West to a non-Western country in the late nineteenth century. The transfer of technology across the world is not new, and has played a critical role in economic history since ancient times. For example, iron production and the alphabet developed in one location and spread all over the world. Metalwork technology, silk weaving, and related know-how from China contributed to the dawning of Japan as a nation. Similarly, the economic development of Western Europe since the start of the twelfth century is attributable to the printing press and assembly technologies for paper, gunpowder, and compasses that were developed in China and the Muslim world (Uchida, 1990).

Historically, Western Europe was technologically less developed and less wealthy than the East. Nonetheless, due to the transfer of technology from other countries and incremental innovations based on this technology, Western Europe developed its own technologies of gun-making, shipbuilding, and navigation. As the industrial revolution gained momentum in Great Britain in the eighteenth and early nineteenth centuries, new technologies to manufacture steam engines, spinning machines, railway lines and ships were created and used. The industrial revolution that followed in Europe and the United States was mainly accomplished by the transfer of these newly created technologies (Uchida, 1990).

Bozeman (2000:629) defines TT as “the movement of know-how, technological knowledge or technology from one organisational setting to another”. TT occurs in many ways through writing, the spoken word, the physical transfer of tangible products resulting from research, or through an IP licensing programme (Bremer, 2001). Similar to Bozeman (2000), Pérez and Sánchez (2003: 824) define TT as “the application of information into use, and involves a source of technology that possesses specialised technical skills, and the transmission to receptors who do not possess them and who cannot or do not want to create the technology themselves”.

The Association of University Technology Transfer Managers (AUTM) defines TT as “the process of transferring scientific findings from one organisation to another for the purpose of further development and commercialisation” (Association of University Technology Managers (AUTM), 2013).

For the purpose of this study, TT is defined by the researcher as the process of moving scientific findings (research results) from research laboratories at universities to businesses in commerce and industry, which proceed to commercialise the technology through the use of new processes and/or the creation of new products.

TT usually happens when new technologies are being commercialised. It implies the transfer or use of a property right created during the course of research. TT activities are linked to universities, as these institutions create valuable commodities that have the promise of commercial exploitation, once the IP is safeguarded.

2.3.3 University technology transfer

As indicated before, TT has been defined by many different authors. Gibbons *et al.* (1994:168) refer to university TT simply as “the transmission of knowledge from universities to industry”, while Gordon (2004:641) claims that university TT is “the process by which a university commercialises inventions and innovations developed by university faculty and researchers". He further asserts that universities are intensifying their commercialisation effort through changes in their core mission statements, as university campuses are bursting with inventions as the result of applied research.

However, Jensen and Thursby (2001) indicate possible drawbacks of university TT, suggesting that, while academics focus their efforts on creating and commercialising technology, less time is spent on teaching and service delivery, which could cause a reduction in the quantity and quality of basic research. Conversely, Debackere and Veugelers (2005) found that universities that were able to exploit the complementarities of teaching, basic research and applied research, were the strongest players in the knowledge market. Basic research is considered to be the earliest stage of the development of new technologies. During this stage it is often doubtful whether an invention has the potential to become a feasible commercial product. Universities usually perform basic research, and then impart the knowledge or new technology created to businesses in commerce and industry that, in turn, complete the R&D (applied research) to create new products or inventions. Dai, Popp and Bretschneider (2005) point out that universities do not produce commercial products, and add that these institutions derive benefits from applied research results by licensing patents (as the mechanism for sharing the imparted knowledge) to businesses in commerce and industry.

TT has become a new mission of universities, whereas historically it was seen as a private activity of individual academics, done in addition to teaching and research (Drori, Meyer & Hwang, 2006). Casual links between academic researchers and researchers in commerce and industry are now formalised, and the responsibility for TT shifted from the individual to the organisation. Drori *et al.* (2006) maintain that the creation of technology transfer offices (TTOs) at universities (section 4.8) is part of a dialogue on how to better utilise scientific knowledge that started in the 1950s.

Universities transfer their new technologies to businesses in commerce and industry using different methods, but most commonly through licensing and the creation of start-up companies (also referred to as "spin-off" or "spin-out" companies). Universities often prefer to grant licenses for a particular use of their patented inventions, reserving the right to revoke the license if a licensee fails to exploit their idea effectively. Fully developed technologies can easily be sold through licensing, while underdeveloped technologies require much more investment in the early stages and are often too risky for investors. This creates what is often referred to as the 'innovation chasm'. To bridge this gap, many universities assist in the formation of university spin-out companies.

Nelson (2001) believes that universities can and should contribute to economic growth in their local economies as well as the global knowledge-based economy through TT activities. In addition, Colyvas *et al.*(2002) point out that, in the early 1980s, the driving force behind university research that produced commercial products via TT efforts was the desire to create new and useful inventions for society. Thus, it was not intended for financial gains only. Yet, what makes IP so profitable that inventors and investors are willing to risk their time, money and effort trying to exploit its commercial potential? Scherer and Harhoff (2000) observe that a small number of inventions often carry the bulk of the economic value in a total IP portfolio. The authors refer to this as the "skewness of innovative returns" and claim that it causes volatility in the returns achieved by the owners of IP.

Breese (2002) remarks that experts often use three patent valuation methods, namely historical cost, the profit method, and the updated future-royalty method to value patents. The *historical cost (research cost) method* values a patent by adding all the R&D expenses incurred in achieving the invention and completing the patent application. This method is not favoured, as the historical costs very seldom reflect the true market value. It is also possible that the costs incurred exceed the market value if the commercial application of the IP is limited.

According to the *profit method*, a patent is valued at 20% of the estimated profits for the duration of the patents' use. Thus, the licensor will receive 20% of the profits for their research efforts, and the licensee will receive 80% of the profits to cover the operating and marketing expenses required to develop and sell products based on the invention. This ratio might vary considerably, depending on the negotiations (Breese, 2002). The *updated future-royalty method* considers the economic potential and associated risks on the date of the valuation. Projected royalties for a license agreement are updated and calculated according to the expected turnover. The results are then weighted by using a risk factor to account for related legal, technical, and commercial risks (Breese, 2002).

According to Goldscheider *et al*, (2002), the so-called 25% rule is often used in valuing patents. This rule is decades old and suggests that the licensee pays a royalty rate equivalent to 25% of the expected profits on products embodying the patented technology. Thus, an estimate is made of the licensee's expected profits, and the profits are then divided by the expected net sales to arrive at the rate of profit. The rate of profit is then multiplied by 25% to arrive at a running royalty rate. If, for example, the profit rate is 16%, then the resulting royalty rate would be 16 x 25% = 4%. The theory underlying this rule is that that both licensee and licensor should share in the profitability of products resulting from and embodying the patented technology (Goldscheider *et al.*, 2002).

The value attributed to a new innovation may change over time, as new discoveries render existing ones partially or completely obsolete (Sherry & Teece, 2004). New inventions can also be complementary to existing ones, resulting in new avenues for commercialisation by combining old and new technologies (Sherry & Teece, 2004). Sherry and Teece (2004) assert that the value of an invention should be based on two different concepts, namely the invention itself (such as a technological breakthrough) and the IPRs attached to the same invention (such as patents, trademarks, copyrights, or trade secrets).

Figure 2.5 below indicates that an invention may have some intrinsic economic value, although the value increases exponentially once it is patented, as the rights granted by a patent exclude others from using the invention for a number of years. The value of a patent usually changes when there is a change in the inventor's legal rights as can be seen from Figure 2.5 below.

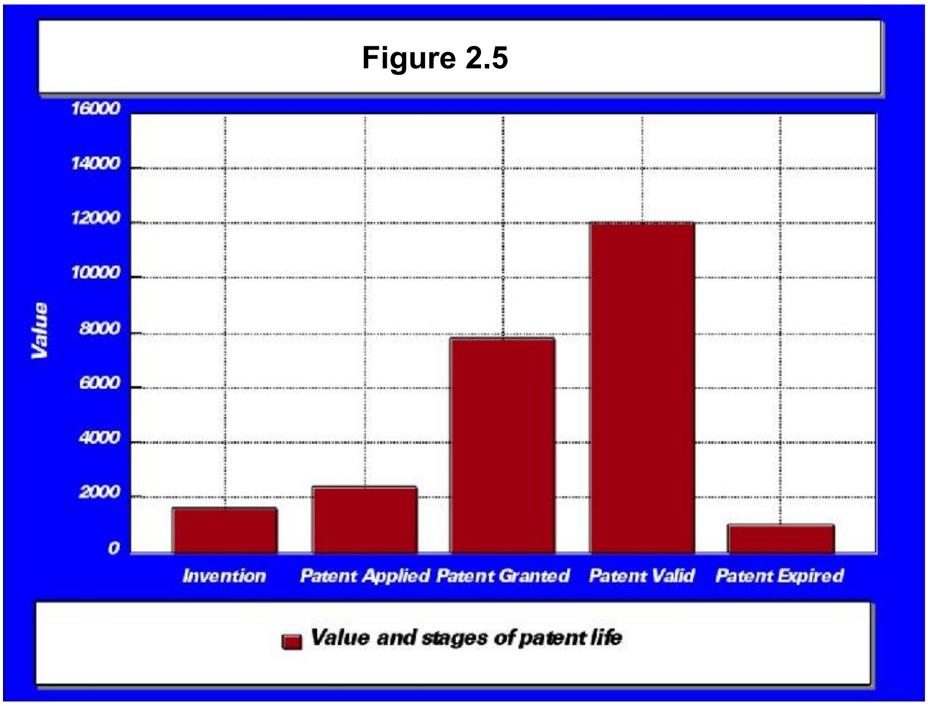


FIGURE 2.5: VALUE ATTRIBUTABLE TO DIFFERENT STAGES OF THE LIFE OF A PATENT
Source: Sherry & Teece (2004: 180)

Heher (2006) contends that the economic value attributable to IP created at universities is linked to the effectiveness of the marketing effort of the university's TTO. Heher (2006) further indicates additional benefits from university TT that are not recorded at the level of the institution, but by the local economy, such as job creation and economic growth. The valuation of IP as intangible asset can be difficult at times and can only be done after obtaining a proper understanding of the strategic and operational issues that affect an asset's ability to generate future economic benefits. Accordingly, the value of intellectual property for universities lies in its ability to confer a competitive advantage for its owners.

The capacity and expertise of understanding and translating the potential of IP into commercial application, and then marketing that IP into appropriate markets, is a crucial goal of TT. While universities generate valuable IP, this IP may not be fully exploited, due to inefficient TT mechanisms. Licensing is often the fastest and preferred method to leverage IP assets for generating future income streams. Taking equity and assisting in the formation of newly created university spin-out companies requires entrepreneurial business skills which are often lacking in developing countries.

Licensing of university IP

The quickest way for university TTOs to take a patented technology to the market is to license it out to another entity, in order to generate a constant income stream in the form of royalties. IP that is valuable generally commands higher royalties, as the value of IP used in a business is directly related to its income-producing capabilities. The more income that is produced from the use of particular IP, the more income there is to share between the licensor and the licensee.

Each party to a license agreement often contributes complementary IP that needs to be considered. Complementary IP may consist of both tacit knowledge (know-how) and explicit knowledge, such as diagrams, reports, and formulations. Other IP in the form of intangible assets contributed by the licensor may include the licensor's name, reputation, and network relationships (Gruetzmacher, Khoury & Willey, 2000). The licensee, on the other hand, contributes manufacturing capabilities and facilities, marketing infrastructure, other patents and licenses, and also its name and reputation. Typically, complementary assets are linked to the licensee, as their unique capabilities enable the enterprise to successfully connect the IP to further innovation and its ultimate commercialisation. Gruetzmacher *et al.* (2000) argue that it remains the core patented technology which determines the price of a license agreement and dictates the royalty rate.

As with most forms of IP commercialisation, risk is also associated with license transactions. The licensor may want a higher royalty to compensate for the possibility of failure on the part of the licensee. Conversely, the licensee may argue for a lower royalty as they have carried the financial risk of taking the technology to the market. Furthermore, when deciding whether to support a particular invention or not, universities must keep in mind that the reputational risk could be significant and needs to be considered, as with all other forms of commercialisation, and not just licensing (Gruetzmacher *et al.*, 2000).

The term *royalty stacking* is used when one product contains more than one technology and all are owned by different parties (Gruetzmacher *et al.*, 2000). The technology is bundled together to produce the final product. Licensing with or without the use of royalty stacking may be exclusive, regional-exclusive, or non-exclusive. In general, an exclusive license agreement will demand a higher royalty rate than a non-exclusive agreement, and an exclusive license agreement usually includes a minimum royalty provision. Licensing may include know-how and IP not covered by patents, trademarks, or designs.

Thursby *et al.* (2001), analysing the same data used by Jensen and Thursby (2001), found that minimum fees for royalties are almost always included in new licence agreements, as well as reimbursement for patent costs paid for by the university TTO. Thursby *et al.* (2001) also found that universities with large TTOs and large medical schools had more licences executed and that royalty rates are higher if licences are executed in the later stages of the IP development and also where the reputation of the academic staff member is stronger.

Typical license agreements make provision for an upfront payment, followed by recurring royalty payments. The upfront royalty allows for the university TTO to collect payment sooner rather than waiting for royalties to accumulate over time (Thursby *et al.*, 2001). Upfront royalties are also useful when the value of the IP related to an invention can be easily determined, and when development of the invention has progressed significantly. Conversely, Shane (2002) notes that the upfront fees are smaller if the commercial viability and expected outcome of an invention is uncertain.

Spin-out companies emanating from universities

Most university spin-out companies establish themselves in close proximity to universities to take advantage of the many benefits and incentives that a connection with the university ensures (Pavitt, 1998). According to Steffensen, Rogers and Speakman (1999), spin-out companies are also known as 'spin-outs' or 'start-ups', and can have a variety of regional impacts:

- the creation of taxable wealth in the local community
  (The economic benefits derived from a spin-out company accrue locally where spin-outs are located close to their parent organisation.)
- the provision of role models for entrepreneurs
- (Regions often have a strong technology base, but lack the entrepreneurial and marketing support.)
- providing jobs for its graduates and revenue-sharing.

Equity comprises shares held in the issued share capital of a spin-out company, representing a portion of the total value of the company. Equity is often used in combination with upfront fees and recurring royalties as compensation for enabling technologies licensed to a university spin-out company. By holding equity in a spin-out company, the academic as inventor is induced to be involved in further commercialisation efforts of the particular technology.

Bray and Lee (2000) assert that holding equity in a spin-out can dramatically improve relationships between the university TTO as licensor and the particular spin-out company as licensee, even if the university holds as little as 5%. These authors conclude that taking equity not only allows licensing managers at universities the freedom to do more deals, but also produces money faster than a typical licence agreement. However, Bray and Lee (2000) also claims that taking equity may not be advisable if the business skill of the academic or entrepreneur is suspect, or if the particular technology is not appropriate for a spin-out company.

Statistics studied by Bray and Lee (2000) in the United States indicated that the highest returns achieved on equity held in university spin-outs are more likely to occur in countries that have an excellent supply of venture capital. This could be problematic for TTOs at SA universities, as venture capital for early-stage seed funding is limited in SA (Koekemoer & Kachieng'a, 2002).

Theoretical analysis by Jensen and Thursby (2001) showed that further development of new inventions would not occur unless the remuneration (return) earned by the inventor is coupled to the output of the licensee when the invention is successfully commercialised. Moreover, conflicts of interest may arise when an academic staff member starts a university spin-out company based on an invention developed in the course of his/her research, leading to equity held in the spin-out company, whilst also sharing in royalty income from a licence to the same spin-out. The potential for such conflict of interest is huge, as the university administration may rightfully question the time allocation of the academic staff member's responsibilities between the university and the spin-out company (Jensen & Thursby, 2001). Most universities have conflict-of-interest policies in place to deal with this problem. The academic staff member should choose who they want to have as their primary employer. Most often the inventor remains employed by the university and acts as non-executive consultant/director to the university spin-out company.

Pérez and Sánchez (2003) note that spin-out companies can be categorised by their origin. In a university spin-out company, the entrepreneur and/or inventor will have gained her/his background knowledge and experience at a university. A university spin-out is often created when an academic becomes an entrepreneur and leaves the employ of the university to start his/her own company. Apart from the know-how associated with the transfer of skilled staff, a university spin-out usually obtains the rights to use IP owned by the university through a license agreement.

The close proximity of spin-outs to a university contributes to their enabling environment. This has led to many successful spin-outs in the United States since 1980. An estimated 70% of these spin-outs were still in operation by the year 2000 (Di Gregorio & Shane, 2003). Often university inventions have huge potential, but are not developed to the point where they can be commercially exploited (Garduño, 2004a). Commonly referred to as the innovation chasm, Garduño (2004a) suggests that SA universities could bridge this gap by assisting in the setting up of spin-out companies to develop new technologies to a point where they are economically useful and successful.

From the discussion in this section it is evident that a separate definition for "university technology transfer" is not needed, and that the researcher's definition for "technology transfer" offered in the previous section is sufficient and appropriate for the purpose of this study. The definition therefore remains that (university) TT is the process of moving scientific findings (research results) from research laboratories (of universities as providers of the science base) to organisations in commerce and industry, which proceed to commercialise the technology through the use of new processes and/or the creation of new products.

Universities are similar to other organisations in the knowledge economy, such as legal and financial institutions, which produce intellectual rather than physical products. However, universities differ from these institutions in that they were not established with a profit motive. The not-for-profit status of universities in no way undermines the position of the university as a community of scholarship and learning with a critical social role of being a centre for creativity, and a stimulus for new ideas. The not-for-profit status simply acknowledges that if universities are to attract or create the funds to achieve their goals, they also need to understand that, in the knowledge economy, a university's assets from which it can generate returns are mainly research results and the course content produced by its academic staff.

2.3.4 Effective measurement of university technology transfer

The Association of University Technology Managers (AUTM) has measured TT activity at United States and Canadian universities annually since 1991. AUTM is a non-profit organisation with more than 3,000 technology managers and business leaders as members. Members of AUTM represents more than 300 universities, research institutions, businesses, and government institutions in the United States. The survey provides statistical data of the activities and performance of university TTOs, measured by the number of invention disclosures, patents issued, and licensing revenue earned.

When measuring the performance of particular universities in the United States, Conceicao *et al* (1998) pointed to the fact that Stanford University earned royalties of more than $111 million since the start of the university's TTO in 1969. Also, Stanford benefited from inventions such as Recombinant DNA ($53.4 million) and FM Sound ($13.9 million). However, despite the above average returns from TT activities at several universities in the United States, Conceicao *et al* (1998) advocate that licensing income on average is negligible within the academic system.

Henderson, Jaffe and Trajtenberg (1998) found that patenting at universities in the United States increased more rapidly than research spending, which resulted in the ratio of university patents issued to the amount spent on R&D to triple over the period between 1965 and 1992. Conversely, the total number of patents issued to organisations other than universities almost halved during the same period. Thus, the ability of universities to register patents rose drastically during a time when the number of registered patents (university and non-university organisations in total) declined. The rise in the propensity of universities to patent inventions from 1965 to 1992 was also apparent from the increase in the number of universities registering patents (Henderson *et al.*, 1998). This number increased from only about thirty universities in 1965 to more than 150 by 1991, although it remained decidedly concentrated (Henderson *et al.*, 1998). Henderson *et al.* (1998) further advised that universities in the United States have increased their volume of research by ten times since 1970, and the output measured from TT activities via patenting and licences more than doubled in the six years prior to 2000.

According to Hopkins (2004), Stanford University earned more than $250 million from the listing of Google, the search engine giant, on the NASDAQ stock exchange in the United States. The university has long benefited from its role in TT activities on its campus. The Silicon Valley University helped spawn 1 200 technology and other spin-out companies, including Hewlett-Packard, Yahoo, and eBay. More than 300 universities in the United States, from California to Florida, are mining their laboratories for discoveries that could become the next Google or anti-cancer drug, while only 25 universities were doing so in 1980 (Hopkins, 2004). The technology used by Google today was created by Sergey Brin and Larry Page, two computer science graduate students at Stanford University. Stanford owns the technology, because it was created with funds from the university. Six years after its start, Google had nearly 2 000 employees and its annual revenue had increased to $962 million. Google pays Stanford University annual licence fees in both shares and cash (Hopkins, 2004). By April 2017, Google employed more than 72 000 employees in 70 offices in over 50 countries all over the world (Statista, 2019a). For the year 2018, Google recorded sales revenue of 136.22 billion US dollars and the company was listed as number one of internet companies globally having a market capitalizstion of 510 billion U.S. dollars (Statista, 2019b).

Siegel and Phan (2005) identify the principal agents and institutions for university technology transfer as university scientists, industry scientists interacting with them, industry-university research centres, university TTOs, science parks, incubators and venture capital firms. They also identify the following indicators as measurements of the output of TT activities:

- invention disclosures,
- patents registered,
- licensing agreements,
- licensing revenue earned,
- research productivity of university and industry scientists,
- spin-out company formation,
- survival of spin-out companies, and
- employment creation.

Another measure of success for university technology transfer is the level of participation by academics in the technology transfer activities, which is reflected by the number of invention disclosures received by a university's TTO. Thursby and Thursby (2011) attest that such invention disclosures are the best way to effectively measure the participation of academic staff in university TT. Finally, employment creation is also seen as a key measure, as spin-out companies frequently employ students who have graduated from the particular university.

Unlike the private sector, where the measurement of success in TT is purely profit driven, the objectives for university TT are varied. Public universities are expected to contribute to economic development in addition to earning income from contract R&D activities. Barnett (Southern African Research and Innovation Management Association (SARIMA), 2012), when referring to South Africa, affirms that the measurements of the economic impact of TT should not be limited to disclosures, patents, and income generated, but should extend to meeting the needs of disadvantaged communities and small local economies.

2.4 Conclusion

This chapter clarified the key terms used in this study. The various types of intangible assets, namely intellectual property, intellectual capital, and goodwill were identified by Ch'ang and Yastreboff (2003) and presented in Table 2.1. IPRs such as patents, trademarks, copyright, industrial designs, know-how, trade secrets, and traditional knowledge were described in more detail. Patents, in particular, were noted by Griliches (1990:1702) as “a unique source for the analysis of the process of technical change. Nothing else even comes close in the quantity of available data, accessibility, and potential industrial, organisational and technological detail”. In the discussion on IPRs, Table 2.2 was provided in summary of the various IP types, the degree of protection they afford, the method, and the duration of the protection.

The definitions of technological innovation and technology transfer, as will be applied in the rest of the dissertation, were briefly stated and discussed. The effective measurement of university technology transfer was also explored. The literature review in the next chapter informs the history of university TT in developed and developing countries and leads to the formulation of a conceptual framework for institutional technology transfer at universities in section 3.3.

Chapter 3: University TT: History and a conceptual framework

3.1 Introduction

This chapter focuses on the history of university technology transfer within some developed and developing countries of the world. The developed countries examined in this chapter are the United States, Canada, the United Kingdom, and Australia, whilst Brazil in Latin America, South Korea in South East Asia and South Africa were selected from developing countries. The chapter also presents a conceptual framework for understanding institutional technology transfer at universities.

It should be emphasised that the following section is not intended to provide a comprehensive review of the history of university TT activities in these countries. However, the selection of countries is useful to illustrate that a number of universities in these counties are increasingly motivated in commercialising research findings emanating from their university campuses.

3.2 A brief history of university technology transfer

A small number of universities in the United States were patenting inventions emanating from their campuses in the early 1900s (Bush, 1945). The Research Corporation, a non-profit third party TT agent, founded in 1912 by professor Frederick Gardner Cottrell, served for many years as a leading broker and licensor of university inventions for these universities. Cottrell, an inventor from the University of California, wanted to support his scientific research from licensing revenues earned by patents (Bush, 1945).

The Wisconsin Alumni Research Foundation (WARF) is another example of a university-affiliated but separate legal entity offering management assistance and support to inventors from universities in the United States. Most universities in the United States were primarily teaching institutions before WARF suggested a plan to commercialise patentable inventions produced by their academic staff in 1924. Between 1925 and 1929 the laboratory system in the United States increased its scientific output significantly. Universities first supported the industrial research programme, mainly by focusing on basic research activities and the training of scientists.

Demands for technological improvements to military equipment increased dramatically during and after World War II and ushered in a new era of public support for higher education (Bush, 1945).

Major research programmes were started during and after World War II, and included the Manhattan District Project, the Metallurgy Laboratory at the University of Chicago, the Applied Research Lab (ARL) at Harvard University (later moved to Pennsylvania State University), and the Lincoln Laboratory at the Massachusetts Institute of Technology (MIT) (Bozeman & Crow, 1990). According to Bozeman and Crow (1990), these developments were dissimilar to the usual department-based single academic-orientated research groups. In those days, university–industry collaboration was facilitated by the large higher education system in the United States, which lacked a centralised national administrative control system for protecting rights to newly created IP. The dissemination of knowledge to society occurred mainly via the traditional means of student recruitment, publications by scientists, and consultation by university academics. In the late 1970s, new transfer techniques were tried and patent offices were set up at universities (Bozeman & Crow, 1990). Equity ownership was one of the transfer techniques tried and industry–university linking programmes were developed. Industry-sponsored research groups and university-led research teams were increasingly engaging one another in promoting regional development plans (Gibbons *et al.*, 1994).

The start of the 1980s saw the enactment of the Bayh–Dole Act in the United States. Many authors, such as Colyvas *et al.* (2002) and Mowery *et al.* (2001), assert that Bayh–Dole had a significant effect on the increase in patenting rates of new discoveries emanating from US universities, but they caution that this effect should not be overstated. Nevertheless, there can be no doubt that Bayh–Dole was instrumental in the launching of TTOs at universities in the United States from the mid1980s to the mid1990s (Garduño, 2004a; Mowery *et al.*, 2001; Thursby & Thursby, 2003). University TTOs were required to comply with this legislation, and it enabled these universities to exercise IP rights they now owned and to fulfil the obligations conferred to it under Bayh–Dole. A detailed analysis of Bayh-Dole is provided in section 4.3.1 of this study. The next section comments on university technology transfer in some developed countries, followed by the penultimate section that is devoted the development of a conceptual framework for this study.

3.2.1 Developed countries

United States

In the United States, the government supported research conducted at government institutions for more than 80 years through the Land Grant College Act (Bush, 1945). After 1900, the federal government established a large number of scientific organisations, numbering more than 40 by 1939 (Bush, 1945). The role of university scientists in wartime initiatives, such as the development of penicillin, convinced public officials in the United States that academics were uniquely placed and capable of undertaking critical research projects (Press & Washburn, 2000). Hence, universities in the United States were active in the transfer of technologies before 1945. However, it was not called technology transfer then and was mostly conducted without a view to commercialise the results (Bozeman & Crow, 1990). Between the two world wars and leading up to 1945, the United States government realised that they did not have enough resources within government laboratories to perform quality research (Bozeman & Crow, 1990). Considerable funding by the United States government was then allocated to research activities conducted at medical faculties at United States universities. The result was that the United States overtook all other nations when it came to medical research and assumed a leading position of authority in this field at the time (Bozeman & Crow, 1990).

The millions of dollars spent by the United States government on medical research to combat diseases caused biomedical patents issued to United States universities to increase by 123% during the period from 1969 to 1979 (Press & Washburn, 2000). The increased spending by the United States government on research conducted at its universities changed the roles of these universities and their contribution to post-war technological advances considerably (Press & Washburn, 2000). By 1979, federal funding for research alone reached $3 billion and much of it was dispensed by the NIH and other agencies (Press & Washburn, 2000).

At the start of the 1980s, a shift occurred in research performed at United States universities that would significantly alter the history of technology transfer at these universities. Bozeman (2000) reports that both universities and government-owned laboratories in the United States intensified their commercial activities meaningfully after 1980. Bozeman (2000) notes that only 25 universities in the United States had technology transfer offices (TTOs) in 1980, but that there were more than 200 of these TTOs in operation by 1990. The share of university R&D paid for by businesses in commerce and industry in the United States increased from only 2.6% in 1970 to reach 6.9% by 1990 (Bozeman, 2000). In 1982, universities in the United States filed a total of 458 patents, of which 70% was by the 100 largest universities (Bozeman, 2000). By 1995, this figure had grown to 1 860 patents filed, while the share by the 100 largest universities had reduced to 50% (Bozeman, 2000). According to Bozeman (2000), the increase was attributable to a number of reasons of which the biggest contributor might have been the Patent and Trademark Law Amendment Act of 1980, commonly known as the Bayh–Dole Act of 1980. This act, drafted by Senators Robert Dole and Birch Bayh, shifted the ownership of federally funded research results developed at United States universities from individual researchers to the institution (Bremer, 2001).

Bozeman (2000) also mentions the Stevenson–Wydler Technology Innovation Act of 1980 as the second most significant piece of legislation focused on technology transfer from United States universities and government agencies to businesses in commerce and industry. This act required the formation of technology transfer offices (TTOs) and compelled universities and government laboratories to allocate a portion of their research budgets to be spent on TT activities (Bozeman, 2000). The main aim of the Stevenson–Wydler Act was to oblige universities and government laboratories to participate actively in the TT process. The United States Federal Technology Transfer Act of 1986 followed Stevenson–Wydler and allowed US universities and government laboratories to conclude Cooperative Research and Development Agreements (CRADAs) and to negotiate license agreements for patents (Bozeman, 2000). Lehman (2001) claims that American products of the mind have been a cause of national prosperity and pride, representing a symbol of the creative and inventive spirit of Americans.

Stevens (2010), reflecting on the growth of university technology transfer in the United States since 1978, reports that the United States government owned 28 000 academic patents in that year and had licensed fewer than 4% of the patents to businesses in commerce and industry. In addition, invention disclosures reported to the NSF and NIH were declining, even though federal funding for research was increasing at the time (Stevens, 2010). Bozeman (2000) claims that the Stevenson–Wydler Act and the Bayh–Dole Act changed this state of affairs completely. Results from AUTM surveys for the three years from 2009 to 2011 indicate that sponsored research from the federal government in the United States were $37.5 billion per year on average (Association of University Technology Managers (AUTM), 2011). During the same three-year period, 62 807 new invention disclosures were recorded, whilst 14 511 new licenses were executed and 1 918 new university spin-out companies were created (Association of University Technology Managers (AUTM), 2011).

AUTM (Association of University Technology Managers (AUTM), 2014) lists the following statistics in a summary of the AUTM licensing activity survey in the United States for the year 2013:

- a total of 14 995 new patent applications were filed (up 5.7% over 2012);
- 5 714 US patents were issued (up 11% over 2012);
- 5 198 license agreements were executed (up 1.3% over 2012);
- 818 spin-out companies were established (up 16% over 2012); and finally
- 4 206 spin-out companies were still in operation as at the end of 2013 (up 5.1%).

The data quoted above shows that the United States is arguably the world leader in generating IP from research results emanating from its university campuses and in commercialising those inventions through recognised TT mechanisms.

Canada

Canada's spent on R&D by businesses in commerce and industry grew by approximately 6.6% (adjusted for inflation) between 1963 and 1997 (Gu & Whewell, 1999). By 1997, expenditure on R&D by businesses in commerce and industry was estimated to be $8.5 billion (Gu & Whewell, 1999). Conversely, government spending on R&D at Canadian universities fell from 38.2% in 1963 to only 12.0% by 1997 (Gu & Whewell, 1999). Businesses in commerce and industry were thus contributing increasingly towards Canada's total R&D effort at universities.

A total of 227 new licenses were executed by Canadian universities as reported in the AUTM survey for 1997, representing an increase of 363% from 49 licenses in 1991 (Gu & Whewell, 1999). Total gross royalty income noted in the same AUTM survey was $11.3 million, which was 242% more than the $3.3 million recorded in 1991 (Gu & Whewell, 1999). A total of $500 million and 4 000 jobs can be attributed to university TT efforts by Canadian universities when using the same proportion of gross license income between Canadian and United States universities to calculate the total economic effect over the period from 1991 to 1997 (Gu & Whewell, 1999). Canadian universities were the leading source of scientific dissemination and they contributed 65% of all scientific publications in Canada at the time (Gu & Whewell, 1999). By 1998, a total of 366 spin-out companies were created by Canadian universities (since 1978). Most of these spin-out companies were created to license technologies from universities (Gu & Whewell, 1999).

The Canadians adopted for a different approach to Bayh–Dole by following a policy route rather than legislation (Organisation for Economic Co-operation and Development (OECD), 2003). The 1991 Policy on Title to Intellectual Property Arising under Crown Contracts (Government of Canada, 2015) acknowledged that the private sector in Canada was best placed to commercialise IP. This policy allowed university researchers to own the IP they generate in the course of carrying out Crown procurement contracts, subject to a range of exceptions (OECD, 2003). Implementation of the policy was not without difficulties and problems that arose were a consequence of ambiguous interpretations of the exceptions, inconsistent application by different government departments, and perceived conflicting objectives with other policies (OECD, 2003). This led to a review of the policy in 1995 that kept key principles and removed weaknesses (OECD, 2003). The result was the 2000 Policy on Title to Intellectual Property Arising under Crown Contracts, which clarified the scope and application of the policy, as well as the exceptions to research contractor ownership (OECD, 2003). The policy has again been reviewed in 2015 to better define roles and responsibilities of various stakeholders (Government of Canada, 2015).

Contrary to the positive effects experienced by some universities in the United States, Kachur (2003:397) is critical in commenting that Canadian universities “are up for sale”. The author claims that public research is lost to private interests as effective ownership of new technologies generated in university-owned facilities were transferred to businesses in commerce and industry through licensing. Kachur (2003) questions the benefits that commercialisation of research results can bring and claims that it may hinder research in areas having less commercial potential. Contrary to Kachur’s view (2003), Garduño (2004b), Mowery (2004) and Lehman (2001) all note that it is widely believed that a huge number of technologies were developed at university laboratories and successfully transferred to businesses in commerce and industry by using licensing agreements since the early 1980s.

The effects of the revised policy initiatives are clearly noticeable in the increased efforts and results of the commercialisation of university technology transfer in Canada since 1991. AUTM (Association of University Technology Managers (AUTM), 2014) notes the following statistics in a summary of the AUTM licensing activity survey in Canada for the year 2013:

- 68 new university spin-out companies were formed (up 19.3% over 2012);
- 92 new products were made by spin-out companies (up 37.3% over 2012);
- $710 million (up 30.3% from 2012) of net product sales were recorded;
- $5.62 billion (up 0.83% over 2012) in total research expenditures were incurred;
- 233 (up 27.3% from 2012) of new non-United States patent applications were filed; and
- a total of 240 (up 34.8% over 2012) US patents were issued to Canadians.

Although these figures are encouraging, it is not nearly as significant as that of the United States.

United Kingdom

By 1999, the United Kingdom had a strong science base and was highly productive in research outputs, as measured by publications and citations (Lambert, 2003). However, by 2000, universities in the United Kingdom accounted for only the small percentage of 5% of all patent applications in the United Kingdom. Patent applications by UK universities had been declining relative to universities in the United States, the European Union, and Japan since the mid-1980s (Lambert, 2003). Scotland, however, had a higher proportion of 10%, being double that of the United Kingdom as a whole (Lambert, 2003). Porter (2003) argues at the time that the United Kingdom was poor at commercialising its research findings despite the United Kingdom's strong position with regard to publications and citations. The Lambert Review (2003:51) identified the following objectives to improve the management of IP emanating from research collaborations in the United Kingdom:

- It would be useful to establish a simple set of ground rules for IP ownership, which would be the default position on which to build most negotiations.
- There should be maximum flexibility in the use of IP, to stop it from being locked up in a way that limits its commercial application and exploitation.
- Funding councils and research councils should make it clear to universities that public funding is intended to promote the public good rather than to raise its own revenues.

- Academic staff should continue to receive incentives from universities to produce research results and commercialise the resultant IP.
- Businesses in commerce and industry should have secure rights to the IP they want to commercialise.
- Ownership to IP should be proportionate: the party, which makes the biggest contribution (intellectual as well as financial), should have first rights to the IP ownership and its commercialisation.

Universities in the United Kingdom (UK) have had mixed results from TT activities. Siegel, Waldman and Link (2003) suggest that the reason for the weak performance of UK universities in technology transfer at the time was that US universities did not share their expertise on TT with European and Asian universities through organisations like AUTM. During 1998, the focus in the United Kingdom was on creating spin-out companies that signaled a move away from licensing (Dorey, 2004). Dorey (2004) agrees with the Lambert Review (2003) that too many university spin-out companies were created between 1998 and 2003 in the United Kingdom and that many of them did not succeed, as they did not generate enough revenue. Both Dorey (2004) and Savage (2006) attest that the reason behind the low revenues is that the people employed in most UK university TTOs were lacking the entrepreneurial and business skills to facilitate the development of new products, and thus ensure the success of a university spin-out company.

Between 2000 and 2005, 39% of universities in the United Kingdom started TTO activities, whilst 81% of them had at least two full-time staff members working in their TTOs (UNICO, 2006). In reaction to Dorey's (2004) comment on the lack of skills within TTOs at UK universities, and in response to similar points raised by the Lambert Review (2003), Savage (2006) elaborates on the spin-out company model followed by Oxford University. Oxford had the highest spending on research and development activities by a university in the United Kingdom at the time and used Isis Innovation, a wholly owned company established by the university to help academic staff commercialise their research findings. Isis Innovation, named after the river Isis, was renamed to Oxford University Innovation (OUI) in June 2016 (University of Oxford, 2017a). Oxford University had a share in 42 spin-out companies that were founded by its academic staff, of which none had failed by 2006 (Savage, 2006). The process followed by Isis Innovation attracted much interest from other universities in the United Kingdom, leading Oxford to establish a division called Isis

Enterprise in 2004 to offer advice in TT practices and in managing a typical university TTO, (Savage, 2006).

Since 1997, OUI has started a new spin-out company every two months on average (University of Oxford, 2017a). The following statistics for OUI relates to the financial year ending 2015 (University of Oxford, 2017c):

- Total revenue from IP commercialisation reached £24.6m (£14.5m in 2014).
- Benefits paid to the University and its academics were £13.6m (£6.7m in 2014).
- A total of 40 start-ups were accommodated into the Oxford University Start-up Incubator (University of Oxford, 2017b), of which 5 led to new spin-out companies (8 in 2014).
- Technology license agreements totaling 75 were concluded.
- OUI managed 2 490 patents and patent applications (2 333 in 2014) on inventions emanating from Oxford University.

More than £266m in funding was raised by OUI spin-out companies since the year 2000, and five of these companies are currently listed on London's Alternative Investment Market (AIM) stock exchange (University of Oxford, 2017a). The establishment of these new spin-out companies ensured millions of pounds flowing back into research at Oxford University, and benefited the local economy whilst creating many new jobs (University of Oxford, 2017a).

Australia

In Australia, the National Survey of Research Commercialisation (NSRC) is conducted every second year and describes the commercialisation results of Australian publicly funded research organisations (PFROs). The data for the years 2010 and 2011 indicate that Australian PFROs have sustained their involvement in commercialisation activities and, in particular, that they moved away from the establishment of spin-out companies in favour of IP licensing, option agreements and assignment agreements (LOAs) (Australian Government: Department of Industry and Science, 2013). As a result, the number of newly started spin-out companies reduced by 75%, from 61 in 2001, at its highest, to only 15 for the year 2011 (Australian Government: Department of Industry and Science, 2013). The number of spin-out companies operational with institutions having an equity stake rose from 69 in 2000 to 200 in 2007 and dropped since then to reach 163 by 2011 (Australian Government, 2013). The value of equity held in university spin-outs stayed fairly constant, whilst total invention disclosures rose gradually from 544 in the year 2000 to reach 1 489 by 2011 (Australian Government, 2013). The total annual number of patents and plant breeder rights issued worldwide to Australian PFROs rose from only 273 in 2001 to 1 021 in 2010 and the cumulative total at the end of 2011 was 11 004 (Australian Government, 2013).

The Australian Government: Department of Industry and Science (2013) maintains that the Australian research system appears to be mainly commercialising IP emanating from research efforts focusing on pharmaceutical and biotechnological inventions. The following were noted by Australia (2013) when comparing Australian PFROs with the United States, Canada, the United Kingdom, and Europe when using research expenditure (per $100m) with US dollar purchasing power parity:

- The number of full-time equivalent staff members at TTOs of Australian research institutions was 11.0 per institution in 2011. This was higher than the figure for the United States (10.9), Canada (9.1), and Europe (7.2), but lower than for the United Kingdom (25.7).
- Australian research institutions (28.8) performed weaker than their counterparts in the United Kingdom (43.7), Canada (41.6), and the United States (35.8) for invention disclosures per $100m of research expenditure in 2011, but slightly better than Europe (28.4).
- The total number of United States patents issued to Australian research institutions per $100m of research expenditure was 2.0 in 2011, compared to 4.1 for Canada and 3.5 for Europe. The total for the United States was 7.7 in 2011 and for the United Kingdom 7.8 in 2010.
- The total number of LOAs implemented per $100m of research expenditure by Australian research institutions dropped to 8.3 in 2011, which means that it measured lower than Canada (13.2), Europe (10.6), and the United States (9.9). The comparative for the United Kingdom was a much higher number of 52.6 LOAs executed in 2010.
- Australia's LOA income as a percentage of total research expenditure dropped to 1.5% in 2011 and was better than the United Kingdom (1.1% in 2010) and Canada (1.2% in 2011), but somewhat less than the rate in Europe (1.6% in 2011). The United States had more than double the figure for these countries and achieved a ratio of 4.1% in 2011.

- The number of Australian spin-out companies established per $100m of research expenditure dropped steadily from a high of 2.2 in 2001 to only 0.3 in 2011. Data from the United Kingdom and Canada indicated a similar drop over the same period, but the number was significantly higher at 2.8 for the United Kingdom in 2010, 3.2 for Europe and 1.6 for Canada in 2011. The United States has kept a steady rate of spin-out company formation per $100m research expenditure at about 1.1 per annum for the 10 years since 2001.
- The licensing of IP emanating from research seems to be a common avenue for commercialisation as opposed to spin-out companies. From 2005–2006 to 2010–2011, the number of LOAs increased by an astounding 204%, whilst the number of spin-out companies established reduced drastically by 82%.

Australian Government: Department of Industry and Science (2014) reports that Australia's gross expenditure on research and development (GERD) as a proportion of its gross domestic product (GDP) increased significantly from 1.47% in 2000–2001 to reach 2.26% by 2008–2009 and to end up at 2.13% by the end of 2011–2012. This is close to what the average figure was for OECD countries, namely 2.33% in 2008–2009. The Australian Government: Department of Industry and Science (2014) also indicates that Australia's GERD rose notably in dollar terms from $10.417m in 2000–2001 to $31.665m by 2011–2012.

From the discussion above, it seems that there are unique differences amongst developed countries in their approach to the protection of IP and commercialisation thereof through TT activities. The main differences are summarised as follows:

- Considerable increases in funding for R&D activities by government-owned universities and laboratories, as well as businesses in commerce and industry, were noted in the United States after 1969.
- National legislation in the United States, such as the Bayh-Dole Act of 1980, the Stevenson-Wydler Technology Innovation Act of 1980, and the United States Federal Technology Transfer Act of 1986, caused major increases in the registration of patents, licensing agreements concluded, and spin-out companies formed since 1980.

- Opposite to the United States, Canada's government spending on R&D dropped sharply from 1963 to 1997, whilst R&D spending by businesses in commerce and industry increased. Canada chose a policy route aimed at getting private sector participation in TT rather than national legislation aimed at using administrators at universities to enforce laws.
- University researchers owned the IP generated by Canadian universities, unlike universities in the other developed countries considered in this section. The number of license agreements increased strongly, and many spin-out companies were formed in Canada to license technologies from universities.
- Like Canada and the United States, the United Kingdom has a strongly funded science base, but experienced low patenting levels. The UK was behind the United States and Canada, due the lack of expertise in TT activities. The Lambert Review (2003) proposed shared ownership of IP in proportion of each contributing party.
- The UK concentrated on creating spin-out companies, but many spin-outs failed, as lacking entrepreneurial skills and business acumen hampered the success rate of new spin-outs.
- Australia preferred license agreements over spin-out companies, resulting in the number of spin-outs decreasing sharply from 2001 to 2011.
- The UK had the highest number of full-time equivalent staff working in their TTOs at more than double that of TTOs in Australia, the United States, and Canada.

The lesson learned from these alternative approaches seems to be that there is more than one route to successful IP protection and TT in developed countries. In the examples above, the use of legislation or policies to guide IP protection or the selection of licenses or spin-outs as methods of commercialisation of the IP had less of an effect on the end result. What seems relevant is the total value and volume of research being conducted and the focus on managing the particular piece of IP emanating from the research efforts of university staff and students. Also apparent is the fact that it is more labour intensive for the TTO to focus on creating and assisting spin-out companies than concluding license agreements or negotiating outright sale of protected IP.

3.2.2 Developing countries

Developing countries have less resources and weaker economies than developed countries and their challenges are often compounded by poor management of their scarce resources. The countries considered for this section are South Korea in South East Asia, Brazil in Latin America, and South Africa in Africa. Bourne (2000) maintains that governments in developing countries should be the main catalysts for promoting R&D in their respective countries through targeted subsidies and incentive schemes, as public–private TT activities comprise an imperative part of innovation policies and can be particularly important for economic growth in developing countries.

South Korea

In South Korea, the government has held rights to new inventions emanating from universities prior to new legislation, effective from June 2002 (Paik, 2002). Professors at Korean universities are seen as government employees and inventions made by professors were thus seen as inventions belonging to the government (Paik, 2002). Professors could patent their own work, but had to pay for the patent filing and subsequent commercialisation efforts themselves. The result of this practice was that very few patents were derived from university projects, and very few projects were commercialised, as professors were not motivated to find funding for patents, only to see the patent assigned to government (Paik, 2002). According to Paik (2002), private universities in South Korea, contrary to public universities (such as the Korea Advanced Institute of Science and Technology [KAIST]), generated more patents and shared the proceeds from these patents in the form of royalties with its academic staff. A Korean version of Bayh–Dole, called the Technology Transfer Act, was enacted in 2000 (Paik, 2002). Under the new legislation, public universities, similar to private universities, own the patent rights and share the profits with inventors and use some of the proceeds to invest in further R&D activities. Special licensing offices were set up at the larger research universities, like Seoul National University, whilst most regional universities shared TTOs. The new legislation addressed the lack of incentives, which prevented many Korean public universities from patenting their research before and transferring it to commercial markets (Paik, 2002).

According to Kim (2003), Korea first focused its research efforts in the 1960s and 1970s by obtaining, compiling, and advancing existing foreign technology through a number of ways, based on replica imitation. As the manufacturing procedures matured in Korea, a shift occurred from labour-intensive established technologies to more knowledge-intensive technologies (Kim, 2003). Technological efforts by the Koreans are concentrated on three major areas, namely foreign TT via formal arrangements, the recruitment of top class human resources from other countries, and local R&D programmes (Kim, 2003). In addition, the Korean government invests significantly in building research capacity at universities. As a result of these efforts, R&D expenditure in Korea increased from $28.6m in 1971 to $4.7 billion by 1990, and again to $12.2 billion by 2000 (Kim, 2003).

The Korean government also passed the Basic Research Promotion Act in 1989, which aim was to get universities to improve their research capabilities (Kim, 2003). According to Kim, patent activity in Korea escalated over the decades towards to end of the previous millennium. A 48% increase was recorded in the 14 years from 1965 to 1978, but it nearly tripled in the 11 years from 1979 to 1989, and virtually tripled again in the next four years from 1989 to 1993 (Kim, 2003). The share of local patents held by Koreans increased from 11.4% in 1980 to 69.2% by 1999 (Kim, 2003). Korean entities further registered an increasing number of foreign patents. For example, Korea jumped from 35th on the list of countries having US patents in 1969 to 11th by owning 538 US patents in 1992. This signifies an average annual growth rate of 22.56% (Kim, 2003). By 1999, Korea had leapfrogged to number 6 on the list with an astonishing 3 679 US patents (Kim, 2003). Samsung Electronics from Korea was ranked 4th, having 1 545 US patents on its own and followed IBM, NEC, and Cannon on the list (Kim, 2003). The rise in the number of patents held by Koreans showed their commitment in obtaining patent rights at home and abroad for its valuable IP (Kim, 2003).

The Korean economy became one of the world’s fastest growing economies and R&D expenditure kept rising as the percentage of R&D of its GDP rose from 0.32% to 2.68% during the same period leading up to 1999. This ratio was better than many countries in Western Europe Kim (2003). Recently, South Korea has widened the gap even further over all other countries and leads the world by spending 4.29% of its GDP or $60.5 billion on R&D in 2014. This is more than its closest rival, Israel, (at 4.11%) and better than Japan and the United States. Most of the funds are directed to applied R&D in industry, but the government has made significant investments in basic science as well (Zastrow, 2016).

Brazil

In Brazil only 307 patent applications were recorded between 1990 and 1999, of which 60% were reported by universities (Lehman & Garduño, 2004). Garduño (2004b) reports that 60% of funding of all R&D in Brazil in 2005 came from the government. Universities were limited by a lack of financial resources to patent their technologies and to engage in the licensing thereof. During the same period, only 27 out of 156 universities in Brazil provided some of kind support to their academic staff in the patenting of their inventions (Lehman & Garduño, 2004). The military government in Brazil, which assumed power in 1964, prolonged the use of the same science and technology (S&T) policies that were implemented after the Second World War (Almeida, 2008). These policies were aimed at national security, technological autonomy, and the broadening of institutional infrastructure and human resources for universities and state-owned corporations (Almeida, 2008). The adoption of research as a university mission first occurred in Brazil in the 1970s (Almeida, 2008). In spite of the military regime at the time, universities were allowed to create spaces for the development of new technologies to be transferred from universities to businesses in commerce and industry (Almeida, 2008).

Almeida (2008) notes that Article 207 of Brazil's 1988 post-military Constitution specifies that research, teaching, and augmentation are indivisible actions of Brazilian universities. Nevertheless, universities were not burdened by having to contribute to economic development (Almeida, 2008). The Technological Innovation Law No. 10.973/2004 was enacted to create innovation incentives and gauge scientific and technological research within Brazil and to promote strategic partnerships between universities, technological institutes, and businesses in commerce and industry (Almeida, 2008).

Maculan and De Mello (2009) note that the first public university in Brazil was established in 1920 in Rio de Janeiro, and the next in 1934, in the state of São Paulo. In the 1950s, the formation of new public and private universities increased exponentially due to industrialisation all over the world (Maculan & De Mello, 2009). By 1980, Brazil had more than 882 higher education institutions (HEIs), although only 65 of these institutions were deemed to be universities (Maculan & De Mello, 2009). The 1980s was signified by a mixture of economic, financial and political instability, which resulted in a prolonged period of sparse resources and a significant reduction in public funding towards tertiary education and scientific research. From 1980 to 1996, the number of HEIs increased from 882 to 922, but the quality of education was doubted, as only 15% of universities were engaged in some kind of research activities (Maculan & De Mello, 2009).

Similar to most Latin American countries during the 1990s, rapid changes in economic policy, privatisation, and the lessening of trade barriers pushed Brazilian businesses in trade and industry into strong international competition whilst lacking sufficient management and technological abilities (Maculan & De Mello, 2009). The government at the time focused on stimulating an environment that was supporting interaction between the university community and Brazilian businesses, such as the enactment of the Law of Goods that provided tax incentives for businesses in commerce and industry that invest in internal R&D activities (Maculan & De Mello, 2009).

Maculan and De Mello (2009) met the gradual move by universities to become more entrepreneurial with resistance. During their research, Maculan and De Mello (2009) noticed a lack of appreciation for the potential income to be generated by universities from patents that could be licensed to businesses in commerce and industry. The authors further indicate that many universities in Brazil have insufficient quantity and quality of research activities to produce viable patents. OECD (2008) reports a decline of 0.09% of government funding towards R&D over the period from 2001 to 2006 in Brazil. R&D as % of GDP for Brazil was low at only 1.02% for the year 2006, of which government spending and spending by businesses in commerce and industry was the same at 0.49% respectively (OECD, 2008). The lack of skilled researchers were an impediment to R&D in Brazil, as there were only 1.48 researchers per 1000 employed citizens, whilst only 10.7% of workers had degrees in the field of science and engineering (OECD, 2008).

Botelho and Almeida (2010) report that incubators have emerged as an accepted way to establish and support early stage technological ventures in Brazil. The number of incubators in Brazil increased from only 2 in 1986 to 60 by 1998, and to 454 by 2010, leading to a total of 6 300 businesses housed by these incubators and creating 33 000 jobs (Botelho & Almeida, 2010). In 2009, a grant programme called PRIME was created, aimed at creating spin-out companies (Botelho & Almeida, 2010). The combined effects of the efforts by the Brazilian government was that patenting of new inventions by Brazilian universities increased and that 1 500 spin-out companies were created in the last two decades leading up to 2010 (Kwon, 2011).

Enacted in 2004, Brazil's Innovation Law allows Brazilian universities to set up TTOs to support the transfer of research results and knowledge created from universities to businesses in commerce and industry. A survey conducted by the Cambridge Enterprise of Brazilian Technology Transfer Functions, published in 2014, indicated that there were 193 Technology Transfer Function units in existence. Many of these units (similar to TTOs) were established around 2006, soon after the Innovation Law was enacted (Republic of South Africa: Department of Science and Technology, National Intellectual Property Management Office (NIPMO), Human Sciences Research Council (HSRC), Centre for Science Technology and Innovation Indicators (CeSTII) & Southern African Research and Innovation Management Association (SARIMA), 2017).

South Africa

As already indicated, technological change and innovation is crucial in knowledge economies of the world. The SA economy is robust when compared to other countries in Southern Africa, and its broad higher education system has a strong focus on research. Successful commercialisation of new inventions emanating from universities can be a significant contributor to economic growth and increased wealth in societies (Koekemoer & Kachieng'a, 2002). Koekemoer and Kachieng'a (2002) argue that R&D activities at universities present a major source of commercial potential. On the other hand, SA faced a number of challenges. The shortcomings, maintains Mouton (2003), were mainly due to the fact that SA was politically isolated for many decades as a result of its policies in support of apartheid. This also led to major inequities within the tertiary education sector.

> It is not surprising that when the new SA government came to power in 1994, it produced various policy documents that contained mechanisms and incentives for increased collaboration: collaboration across institutional and disciplinary boundaries to address the socio-economic challenges facing the country; regional collaboration between institutions that were formerly divided by ideology; and collaboration between historically advantaged and disadvantaged institutions in order to promote the transfer of knowledge and expertise, especially to black scholars (Mouton, 2003:243).

HESA (2007) point out that SA universities were experiencing a time of rapid development in policies aimed at promoting national goals, and that promising developments of technology transfer activities had taken root in the higher education sector over the decade leading up to 2006. Many SA universities that did not have an approved IP policy in the past started to compile policies in accordance with the requirements of the IPR-PFRD Act (Sibanda, 2009). Reichelt (2007) and DST (Republic of South Africa: Department of Science and Technology, 2006) both observe that a national framework and unambiguous legislation was needed to manage IP emanating from public funds used at SA universities as part of the enabling environment. Having a clear legal framework, the author argues, hugely adds to the success of university technology transfer activities (Reichelt, 2007).

DST (Republic of South Africa: Department of Science and Technology, 2006) remarks on the low number of United States patents registered by South Africans (only 2.5 patents per million people), which is poor compared to the rest of the world. DST (Republic of South Africa: Department of Science and Technology, 2006) further claims that the low number of United States patents registered by SA citizens constitutes a major disadvantage to SA's aspiration of meaningful participation in the knowledge economy of the world. SA is a participant of the Patent Co-operation Treaty (PCT), administered by the World Intellectual Property Organisation (WIPO), which comprises more than 125 member countries who are all signatories to the Paris Convention. PCT allows for the coordination, filing, searching, and assessment of new patent applications. In a comparison of PCT applications from developing countries between 1998 and 2004, DST (Republic of South Africa: Department of Science and Technology, 2006) found that SA had not increased their number of patents, while South Korea [Korea], China, and India's patent applications had grown exponentially over the corresponding period. Korea managed to increase its PCT applications by seven (7) times and India by nearly twelve (12) times over the same period.

DST (Republic of South Africa: Department of Science and Technology, 2006) further argues that these disparate patenting rates reflect a growing divide in the global knowledge economy. As patents and copyright signify the strongest form of IP in the knowledge economy, DST (Republic of South Africa: Department of Science and Technology, 2006) maintains that the poor performance of SA at the time represented a key weakness in preventing the country from becoming a full participant in the global knowledge economy. Low levels of patenting causes fewer license agreements to be concluded, and consequently also less income earned from royalties.

Heher (2006) argues that the success from commercialisation activities, as reflected through patenting rates, is directly related to the level of investment in R&D activities of any country. The average percentage of the GDP that was spent on R&D activities in 2006 for member countries of the Organisation for Economic Co-operation and Development (OECD) was 2.15% (Organisation for Economic Co-operation and Development (OECD), 2007). Finland, however, with an economy about half the size of SA at the time, was spending significantly more (3.338%) on R&D as a percentage of their GDP, whilst SA fell well short at 0,898% (OECD 2007). The International Intellectual Property Institute (IIPI) (Reichelt, 2007) also attests that the success of a country's innovation system is directly linked to the level of funding made available for research activities. For 2013, the ratio indicates a deterioration, as R&D expenditure by SA then was 0.726% of SA's GDP, compared to the average level of R&D expenditure by OECD countries of 2.364% of their GDP (Organisation for Economic Co-operation and Development (OECD), 2017).

Garduño (2004b) reasons that there is a major difference between funding for R&D between developing countries and developed countries. Overall funding for basic and applied R&D in developed countries, he expounds, is much more than in developing countries and it is mostly led by the business sector. Conversely, the author states that basic research in developing countries is mainly funded by governments and performed by public institutions. He further argues that the high percentage of public participation in R&D in developing countries causes a weaker market for university technologies, and consequently it is more difficult for universities in developing countries to find licensees for its new technologies, compared to their counterparts in developed countries. Garduño (2004b) also maintains that gross licensing income generated by universities is used in developed counties as a key measure of success for TT activities. However, he claims that universities in developing countries should focus on creating spin-out companies to commercialise new technologies, and that the number of such newly created spin-out companies should be the measure of success for universities in these countries.

Heher (2005) ascertains that performances between countries with different innovation systems and cultures display strong similarities. This indicates that the innovation process is inherently similar, regardless of the environment. Therefore, Heher (2005) argues, the single biggest factor affecting the performance of a university TTO is the total expenditure on R&D. Dai *et al.* (2005) observe that funding by the United States government on basic and applied research at universities increases when the economy is stronger and decreases when the economy is weaker. This may be particularly true for developing countries with small economies (Nishimura, 2003). Schiller (2006) claims that investments in innovation infrastructure must be made by the public sector in developing countries and should include human capital development, broadening academic capacity, and advancing industrial innovation and technology transfer.

Although the SA economy is strong when compared to other countries in Southern Africa, and its higher education system has a solid focus on research, the country spends too little on R&D as percentage of its GDP. For 2013, this ratio was only 0.726% compared to the average of other OECD countries of 2.36% (Organisation for Economic Co-operation and Development (OECD), 2017). It seems that SA, like Brazil, is spending less and less on R&D activities. That could cause these countries inevitably to fall behind other countries on the global stage when considering research outputs.

3.3 Conceptual framework for institutional technology transfer at universities

There are external factors and internal factors affecting university technology transfer. These factors can be enablers or barriers to effective university TT. External factors relate to international treaties and national policies that are beyond the control of a university as institution and the TTO as unit within universities. This section, however, focuses on the internal enablers that comprise the enabling environment for university TT, such as the culture necessary to stimulate new inventions, the policy environment, the legal milieu, funding requirements, human resources needed, and R&D capacity at universities. Siegel, Waldman, Atwater and Link (2004) argue that there are a number of impediments to effective university technology transfer, of which cultural barriers, such as inadequate reward systems, are one. These authors found that many academic staff at universities decide to elude the formal TT process due to these barriers.

Siegel *et al.* (2004) performed an inductive analysis of qualitative data obtained from 55 structured interviews of three different TT role-players at universities and businesses in the United States, including (1) academics as scientists; (2) TTO staff and university managers; and (3) managers as businesses in commerce and industry. The authors attest that there is scope for significant conflicts and confusion in university TT, as different role-players are involved. Siegel *et al.* (2004) suggest that top management allocate time and effort to instilling a positive culture towards TT, as it is a source of revenue for the university and it aids local economic development. An analysis of their interviews showed that one-third of university managers noted spin-outs as an output, but most of their focus was concentrated on funding for R&D as a dimension of university TT and on outputs such as licensing and patenting. Some academics were pessimistic on the idea of spin-outs as a TT output. One academic participating in the study voiced his disapproval strong by stating:

> I know that our university wants to see more academic start-ups but I think that is the wrong way to go. I do not encourage my students or colleagues to go down that road. We need to stop pretending that academics can be entrepreneurs, or at least good ones (Siegel *et al*., 2004:130).

The study by Siegel *et al.* (2004) found that eighty percent of entrepreneurs believe that universities are too forceful in applying IPRs, causing difficult negotiations. A former TTO director, as well as a number of scientists in the study (70.0%), mentioned inadequate rewards for academic staff as researchers as a deterrent to effective university TT. They asserted that, at the time, most promotion and tenure positions were founded mainly on publications and research subsidies. Another barrier to successful university technology transfer highlighted by participants was a lack of marketing and expertise within the TTO, where personal contacts were seen to be more essential than contractual relationships. The need to increase networking between scientists and practitioners was also explicitly mentioned as a suggested improvement by about a third of all respondents. The authors concluded from the results that social networks may be an imperative as an enabler in university TT activities.

Furthermore, Siegel *et al.* (2004) observed in their study that the skill of staff employed within the university TTOs was an additional worrying factor, in particular relating the marketing and negotiation abilities of TTO staff members. Finally, there was also a conviction that universities are not allocating enough resources to TT activities. The study shows that university managers who want to promote commercialisation efforts should focus on:

- adequate rewards for TT efforts to inventors;
- human resource customs in the TTO;
- fluidity of university policies on TT;
- allocating sufficient extra resources to TT; and
- efforts to eradicate cultural obstacles impeding on the TT process.

In addition, Siegel *et al.* (2004) found that participation in TT activities may actually increase the quantity and quality of R&D activities performed by academic staff at universities. This is an important finding, as it indicates that a feedback loop exists between efforts and results of the university TTO and researchers as innovators and creators of novel technologies at universities. Knowledge transfer seems to work in both directions, with sixty-five percent of the interviewees specifically noting this point, and several mentioning that connecting with businesses in commerce and industry allow them to do better basic research.

Alessandrini *et al.* (2013) note that eleven of the thirteen SA universities they surveyed had formal TTOs by 2009. However, based on their survey results, Alessandrini *et al.* (2013) echo the lack of the availability of trained technology transfer professionals in SA, and they claim that there might still be considerable dormant, untapped IP present at SA universities. Alessandrini *et al.* (2013), like Sibanda (2009), stress that strong, trustworthy personal relationships between academic staff and TTO officials are critical to successful technology transfer. Alessandrini *et al.* (2013) also list the constraints that further impede TT processes at SA universities. Notable is a weak flow of new invention disclosures and the authors allege that no TTO can effectively operate and be successful without a steady flow (pipeline) of new inventions of proprietary IP. Alessandrini *et al.* (2013) maintain that the low levels of funding by the SA government for R&D in general is the main reason for the low levels of unencumbered IP. They report that Invention disclosures at SA universities increased from 40 in 2004 to 123 in 2008. However, the conversion rate from disclosures to patents and then to commercial products are disappointingly small, as overall licences increased from 12 in 2004 to only 30 in 2008. The authors suggest that this low rate might be due to insufficient entrepreneurial skills or insufficient additional seed funding for taking novel technologies to the market.

Alessandrini *et al.* (2013) also considered organisational structures, factors guiding the success of TT, and measurements of success of TT at SA universities. Success factors evaluated by these authors were policies and a labour milieu that foster innovative thinking and entrepreneurship; commitment from university senior management; unambiguous IPR policies; well established TTOs; dedicated and sufficient human capacity to produce IPR’s; and adequate incentives to knowledgeable staff to enable TT. The authors also noted the following deterrents to effective university TT: a lack of understanding by academics of the benefits of commercialising research; the capacity to identify early stage technologies; insufficient human resource capacity to manage and monitor TT activities; inadequate interaction with businesses in commerce and industry; a lack of seed funding; and a poor IP pipeline.

Alessandrini *et al.* (2013) assert that university TT in SA is in a growth phase and universities have the option to apply the best methods in use by foreign TTOs. The authors further alert to the fact that institutional policy and operational changes, with the commitment from university top management, are key for effective technology transfer.

Pointers of success identified by Alessandrini *et al.* (2013) illustrate a rising tendency in the number of SA patents emanating from SA universities. The authors also contend that present methods to gauge TT outputs are not adequately demarcated and do not consider the impact of the activities of the TTO staff. Rather, Alessandrini *et al.* (2013) maintain that the strict focus on, for example, the quantity of registered patents and total income earned from licenses may not be appropriate for SA universities. Indicators such as the social influence on communities, job creation, and decline in poverty levels should rather determine the value of the TT function at SA universities, according to the authors.

Secundo, De Beer and Passiante (2016) developed a Maturity Model to monitor the proficiency of TT activities at universities. Specifically, the authors point to six non-monetary dimensions discovered by them in the literature that represent an enabling environment for effective university TT. The six dimensions are: IP strategy and policy; organisational plan and construct; human resource allocation; the technologies emanating from research efforts; collaboration between various TT actors within academia and commerce and industry; and networking between university management, scientists and TTO staff at universities.

Secundo *et al.* (2016) note that the process of innovation in developing countries is dissimilar to that of developed countries and that proven technologies are frequently not being successfully commercialised. The authors maintain that universities are seen as mechanisms for innovation via the university TTO, but universities in developing countries has applied ineffective methods with the implementation of new IPR legislation. Secundo *et al.* (2016) refer to SA and, like

Alessandrini *et al.* (2013), observe that concentrating on financial returns only is not an appropriate way to gauge the effectiveness of TTOs. The premise of the study by Secundo *et al.* (2016) is that TTOs should be classified and evaluated in accordance with their level of maturity.

Bansi (2016) conducted interviews with selected researchers at 23 SA universities using a semi-structured interview schedule. She found that lacking support from top management and few funding opportunities were the biggest deterrents to IP commercialisation. Bansi (2016) added that a top-down vision, strategy and leadership, displaying strong support, is needed for successful academic entrepreneurship and the establishment of an environment that recognises and motivates scientists as inventors. The author states that universities have a duty to drive business and entrepreneurship teaching and that a culture of commitment by university top management towards supporting TT must be robust to ensure the chances of its success.

For Bansi (2016), the kinds of inventions that researchers develop is contingent to a large degree on the country's national pioneering capacity, its ability to engage, and government's policies which include R&D policies. Bansi (2016) also highlighted inferior knowledge and TTO experience along with inadequate incentives for inventors as problem factors. Also, universities have to provide sufficient funding support for IP protection and investment in TTO activities through appointing suitably qualified personnel, according to Bansi (2016). The author identifies the IP policy of universities as something that all university staff and students should know well, while another imperative is networks that enable academic staff to connect with researchers at other universities and government research institutions.

Different dimensions and factors influencing university TT practices, gathered from the studies performed by the authors quoted above, are listed in Table 3.1 below. Although there appears to be no generally accepted conceptual framework to evaluate dimensions of technology transfer and the factors that enable or constrain it, a few positions are held in this regard by a number of writers such as Siegel *et al.* (2004), Alessandrini *et al.* (2013), Secundo *et al.* (2016) and Bansi (2016). Apart from certain overlaps in some of these dimensions and factors listed above, there is no overall consensus on specific enabling factors in this field of study. Thus, based on the approaches by these writers, the researcher propose a conceptual framework (Figure 3.1) that borrows from all the above and that comprises five dimensions out of the seven listed in Table 3.1 below.

TABLE 3.1: DIMENSIONS AND FACTORS PROMOTING OR IMPEDING EFFECTIVE UNIVERSITY TT

Dimension	Factors to consider	Siegel 2004	Alessandrini *et al.* 2013	Secundo *et al.* 2016	Bansi 2016
1 **Policies**	**Natonal Policies**				
	White papers	-	-	-	X
	Institutional Policies				
	IPR policy	X	X	X	X
2 **Legal**	IPR Legislation	X	X	X	X
3 **Institutional Commitment**	Dedication by Management	X	X	-	X
4 **Funding**	Funding for R&D	X	-	-	X
	TTO Commercialisation activities	X	X	-	X
	Venture Capital & Angel Investors	-	-	-	-
5 **R&D Capacity**	Infrastructure	-	-	-	-
	Quantity and Quality of R&D	X	-	-	-
	Technologies	-	-	X	-
6 **Human Resources**	Incentives to inventors	X	X		X
	Networks and collaborations	X	X	X	X
	TTO staff capacity & skills	X	X	X	X
7 **Marketing**	Marketing Expertise	X	X	-	-

The proposed framework comprises external enablers and internal enablers as dimensions. The reason for including the five dimensions listed as internal enablers in Table 3.1 is that they reflect the five most common themes that have emerged from the literature. These dimensions are: the policy environment, institutional commitment, the legal milieu, the funding arena, and human resources. The TTO is central to this framework, as it represents the conduit through which TT occurs at universities. The TTO uses these enablers to drive commercialisation outputs and it forms a feedback loop with academic staff and students that performs R&D activities resulting in a repeat of the technology transfer cycle.

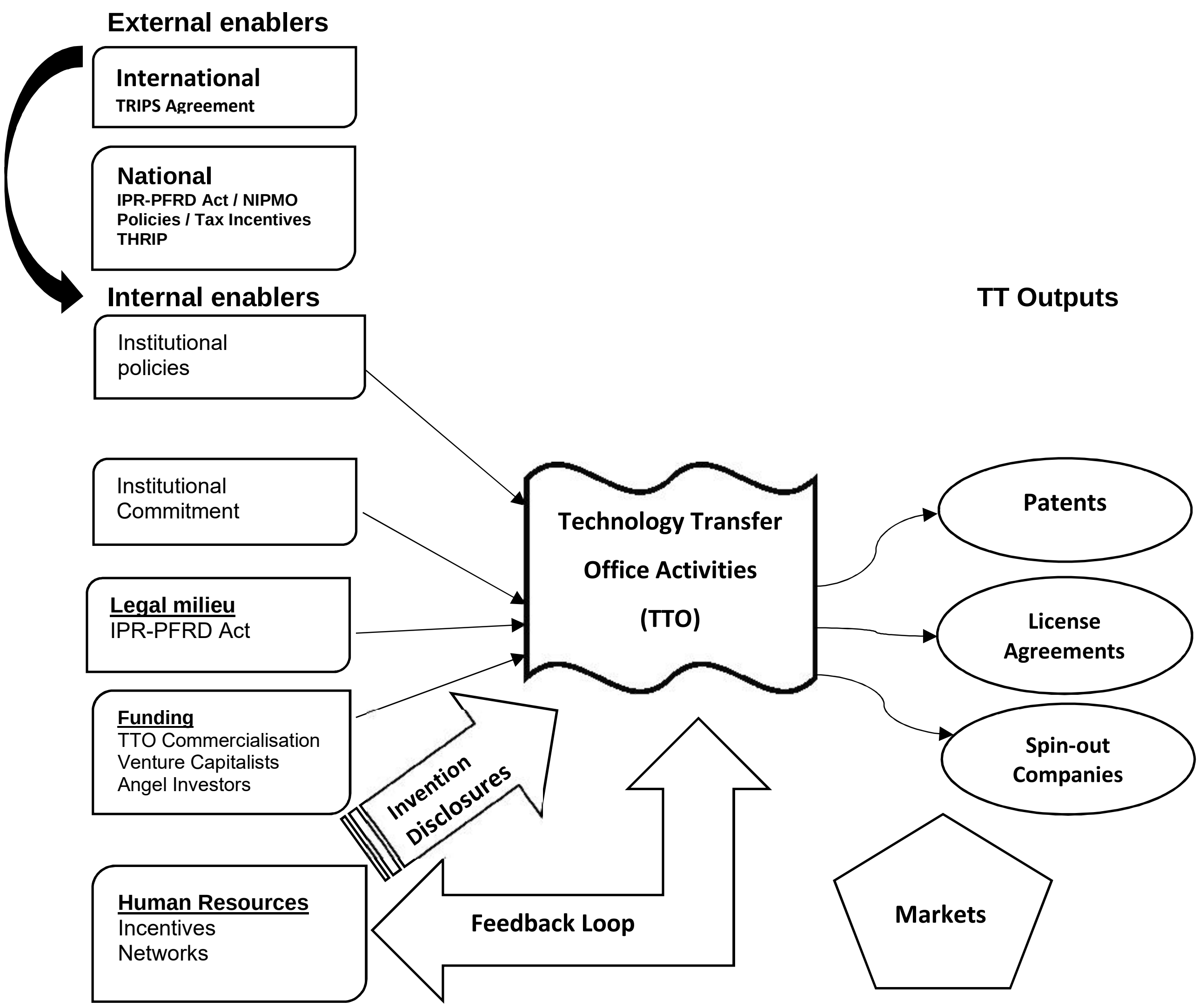


FIGURE 3.1: CONCEPTUAL FRAMEWORK FOR DIMENSIONS OF UNIVERSITY TECHNOLOGY TRANSFER

The five dimensions chosen for the framework are supported by the contents of a report by DST et al. (2017). This report contains the SA National Survey of IP and TT at Publicly Funded Research Institutions, conducted in 2016, and is the initial standard survey by the Centre for Science, Technology and Innovation Indicators (CESTII) of the HSRC in SA. The section in the report dealing with the TT function indicates similar activities, systems, and resources to those selected for the framework. The specific activities mentioned are (1) IP management, including receiving of invention disclosures; (2) novelty searches; (3) IP registration and maintenance; and (4) commercialisation activities, such as (a) statutory compliance, (b) fundraising, (c) mentoring and support for spin-outs, (d) negotiating license agreements, and the (e) marketing of technologies. Administration included managing funding and holding workshops (5) to increase awareness of IP issues on campuses. Enforcement was linked to the IPR policy and included (6) infringement litigation and monitoring. Promoters of TT were listed in Figure 14 of the same survey and given to include: dedicated TT funds from government (funding), internal (institutional) relationships (commitment), TTO staff capacity (human resources), marketing channels, forums to discuss and showcase new technologies, and finally informal and formal interaction with businesses in commerce and industry (networks).

3.4 Conclusion

This chapter provided a brief history of university TT within a few developed and developing countries of the world. The formulation of a conceptual framework for this study followed. The proposed conceptual framework depicts institutional technology transfer at universities and drew mainly from Siegel *et al.* (2004), Alessandrini *et al.* (2013), Secundo e*t al* (2016) and Bansi (2016).

From the discussions above, it is evident that developing countries often have less resources and weaker economies, resulting in less R&D being undertaken and which is of lower quality than developed countries, due to underdeveloped human capacity. Bourne (2000) claims that governments in developing countries should invest more in R&D to stimulate innovation and economic growth. Brazil managed to increase their number of HEI's notably, but only 15% of their universities were active in research activities (Maculan & De Mello, 2009). The effects of the efforts by the Brazilian government in providing tax incentives led to a total of 1 500 spin-out companies created in the 20 years up to 2010 (Kwon, 2011).

South Korea has seen incredible improvements in technology transfer since the government enacted a Korean version of Bayh–Dole (the Technology Transfer Act), effective from 2002 (Paik, 2002), allowing public universities to own patent rights and share profits with inventors. More importantly, R&D expenditure in Korea increased from $28.6m in 1971 to $4.7 billion by 1990, and again to $12.2 billion by 2000 (Kim, 2003) and to $60.5 billion in 2014 (Zastrow, 2016). As a result, Korean universities could improve their research capabilities significantly, which contributed to the Korean economy becoming one of the world's fastest growing economies that spent 4.29% of its GDP on R&D in the year 2014 (Zastrow, 2016).

Differences and similarities were noted amongst developed and developing countries regarding their methods of protecting of IP and commercialising it. The main items of importance are:

- Significant spending on R&D activities by governments and businesses in developed countries were noted, in particular in the United States after 1969 and in South Korea as a developing country. The Korean economy became one of the world's fastest growing economies and spent 4.29% of its GDP on R&D in the year 2014 (Zastrow, 2016).
- Conversely, R&D spending as % of GDP reduced for both Brazil and SA, as these developing countries struggled to obtain real economic growth. For SA in 2013, this ratio was only 0.726% compared to the average of other OECD countries of 2.36% (Organisation for Economic Co-operation and Development (OECD), 2017). It seems that SA, like Brazil, is spending less on R&D activities, which could cause these countries inevitably to fall behind other countries on the global stage when considering research outputs.
- Garduño (2004b) posits that funding for R&D is much more in developed countries and it is mostly led by the business sector, compared to basic research in developing countries that is mainly funded by governments and performed by public research institutions. The author's assertion seems to be true, especially in the case of South Korea as developing country, where its government invested heavily in R&D capacity over the last three decades. This investment in R&D capacity is exactly what Schiller (2006) advocates.
- The revised legal milieu in the United States, incorporating the Bayh-Dole Act of 1980, the Stevenson-Wydler Technology Innovation Act of 1980, and the United States Federal Technology Transfer Act of 1986, spurred patent registrations, licensing agreements, and spin-out company formation in that country. Similarly, South Korea has experienced exponential growth in university TT activities from public universities since they enacted the Technology Transfer Act of 2002. It remains to be seen what the effect of comparable legislation in SA would be after its enactment in 2010 and against the background of stagnating or reduced spending on R&D as % of its GDP.
- Canada opted for a policy path aimed at boosting private sector participation in TT rather than national legislation aimed at using administrators at universities to enforce laws.
- Many spin-out companies were formed in Canada and the UK from technologies that were licensed from university campuses. Many of these companies failed due to lacking

entrepreneurial skills and business acumen. In Brazil, many new spin-out companies resulted from innovative tax incentives for R&D expenditures (Kwon, 2011).

- Australian universities preferred license agreements over spin-out companies, resulting in the number of spin-outs decreasing sharply from 2001 to 2011.
- The UK had the highest number of full-time equivalent staff working in their TTOs. It was more than double that of university TTOs in Australia, the United States, and Canada.

The alternative courses embarked upon by universities, whether from developed or developing countries, indicate that anyone or a combination of methods may work to grow IP protection and TT commercialisation practices at universities. What seems pertinent is the value and capacity of research undertaken and the ability of the particular university TTO to convert a piece of IP into commercial success. Garduño (2004b) argues that the high percentage of public participation in R&D in developing countries causes a weaker market for university technologies; hence it is more difficult for universities in developing countries to find licensees for its new technologies than for universities in developed countries. Garduño (2004b) further asserts that, while gross licensing income generated by universities is used in developed counties as a vital determinant of success for TT activities, the creation of spin-out companies should be the key measure of success for universities in developing countries.

Heher (2005) correctly observes clear similarities between the performances of countries with different innovation systems and cultures. He further claims that the innovation process is fundamentally the same, irrespective of the environment. I also concur with Heher (2005) who states that the single biggest factor influencing the performance of a university TTO is the total expenditure on R&D, as it has a direct impact on the success from commercialisation activities as reflected through patenting rates, licensing agreements, and spin-out company formation.

The conceptual framework derived at in the previous section contains external and internal enablers for university TT that forms the basis for debates in the chapters to come. The first enabler is the institutional commitment affecting university TT. This enabler depicts the devotion by university top management towards TT activities. Institutional commitment emanates from a positive inclination towards entrepreneurial activities on campus. It is manifested at the organisational level through (a) the attitude of top management in driving research intensiveness, and (b) institutional support to the university TTO.

The second dimension as enabler for university TT contains the legislative environment that is considered in this study as it relates to IP protection for newly created inventions at universities. The national and institutional policy environment constitutes the third dimension chosen as part of the enabling environment for university TT. The fourth dimension eluded to in this study is the funding environment. This environment involves (a) SA's funding schemes for the stimulation of R&D plus tax incentives to stimulate expenditure on R&D, and (b) private equity, venture capital, and angel investors. The fifth dimension as enabler includes human resources. This enabler constitutes (a) incentives for academic staff and students and (b) networks seeking collaboration.

Chapter Six to Chapter Nine, containing each of the four case studies, will be guided by the conceptual framework derived at in this chapter. The next chapter is devoted to a discussion of the enabling environment trends for university technology transfer, both globally and in SA.

Chapter 4: University technology transfer: Global and SA trends

4.1 Introduction

Following from the literature review and discussion of university technology transfer in Chapter Three, this chapter considers the history of developments of university technology transfer activities in SA as a developing country from 1990, as well as developments around the globe pertaining to the specific dimensions determined in the conceptual framework.

The chapter also includes selective reference to the same dimensions prevalent at other universities across the globe, and where appropriate, comparisons are drawn to circumstances and methods in use at those universities. The chapter commences by examining the policy environment applicable to SA universities followed by the institutional commitment of national institutions in SA that exemplify the obligation by the SA government towards university TT activities. The sections that follow reflect on the remaining dimensions of the enabling environment for university TT, namely the legal, funding, and human resource environments. A discussion of TTOs are included as the penultimate section of this chapter, whilst the last section draws together the chapter as a whole and concludes the background of TT at SA universities.

4.2 The policy environment for universities

4.2.1 Developments in SA Science and Technology Policy (1990 to 2010)

From 1990, especially between 1992 and 1995, and after a new democratic regime was established in 1994, the focus in SA was on social and economic reconstruction. From this focus, S&T in SA enjoyed increased importance, which led to the establishment in 1996 of a national Ministry of Arts, Culture, Science and Technology, a Ministers' Committee for S&T, as well as the Department of Arts, Culture, Science and Technology (DACST). DACST, formed to strengthen the ministers' efforts in implementing national policy in SA, released a White Paper on Science and Technology in September 1996. The vision of the White Paper of 1996 was the modelling of the National System of Innovation (NSI) to connect the various aspects of S&T in SA through the institutions where innovation is practised and developed (Republic of South Africa, 1996).

Another aim of the White Paper of 1996 was to create an enabling environment that would support both creativity and innovativeness, and connect individuals (like academic staff) and organisations (including universities) to formalise a national system of innovation (Republic of South Africa, 1996).

> Science creates conditions for economic and national development, and raises the prestige of a country in the modern world. The most important goal of science and technology policy is to achieve results which in the near future will support the process of social and economic transformation and in the long run will ensure economic growth and social development of the country. ... [T]o reach this goal, it will be essential to link science effectively with other areas of social and economic activity; and with education in particular (Republic of South Africa, 1996 Chapter 3.1)

The initiatives proposed by the White Paper of 1996 included the creation of the NSF to manage grants earmarked for S&T, the IF to assist in longer term research projects, and NACI.

A National Biotechnology Strategy was compiled in 2001 and was followed in 2002 by the release of a new R&D Strategy for SA. The R&D Strategy noted key shortcomings in the NSI, such as low levels of funding, declining R&D in the private sector, and uncertainty about IP rights (Republic of South Africa: Department of Science and Technology, 2002). The lack of protection of IP was one of the many issues in need of correction, as inventions emanating from publicly financed research at SA universities were not being successfully safeguarded and administered in SA (Republic of South Africa: Department of Science and Technology, 2002). The R&D Strategy of 2002 had three pillars, namely (1) innovation; (2) science, engineering and technology (SET) human resources and transformation; and (3) the creation of an effective government science and technology system (Republic of South Africa: Department of Science and Technology, 2002:16). The R&D Strategy also noted the decline of total R&D spending in SA from 1.1% of GDP in 1990 to 0.7% in 1994, and set an objective of reaching 1% within the three years following from 2002 (Republic of South Africa: Department of Science and Technology, 2002).

Mouton (2003) observed more initiatives geared towards considering the present and future state of S&T in SA. Worth mentioning, according to the author, were (a) the national R&D Technology Audit (1997-1998); (b) the National Research Foresight exercise (1998-2000); and (c) a review of the whole system of the science councils and national laboratories (1998-1999). Mouton (2003) concluded that the ageing scientific workforce and lack of a strong human-resource base was a major challenge for S&T in SA. The author also stressed inadequate funding for basic research, as the capacity to do basic research had been reduced over a number of decades due to a focus on strategic and applied research.

The National Biotechnology Strategy, which emerged in 2001, led to the setting up of Biotechnology Regional Innovation Centres (BRICs). The role of the BRICs was to promote interaction between academic staff at universities and businesses in commerce and industry.

On the 1st of August 2002, DACST was split into two departments, namely the Department of Arts and Culture (DAC) and the Department of Science and Technology (DST). Following on the R&D Strategy of 2002, and in response to the lack of coherence in controlling intellectual property rights emanating from publicly financed research, DST released the Intellectual Property Rights from Publicly Financed Research Framework in 2006. This framework (section 4.3.2) was the forerunner of the Intellectual Property Rights from Publicly Financed Research and Development Act 51 of 2008 (section 4.3.3).

In 2004 the DST and the NRF initiated the formation of Centres of Excellence (CoEs). The CoEs are practical research hubs that focus current research expertise, capacity, and resources to enable researchers to work together across different fields and organisations on long-term research projects. Seven CoEs was started in the first year. Since 2004, three extra CoEs were formed between 2009 and 2013, and five additional ones in 2014, bringing the total to 15. The five main focus areas of the CoEs are: research/knowledge production, education and training, information management, networking, and service delivery. Each of the CoEs has an advisory board that guides and monitors its performance (National Research Foundation (NRF), 2014).

With regards to SA, the 2007 OECD review found some flaws in the SA innovation policy environment. Some of the flaws noted were:

- There appears to be inadequate consistency and amalgamation between agencies in the NSI,
- Businesses in commerce and industry were not sufficiently involved in the building of the NSI.
- The notion of a NSI had not yet been fully embraced by key stakeholders, such as government departments and higher education institutions.

- The concept of innovation was badly understood, particularly on the demand side.
- The implementation of the NSI is critically hampered by the shortage of high-level skills, notably in the fields of design, engineering, entrepreneurship and management.
- The science, technology and innovation measurement have not been adequately incorporated into a structured and well-established system.
- SA must compete for top-rated academic scientists from elsewhere in the world, and against other countries that are implementing attractive immigration procedures to lure highly-rated scientific and technological competencies (Republic of South Africa: Department of Science and Technology, 2012b).

There was no public response from the DST to the 2007 OECD Review, but shortly thereafter DST's Ten-Year Innovation Plan appeared that led to the establishment of the Technology Innovation Agency (TIA). TIA consolidates seven entities of DST that were tasked with supporting and advancing innovation in SA. Since the amalgamation of these seven agencies, TIA has helped to start a network of centres that focus on marketing and commercialisation activities shared by businesses in commerce and industry and universities, as public research institutions.

During 2007, DST introduced its ten-year Innovation Plan to build on the foundation of the NSI. In the plan, reference is made to the progress made by DST since 2002 in creating an enabling framework for S&T that is essential for SA's economic growth and socio-economic development. The plan of DST proposed the following four key elements as drivers for SA to make progress towards becoming a reckoned knowledge-based economy:

- human capital development,
- knowledge generation and exploitation (R&D),
- knowledge infrastructure, and
- enablers to address the “innovation chasm” between research results and socio-economic outcomes (Republic of South Africa: Department of Science and Technology, 2007:vii).

In promoting DST's strategic plan for 2011 to 2016, the Minister of Science and Technology stated that SA intended spending R45 billion on R&D by 2014 to reach its target of 1.5% of GDP on R&D (Republic of South Africa: Department of Science and Technology, 2012a). It was anticipated that the increased spending would have a positive effect, and lead to growing levels of research activity and consequently also the number of research publications.

DST also introduced the prestigious SA Research Chair Initiative (SARChI), to deter academics leaving SA and to attract top researchers in R&D and innovation to public universities in SA. The award is a fulltime research position offered to world-class scholars. Allocated by open contest, the award includes a significant budget per year for salary, scholarships, postdoctoral fellows, operating expenses, and small equipment requirements. Initially the levels of funding for Research Chairs were set at R2.5 million and R1.5 million per annum for Tier 1 and Tier 2 respectively. The funding provided was meant for the salary of the Chair holder, postdoctoral fellowships, postgraduate student bursaries, operating costs, small items of equipment, and limited administrative and technical support, within predetermined confines. It was expected from the holder of a Research Chair to allocate no less than 95% of his/her time to doing research, managing ten masters and doctoral students per year overall, and guiding up-and-coming researchers. The balance of the time (5%) may be spent on doing administration or teaching to undergraduate students. The intervention was intended to lure new research capacity into public universities, as well as to retain researchers already at universities. Another aim was to attract about 60% of candidates from other countries and the remaining 40% from within SA. Foreign candidates could include African scholars and South Africans in other countries (NRF, 2015).

Some enhancements to the SARChI programme have already been made by the NRF in reaction to findings from the Mid-Term Internal Review. Major adjustments comprised the establishment of research chairs at the Tier 2 level and the broadening of criteria for selection of staff at Tier levels 1 and 2 during 2009. Research chairs allocated in terms of Tier 1 were based on a candidate's research history and international standing in the academic community, whilst Tier 2 appointments were designated for researchers showing potential to attain international recognition for their research efforts within five years to a decade. The research chairs were allocated for five years and renewable for two further periods of five years each, if reviews of the work of the researcher were adequate, based on three main criteria, namely:

- "outputs, which included the number of peer-reviewed journal publications, conferences organised and conference presentations, and chapters in books;

- human capacity outputs: numbers of master's and doctoral graduates and completed postdoctoral fellowships; and
- impact on local and international research communities, indicated by improved NRF rating, etc." (National Research Foundation (NRF), 2015:5).

The implementation of the SARChI programme resulted in the preservation of gifted academics, larger numbers of graduate students (masters, doctoral and postdoctoral), and more publications (National Research Foundation (NRF), 2015).

Since the start of the programme, 150 research chairs were allocated to 21 public universities across SA in areas such as science and technology, in line with the national science and technology objectives for poverty alleviation; innovation, engineering and technology development (National Research Foundation (NRF), 2015). The SARChI programme, starting with 21 research professors in 2006, has since increased to 198 research professors in various fields, such as the natural sciences, engineering, humanities and the social sciences. Pandor (2015) reported then that these chairs were receiving funding to the value of R470m per annum. The program is extremely beneficial for partnerships between government, universities, and businesses in commerce and industry. By 2014, the total cumulative public investment in SARChI since 2006 added up to R1.5-billion, whilst research chair holders were able to obtain additional funding to the value of R3-billion from foreign funds, government departments, and businesses in commerce and industry (Pandor, 2015).

However, the 2017 Draft White paper on STI noted that SA does not have an all-embracing innovation policy for matters relating to trade and innovation, competition regulation, public procurement, and aspects pertaining to STI policy. The white paper states that a national innovation policy will be developed. The policy will promote interaction between various governmental organisations, which will be managed by a high-ranking unit within the office of the Presidency. The SA government will also act entrepreneurial by investing and stimulating the economic growth of high risk technology areas such as information technology, biotechnology, nanotechnology, and green technology. The white paper further reveals the commitment of the SA government to increased spending on public and private R&D activities. It remains to be seen if this objective can be reached, given the budget limitations faced by the government in managing its fiscus (Republic of South Africa: Department of Science and Technology, 2017b).

The 2017 Draft White paper on STI promotes a new, inclusive innovation system, where smaller businesses in local economies of remote and rural districts will also have access to the NSI system which, until now, has been biased towards R&D activities for big businesses in major metropolitan regions. In this paper, the SA government commits to the following involvements:

- *Sufficient funding for strategic priorities*. The SA government will continue to support and fund R&D and R&D commercialisation activities directed towards the creation of new industries, particularly in the mineral and agricultural industries. Preference will be given to previously disadvantaged women and black entrepreneurs, so that they can capitalise from IP that is publicly financed and subsequently commercialised.
- *A more prominent role for technology transfer offices*. TTOs at higher education institutions and science councils are key in the identification and protection of new inventions, the finding of licensing partners, and/or the formation of new spin-out companies to move the technologies developed to market. The SA government, in accordance with global practice, will strengthen support for TTOs through current mechanisms to grow capacity, and increase the quantity and extent of TT outputs. In particular, transformation of the higher education arena by the SA government to sustain these TTOs will be segregated by referring to the research intensity and technology transfer maturity of the specific institution (Republic of South Africa: Department of Science and Technology, 2017b). Also, it is recorded that, at present, there are not enough individuals in SA who are able to manage the innovation value chain at TTOs. A thorough training programme, based on practical experience, will be created to enhance the necessary proficiencies for effective technology transfer.
- *Pairing incentives on offer.* It is noted that the present incentives on offer benefits good publishers more than good inventors. Mouton (2017) agrees and advocates that more incentives and systems for measuring technological innovations must be created and used. Academics as inventors active in the public arena should be rewarded and have a growing career trajectory that includes recognition of innovation outputs that compare with their efforts in teaching and research activities. The incentives for innovation suggested

by DHET will be observed by the DST, while the NRF rating system will be revised to detect any shortcomings in recognising productive innovators.

- *Fostering technopreneurs.* Investment in people is crucial to innovation and technological change. Often researchers do not possess the required skills to take new technologies to market. To overcome this challenge, the SA government intends fostering technopreneurs through entrepreneurship in curricula, establishing an enabling incentive milieu, and creating entrepreneurs-in-residence support programmes to assist in business development, licensing, and the formation of start-up companies.
- *Technical skills development.* During the move of an STI idea from conception to production, the skill set required shifts from scientists to technicians. A skills development programme for both researchers and technical staff will be promoted in conjunction with DHET and other appropriate bodies, with a strong focus on entrepreneurial thinking.
- *A national policy for estimated changes in technology-driven employment relationships.* DST, DHET and the South African Department of Labour will consult businesses in commerce and industry to encourage movements in jobs over different sectors, and to limit the impact of possible job losses.
- *Harmonisation of funding instruments*. The SA landscape for funding research and development is complex, often requiring duplication of information in application requirements to the frustration of the inventor, and often leading to unnecessary additional costs. To sole this issue, funding mechanisms will be aligned to prevent duplication. The mandate of TIA will be expanded to possibly include the functions of NIPMO, SEDA, THRIP, SPII, and certain functions of both the IDC and the NRF.
- *Sovereign innovation fund*. With regard to technology commercialisation, an autonomous fund will be established to promote co-investment by the public sector and businesses in commerce and industry.

The National Development Plan (NDP) has elevated science, technology and innovation (STI) in government planning, and line departments must choose their research priorities informed by the NDP. The NDP recognises that research and scholarship are key functions of universities, and has set a number of human capital development targets, such as:

- Increasing university participation rate to 25% by 2030;
- increasing student throughput rates to 75% by 2030;

- increasing the proportion of postgraduate students of total student numbers (masters and PhDs) from 16% to 25% by 2030;
- doubling the number of science graduates, and increasing the number of African and women postgraduates;
- increasing the percentage of PhD-qualified academic staff to 75% by 2030 (from 39% in 2013), and
- producing 100 PhDs per million population per annum, or 5 000 PhDs per annum by 2030 (Republic of South Africa: Department of Science and Technology, 2017b).

The targets if reached or closely attained will no doubt contribute to increasing research intensiveness at SA universities. Research intensiveness can be described as an ever increasing degree in the extent of research activities being conducted. Cillins (2017) denotes *intensive* as a process illustrated by intensity thorough a profound concentrated or exhaustive effort that may be sustained to achieve results.

The Draft White Paper of 2017 also refers to the Bayh-Dole Act of 1980 in the USA, and highlights statistics indicating that the implementation of Bayh-Dole led to the creation of an estimated 300 TTOs, and the start of more than 10,000 spin-off companies, of which more than 4 000 were still active in 2012. Despite licensing revenues of US$28 billion in 2014, many authors quoted earlier in this study noted that a small percentage of USA TTOs are self-funded and need ongoing funding support to maintain their activities. This view is echoed by Mouton (2017) in reviewing the said Draft White Paper (RSA: DST, 2017b).

This section highlighted developments in S&T policy in SA from 1990 to 2010. The sections that follow elaborate on policy intervention initiatives by the SA government over the same period.

4.2.2 Institutional IP Policies

Universities across the United States adopted formal IP policies, as Bayh–Dole requires that patentable inventions and other IP must be disclosed to the university TTO tasked with facilitating the TT process. The role of a university TTO is fully discussed in section 4.7. The primary focus of a university TTO is to oversee the many kinds of agreements used to protect and manage the university's IP. The TTO often works closely with the legal department within the university on clauses and issues relating to IP in all research-related contracts.

Goldfarb and Henrekson (2003) assert that ownership of IPRs, when awarded to individual academics, creates disincentives for the university, as there is no profit sharing by the department of the academic staff member. As such, anti-entrepreneurial peer pressure can be the result when university departments do not share in the profits of commercialisation activities. According to Siegel *et al.* (2004), the TT process starts with an invention by a university academic as scientist in a laboratory. Disclosure of the invention is made to the TTO at the university in terms of its IP policy (Siegel *et al.*, 2004). The disclosure document starts the clock on the patent process and serves as evidence of the date of the invention and the identity of the inventors (Siegel *et al.*, 2004). The filing of an invention disclosure does not secure patent protection, and academic staff cannot openly discuss their research in the public domain in formal speech, a published article, or even in informal conversations (Siegel *et al.*, 2004).

Garduño (2004a) compiled a comparative analysis of SA university TT and found in 2003 that eight out of ten universities he surveyed had an IPR policy. Of these, five universities, namely UCT, SU, UP, North West University (NWU), and the Nelson Mandela Metropolitan University (NMMU), had policies of claiming ownership of IP created in the course and scope of their researchers' employment. These policies also required university inventors to disclose new inventions to their universities, which could then secure the right to license the inventions or dispose of it to third parties. Established formulas were used for benefit sharing of royalty income with academics as inventors. Rights to IP were assigned back to inventors where the university chose not to commercialise the technology (Garduño, 2004a).

Wolson (2007), like Garduño (2004a), notes that not all SA universities had IP policies by 2005, and that the policies that did exist were not homogeneous and varied widely. Unlike the universities mentioned above, the University of KwaZulu-Natal and Rhodes University had IPR policies where the IP rights remained with the academic staff member (Garduño, 2004a). The University of KwaZulu-Natal required disclosure of inventions and recovered any costs that were borne by the university in delivering the research results. In addition, this university received from 5% to 25% of the licensing income as payment for the use of the university's facilities in the creation of the invention. At Rhodes University, ownership of IPRs was also vested in the academic staff member, but the university claimed ownership if the inventor was on the non-academic staff list (Garduño, 2004a).

Businesses in commerce and industry, at the time, usually claimed full ownership of IP created from funding they provided to universities. Wolson (2007) claims, however, that SA universities should share in these IP rights to cover costs to the university that are not recovered in research contracts. Moreover, Reichelt (2007) maintains that universities must have trained TT professionals working in dedicated TTOs, which cannot operate without clear policies to protect and exploit IP developed by its academic staff. An IP policy helps to clear any doubts about the ownership of university-created IP, created by academic staff. University IP policies clearly state the incentives for academic staff who participate in the TT process, as well as the roles and responsibilities of all parties involved in the commercialisation process. Such policies need to be widely advertised among academic staff members on campus.

HESA (2007) reported that 60% of universities in SA had TT as part of their mission statements prior to the implementation of the IPR-PFRD Act, and that 80% of them had IPR policies. This act changed the disparate treatment of IP rights at SA universities permanently. The rights of academic staff, as the creators, to income generated by such IP are now specifically addressed in the act. Section 10 (2) of the act states that, as the creators of IP, academic staff, students and their heirs are entitled to at least 20% of the first R1million, and thereafter at least 30% of the net income derived from IP by the university.

Sibanda (2009) attests that the IPR-PFRD Act of 2008 was a policy intervention by DST, aimed at improving the output from university technology transfer in SA. The author advises that TTOs at SA universities prior to the Act were under-staffed, resulting in the low number of patents and the limited creation of sellable products.

NIPMO was tasked to help universities set up TTOs if they had not already done so (Sibanda, 2009), as all universities are now required to have both IP policies and dedicated TTOs. The SA government pursued an approach comparable to the Bayh-Dole Act in protecting IP generated from public funding, and revealed its commitment to this (Alessandrini *et al.*, 2013).

University IP policies incorporate a declaration of mission and aims. The main aim of IP policies is to demarcate the legal title and allocation of income earned via commercialisation efforts. Comparable to what Bayh-Dole accomplished for the USA, the SA IPR act caused most SA universities to create or amend IP policies that allocate IP rights in order to possess, consume and benefit financially from IP created by university staff (Bansi, 2016). Tension develops between academics as inventors and university management when income from commercialisation activities needs to be allotted. University IP polices must be compiled in a way that allocate the ownership of IP rights unambiguously, so that academic inventors and university management may settle differences cordially (Bansi, 2016).

All SA universities had to develop or amend their IPR policies after the enactment in 2010 of the IPR-PFRD Act of 2008 to comply with its provisions. Smaller universities within a region were allowed to jointly develop and implement an IPR policy, and to set up a single, regional TTO that is jointly controlled. The guidelines are set by the act and NIPMO has to monitor and evaluate the content of these IPR policies to ensure compliance to the act.

As reported in section 3.2.1, Canada adopted a different approach to Bayh–Dole by following a policy route rather than legislation. Its 1991 Policy on Title to Intellectual Property Arising under Crown Contracts (Government of Canada, 2015) acknowledged that the private sector in Canada was best placed to commercialise IP and allowed university researchers to own the IP they generate in the course of carrying out research contracts.

Trotter (2016) considers how the IP policies of HEI's as well as copyright law affects the rights of lecturers who develop teaching materials that are regarded as Open Educational Resources (OER). The capacity of academic staff at HEIs to develop and disseminate OER is based on having copyright over the study materials that they create. Mostly, lecturers of institutions do not own copyright over their teaching materials created in the ordinary course of their employment, and consequently they are not free to disclose their own teaching materials openly, due to the fact that they do not have the legal right to do so (Trotter, 2016).

Trotter and a fellow colleague named Glenda Cox examined academic staff at all SA public universities, and interestingly discovered that each university had varying positions on the ownership to copyright contained in their IP policies. At UCT, where they both work, academic staff own the copyright embodied in their academic notes and they are free to distribute it as open educational resources. They found that 5 (five) universities have IP policies that allocate copyright over academic content to academic staff. These universities are Nelson Mandela Metropolitan University (NMMU), Rhodes University, University of Cape Town (UCT), University of Limpopo, and the University of Venda (UniVen). The rest of the SA universities all claim ownership of the resultant copyright from teaching materials created by their academic staff (Trotter, 2016).

National law in SA sets the foundation for universities to own the copyright of works created by academic staff and many university IP policies indicate that section 21(1) (d) of the Copyright Act of 1978 justifies the university's privilege to copyright over academic content produced by their staff members in the ordinary course of their employment. The IP policies of some SA universities also point to the IPR-PFRD Act of 2008, which states that IP created by public funds must be detected, safeguarded, used, and commercialised for the benefit of all SA citizens (Trotter, 2016).

Read together, these two laws allocate to SA universities automatic copyright over academic content developed by teaching staff as part of their work. Negotiation to keep copyright of their works was the reason that the five universities mentioned above departed from the norm. Academic staff can request deviation from their university's IP policy in order to disseminate academic content as part of OER when their university's IP policy prevents them from doing so (Trotter, 2016).

Dr Andrew Bailey, IP manager at UCT, confirmed that UCT's IP policy indeed allows academic staff to retain ownership of academic content created by them (Bailey, 2017). However, the IP relating to academic content created by visiting scholars and academics belongs to UCT, unless a different arrangement has been agreed between the parties prior to the start of the visitors' tenure. In addition, Dr Bailey noted that UCT's IP policy also provides for an advisory committee on IP issues that is not standard practise in accordance with the IPR-PFRD Act.

The SA government, in conjunction with international partners and businesses in commerce and industry, will continue to purposefully cultivate research-intensive universities with an emphasis on HEIs and UoTs (Republic of South Africa: Department of Science and Technology, 2017b). The institutional IP policies of HEIs and UoTs, although adhering to the IPR-PFRD Act of 2008, must promote this aim of developing research-intensive universities and not discourage researchers from creating new IP.

This section has indicated that the IP policies of SA universities mostly agree and are expected to agree on and include the regulations set by the IPR-PFRD Act of 2008, which was enacted in 2010. It is evident that all SA universities now comply, although their IP policies differ from each other regarding certain aspects, as illustrated by the issue relating with copyright on the academic content generated by university staff members. The next section deliberates on the funding environment affecting and pertaining to university TT in SA.

4.3 Institutional commitment towards TT

Powers (2004), investigating the effect of R&D resources on university licensing to SMMEs and larger businesses, raises the important question: What is stimulating universities to be more entrepreneurial? He concludes that to promote involvement by academic staff in commercialisation activities, university institutional culture needs to actively encourage entrepreneurship and reflect strong institutional commitment from top management at all levels.

Commitment from university top management thus seems to be the starting point in cultivating an entrepreneurial spirit and institutional commitment that is conducive to successful university TT. The rector of a university is often responsible for creating an organisational culture and an institutional commitment that fosters TT (Siegel *et al.*, 2004). Such an institutional commitment is one that is likely to place a strong emphasis on developing relationships between academics, entrepreneurs, businesses in commerce and industry and industry scientists. In the United Kingdom, for example, there has been a notable positive change in the institutional commitment of universities towards commercialisation in the decade leading up to 2004 (Davis, 2005). Davis (2005) contends that this attitude of university vice-chancellors is the key to successful TT at academic institutions. The type of university does not matter, according to Davis (2005). What matters are those at the top, he asserts and whether or not they truly believe in entrepreneurship and are willing to commit time, effort and the resources of the institution to it.

Since 2004, many SA universities have been attracted to the benefits that commercialisation of IP could provide in generating a third income stream, or at least recovering the costs incurred in running a TTO (Kruss, 2008). As Alessandrini *et al.* (2013) claim, support from university top management is crucial to the success of any TT initiative. This was especially true for SA universities prior to implementation of the IPR-PFRD Act. Since 2010, SA universities have been compelled to comply with the IPR-PFRD Act and to operate a dedicated TTO to manage the technology transfer process.

The National Intellectual Property Management Office (NIPMO) was tasked with assisting in the setting up of TTOs and providing training to university staff members to operate it. Prior to the IPR-PFRD Act, it was left to SA universities' central management to start TTOs for commercialising IP emanating from their campuses. SA universities that started TTOs as early as 1999 (Stellenbosch University and the University of Cape Town) are reaping the benefits of having a longer pipeline of disclosures and patents that are closer to being ready for commercialisation. The survey by Alessandrini *et al.* (2013) highlighted a short pipeline as an impediment to effective university TT.

Thus, much of the success of any university TT programme can be attributed to the institutional commitment demonstrated by senior management within universities, such as the Dean of Research or an academic department head or director. Considerable examples from the literature confirm the effect of university top management on TT efforts. Studies by Tornatzky *et al.* (2002) and Henton *et al.* (2002), for example, contend that the University of California at San Diego (UCSD) has had dynamic and imaginative leaders during its history, who contributed to growth and achievement. Both sets of authors found that the institutional commitment at San Diego is well established and mutually reinforcing, due to a number of early successes, which attracted academic staff to join the university and who were and still are positively orientated towards entrepreneurship. Henton *et al.* (2002) argue that the commitment displayed by top management at universities such as San Diego, Austin and San Francisco, makes the difference between successful regions and others that have not been as successful.

The commitment exerted by top management of universities stems from national policies and the landscape for technology transfer activities that are created by national institutions and their programmes and initiatives that have been established to facilitate and promote TT. Some of the institutions created includes the National Advisory Council on Innovation (NACI) and the National Research Foundation (NRF) that included the Technology and Human Resources for Industry Programme (THRIP) and the Innovation Fund (IF). Other units launched since the enactment of the IPR-PFRD Act of 2008 is the National Intellectual Property Management Office (NIPMO) and the Technology Innovation Agency (TIA).

4.3.1 National institutions in SA

One of the initiatives proposed by the White Paper on S&T (1996) in SA was the creation of the *National Advisory Council on Innovation* (NACI). The role of NACI is to advise the Department of Arts, Culture, Science and Technology (DACST) and the Minister of S&T on matters relating to the National System of Innovation (NSI) (Republic of South Africa, 1996). In 2003, a study on the utilisation of research outputs by NACI found that research driven largely by curiosity has the lowest levels of reported utilisation (54%) compared to applied research (70%). The study lists the following limiting factors of technology transfer activities in SA:

- the lack of appropriately skilled human resources
- declining or inadequate capacity in universities and science councils
- the lack of certain equipment and facilities
- inadequate sources of knowledge or information
- the secrecy around intellectual property (This factor has since been largely addressed by the new IPR-PFRD Act of 2008 which is discussed in section 4.3.3.)
- inadequate government incentives, resources and support (This factor has also since been addressed by the IPR-PFRD Act which established the National Intellectual Property Management Office [NIPMO])
- the conflicting agendas of industry and academia in the context of R&D collaboration and outsourcing
- limited or stagnating local markets (National Advisory Council on Innovation (NACI), 2003: 28)

Factors promoting R&D were also highlighted by the NACI study and respondents to the study reported on a range of positive factors, including:

- adequate financial, human and knowledge resources,
- organisations geared towards innovation and R&D, and
- good human resources management.

The Republic of South Africa: Department of Trade and Industry (2017) reports that NACI will be changed to serve as the national institution of science and technology information (STI) in SA and be tasked with:

- monitoring and evaluating STI and performing STI projections to better equip the government's planning on STI holistically;
- maintaining the current data collection role for innovation and R&D surveys and broadening it to more surveys where needed;
- establishing a national STI portal to improve the examination of NSI operations, where the expertise of a number of leading centres will be used to share data and add value to the portal such as DHET's Higher Education Information Management System, the Centre for STI Indicators, the centres of excellence, the Centre for Research on Evaluation, Science and Technology, and the Institute for Economic Research on Innovation;
- reducing the reporting and compliance burden for monitoring and evaluation (M&E) for other government units, whilst increasing the value obtained from it, while government will monitor how NSI actors are using the M&E information to shape their policy responses and change their planning; and
- training and allocating a number of M&E specialists in government (RSA: DTI, 2017).

The National Research Foundation (NRF) was created through the enactment of the NRF Act No 23 of 1998 to unify a number of separate funds. Its directive was to focus on basic and strategic research in line with the national priorities of SA. The NRF is instructed to fund research, do human resource development, and finance important research infrastructure in order to provide facilities that foster the creation of knowledge and which stimulates innovation in S&T in SA. The aim of the NRF is to produce new funding vehicles, promote research occupations, grow public commitment towards science, and create cutting-edge research programs that will renovate the scientific environment in SA and motivate researchers to become as good as anyone in the world. The NRF advances the importance of SA research in the country and around the world (National Research Foundation (NRF), 2017).

The NRF stresses its role within its strategic plan towards 2020 as implementing agent of policies inside the National System of Innovation (NSI). The said strategic plan of the NRF is centred on four pillars, namely “Transformation, Excellence, Service Culture and Sustainability” (NRF, 2017). The NRF was entrusted by DST to enhance and facilitate innovation in SA and to manage several initiatives, such as *The Technology and Human Resources for Industry Programme* (THRIP) and the Innovation Fund (IF).

THRIP is a good example of a funding programme in SA. Managed by the NRF, the programme promotes collaboration in research on science, engineering and technology for universities, while addressing the technology and human resources needs of businesses in commerce and industry in SA. In its early years, historically white universities were the major beneficiaries of THRIP, but the balance of funding has shifted steadily towards science, engineering and technology institutions, historically black universities, and universities of technology (UoT) (known as technikons prior to 2004).

THRIP offers two services to its stakeholders, namely network brokerage and funding support. Network brokerage entails facilitating linkages between researchers at universities and science councils with industrial managers. These linkages often lead to collaboration for productive and innovative applied research (National Research Foundation (NRF), 2004). THRIP identified the following transformational priorities:

- to facilitate an increase in the number of female and black students who intend to pursue technological and engineering careers;
- to promote technological know-how within the small, medium and micro enterprise (SMME) sector, through the deployment of skills vested in HEIs and SETIs; and
- to facilitate and support multi-firm projects in which firms collaborate and share in the project outcomes (National Research Foundation (NRF), 2004:33).

Despite tough economic conditions, the SA government has continued to increase its funding for the THRIP programme (Reichelt, 2007). Reichelt (2007) claims that THRIP effectively removes the risk of the cost of development of new technologies for universities by sharing it with commerce and industry. The mission of THRIP is to leverage partnerships for research in science, engineering and technology through cost-sharing, in order to provide new technologies and to produce highly skilled researchers and technology managers (THRIP & National Research Foundation (NRF), 2013). The following objectives are included in a list of objectives noted by the NRF in fulfilling its mission for the THRIP programme:

- to help increase the quantity and quality of people with appropriate skills in the development and management of research-based technology;
- to promote increased interaction and mobility among academic staff at universities, technology managers in commerce and industry, and science, engineering and technology institutions (SETIs), with the aim of developing skills for product development and technology transfer;
- to stimulate industry and government to increase investment in R&D, technology diffusion, and the promotion of innovation; and
- to foster the social and economic upliftment of all South Africans (THRIP & NRF, 2013).

Each year the programme leverages millions of rands towards R&D funding in SA. Funding is provided by the Department of Trade and Industry (DTI), while matching funds come from local and international business partners in commerce and industry. Effectively, the cost and risk of developing new technology is shared between DTI and a matching funder on a 50:50 cost sharing ratio, up to a maximum of R8m per annum (Republic of South Africa: DTI, 2017). THRIP was thus introduced by the NRF as an enabling instrument to promote TT and research collaboration between universities and industry.

The Innovation Fund (incorporated into the Technology Innovation Agency (TIA)) was set up in 1998 to act as a funding agency in support of researchers at SA universities. The strategy of the fund was to create a seamless funding arena that “crosses disciplinary divides, supports young academics to become top-class researchers, and funds exploration from basic research to technology development” (National Research Foundation (NRF), 2004:8). The Innovation Fund Commercialisation Office (IFCO) was formed within the IF to support university TT and IP commercialisation. IFCO's role was to assist in structuring deals, planning a path to market IP, and performing financial due diligence exercises on new and novel university technologies. The IF was primarily tasked with implementing the National R&D Strategy (Wolson, 2007) and was designed to assist in the early-stage development of technologies, not to fund later stages of growth and development. Wolson (2007) reveals that the IF assisted in capacity building by co-hosting a number of training courses for technology transfer managers, aimed at the training of professionals for the exploitation of IP. Kruss (2008) maintains that both THRIP and the IF were aimed at promoting "multi-institutional" and "multi-sectoral" transfer of technological knowledge.

After this brief summary of a number of national institutions in support of technology transfer activities at SA universities, the National Intellectual Property Management Office (NIPMO) and the Technology Innovation Agency (TIA) established after the promulgation and enactment of the IPR-PFRD Act of 2008, is explored.

4.3.2 The National Intellectual Property Management Office (NIPMO)

Established in 2011 in terms of the IPR-PFRD Act as a unit within DST, the National Intellectual Property Management Office (NIPMO) must oversee the implementation of the IPR-PFRD Act in SA. DST (Republic of South Africa: Department of Science and Technology, 2012a) issued a guideline on 12 December 2012 on the interpretation of the scope of the IPR-PFRD Act of 2008. In terms of the guideline, THRIP funding is deemed to be a source of public funding and, as a result, any recipient of THRIP funding must comply with the provisions of the IPR-PFRD Act and report to NIPMO. Similarly, recipients of the Support Program for Industrial Innovation (SPII), which is managed by the Industrial Development Corporation (IDC), must also comply with the IPR-PFRD Act, as it too allocates public funds towards R&D. However, scholarships and bursaries are excluded and not considered to be public funding in terms of the IPR-PFRD Act.

NIPMO is founded as a focussed service delivery unit within DST. The unit not only monitors compliance and reviews and ensures enforcement of the Act, but also provides administrative support to universities on behalf of the SA government. In this regard, NIPMO is an interface between the public and private sector on a number of R&D issues, as well as IP management and commercialisation (National Intellectual Property Management Office (NIPMO), 2013).

Importantly, NIPMO must ensure that it has the capacity to deal with IP referred to it by SA universities in order to

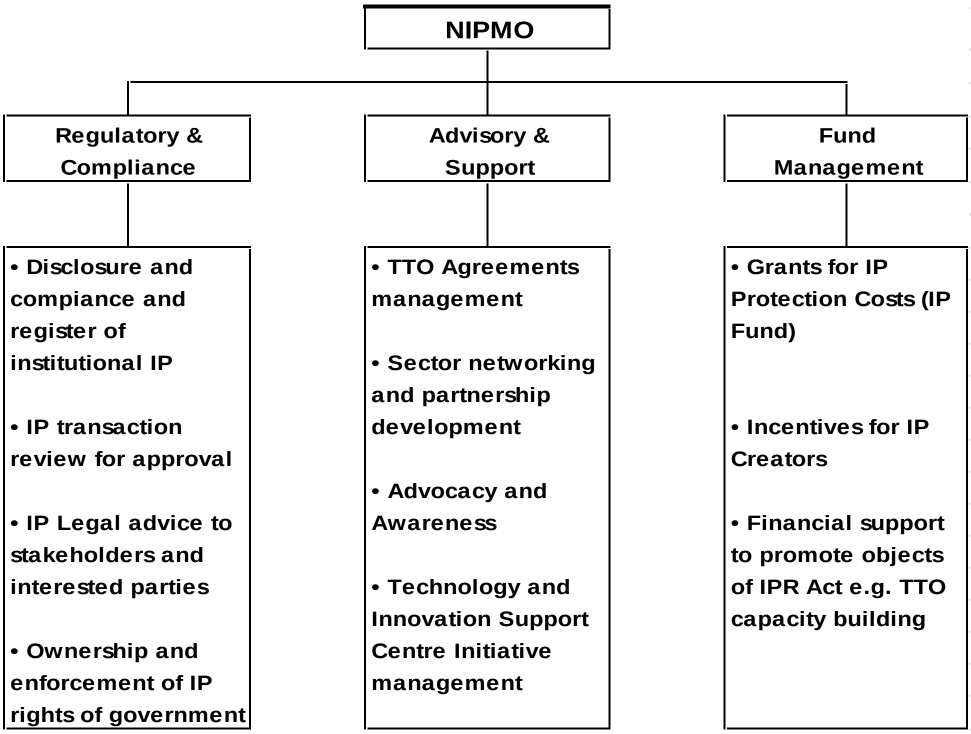
- acquire statutory protection for the IP (where appropriate),
- advance the aims of the APR-PFRD Act,
- conclude intellectual property transactions, and
- fully commercialise the said intellectual property referred to it (NIPMO, 2013).

NIPMO also has administrative duties, and the Act compels NIPMO to

- manage information regarding IP and related data received from universities,
- grant incentives to universities and academic staff at universities for their efforts in securing and successfully commercialising their IP,
- offer assistance to universities with the setting up of their TTOs and help with particular transactions in the commercialisation process,
- impart standards and best practices in consultation with universities,
- develop directives for transactions involving foreign businesses, and
- monitor, assess, and reconsider the duties of universities (NIPMO, 2013).

Section 13 of the Act makes provision for the establishment of an IP Fund. The fund started as a merger of the Patent Incentive Fund and the Patent Support Fund. The rationale for the creation of the fund was to offer financial assistance to universities for the safeguarding of IP rights as determined by NIPMO. The fund was intended to provide NIPMO with funding to secure IP rights on inventions received from universities that choose not to protect it (NIPMO, 2013). NIPMO consists of three directorates guiding its roles and responsibilities, illustrated in Table 4.1 below.

TABLE 4.1: NIPMO DIRECTORATES



The establishment of NIPMO is an indication of the commitment by the SA government to promote innovation as envisaged by the Act (Alessandrini *et al.*, 2013). Alessandrini *et al.* (2013) believe that the enactment of the IPR-PFRD Act and the establishment of NIPMO signal a landmark era for innovation at SA universities.

4.3.3 The Technology Innovation Agency (TIA)

Based on the Technology Innovation Agency Act No 26 of 2008, TIA was established with the broad aims of assisting the SA government in promoting technological innovation in SA; providing financial aid for the development of innovations, supervision of technological innovation, incubation, and for building capacity for the commercialisation of IP emanating from publicly financed research. The agency is involved in basic scientific research, and identifies and evaluates new technologies through the funding of research activities. The agency also promotes and facilitates venture capital (VC) investments into new technology based companies in SA (Naidoo, 2009).

TIA was established by DST as part of a ten-year innovation plan that appeared shortly after the 2007 OECD review. TIA consolidates various funding mechanisms and prevents the fragmentation of R&D funding by the SA government (Republic of South Africa: Department of Science and Technology, 2007). TIA provides both financial and non-financial support and resources to individual entrepreneurs, universities, and science councils in SA to commercialise their inventions. Its role is to promote partnerships, both locally and abroad, that would benefit the development of IP, scarce human resources, and investment opportunities in local R&D (DST, 2007).

Since the amalgamation of the seven entities of DST, TIA has helped to start a network of public research institutions that focus on marketing and commercialisation activities shared by businesses in commerce and industry and universities. Four of the seven agencies are the four Biotechnology Regional Innovation Centres (BRICs), namely Cape Biotech Trust, PlantBio Trust, LIFElab, and BioPAD Trust. The other three agencies are the Innovation Fund, the Tshumisano Trust, and the Advanced Manufacturing Technology Strategy (AMTS) (Technology Innovation Agency (TIA), 2013a).

The establishment of TIA and NIPMO and the passage of the IPR-PFRD Act are some of the major public policy initiatives that resulted from the publication of the 2007 OECD review of innovation policy in SA. The review by OECD (Organisation for Economic Co-operation and Development (OECD), 2007) highlighted scarce human resources as a major obstacle to developing a knowledge-based economy in SA.

The function of TIA is not to be involved with basic scientific research, but to identify and evaluate new technologies through funding applied research activities. It must also promote joint R&D efforts and support commercialisation services for current and evolving industries (Naidoo, 2009). By considering SA's national context and the international lessons learnt, the more specific main objectives of the TIA are to

- provide the link between the recognised knowledge base and the actual economy;
- encourage the progress of technology-based products and services;
- promote the founding of technology-based businesses;

- grow a meaningful technology foundation for SA;
- offer an IP protection support platform;
- solicit investment through VC and Foreign Direct Investment (FDI); and
- promote the development of human resources for innovation (Naidoo, 2009).

Kahn (2013), however, is cynical when noting that the establishment of TIA was not a new initiative, as it merely represents an institutional reshuffle. According to the author, the resettlement of government departments in SA appears to be a recurring characteristic of the innovation system within the country.

Nonetheless, TIA is required to have an organisational examination every five years. The first review of TIA was developmental and formative and considered the rigour for the purpose of the operations of TIA, as well as the fitness-for-purpose of TIA within the NSI. The review panel for conducting an external institutional review was appointed in 2012. The purpose of this review of TIA was to consider whether the organisational structures, policies and programmes of the agency are suitable for its purpose. The review evaluated the following aspects of TIA:

- support for the early commercialisation of ideas and challenges that were faced in moving ideas to full commercialisation;
- contribution in assisting universities and publicly-funded research institutions to develop a culture that promotes commercialisation of IP;
- investment in decision-making processes, as well as the sufficiency and efficacy of its performance monitoring systems; and
- success in amalgamating a number of entities/programmes allocated to the TIA on its establishment (Technology Innovation Agency (TIA), 2013b).

The reach of TIA since 2010 has been impressive. The annual financial report of TIA for the financial year 2013/2014 states that the agency has continued to deliver on its mandate of promoting and enhancing the knowledge economy in SA since its inception. From 2010 to 2014, the cumulative performance of TIA reflected that R1.2 billion was contributed towards funding various projects, contracts and grants (Technology Innovation Agency (TIA), 2014). More than 6,800 SMMEs were assisted through the Technology Stations Programme, whilst 98 new products, processes, and services were created from funded projects. A total of R563, 9 million worth of funding was leveraged from businesses in commerce and industry. Moreover, internships numbering 501 were undertaken by individuals in various training programmes over the period under review (Technology Innovation Agency (TIA), 2014).

It seems, therefore, that TIA is playing a significant role in technological innovation and building capacity for the commercialisation of IP emanating from publicly financed research in SA. An external institutional review found that the basic function of TIA comprises a publicly funded entity which guarantees that the national system of innovation is working at maximum proficiency. The scope of activities of TIA covers the whole innovation value-chain, from the beginning stages of innovative ideas emanating from R&D to the full commercialisation stage.

4.3.4 The role of the SARIMA in building capacity and training of TT professionals

The Southern African Research and Innovation Management Association (SARIMA) focuses on the training of technology transfer professionals and promotes the level of understanding of technology transfer issues in SA and throughout Southern Africa. Many SA universities have benefitted from this association (Garduño, 2004a).

The Intellectual Property Rights from the Publicly Financed Research Framework (IPR-PFRD Framework) notes the importance of an obligation to educate, train, and build capacity in SA. As the authors of the framework maintain, an increase in IP outputs will only be achieved if the NSI is also strengthened by appropriately skilled human resources. Wolson (2007) correctly observes that SARIMA provides a forum for individuals from universities, government, and businesses in commerce and industry, who are all interested in the management of research and innovation.

SARIMA was formed at a meeting of the Research Directors Forum (RDF) in 2001 and seeks to address the specific issue of human capital development, raised in the IPR-PFRD Framework, through its workshops on capacity building. The RDF was initiated in 1997 by Prof Johann Mouton, director of the Centre for Research on Evaluation, Science and Technology (CREST) at Stellenbosch University. Other participants to the meeting were Dr Tony Heher (University of Cape Town), Dr Tony Bunn (Medical Research Council), and Mr Johan Hattingh (University of Pretoria/CSIR). At inception, the founders adopted its slogan, “Waving research into the fabric of society”. SARIMA is unequivocally a leading Southern African association, and extends to international borders of countries within the Southern African Development Community [SADC] (Southern African Research and Innovation Management Association (SARIMA), 2012).

As a non-profit organisation, SARIMA is funded by grants; research projects; and members, conference and training fees. Membership of SARIMA grew from 71 in 2005 to 334 by 2012. The organisation is also financially supported by DST, although in its early years of operation seed funding was also received from the United States Agency for International Development (USAID) and the Association of Commonwealth Universities (ACU) (SARIMA, 2012).

SARIMA has set up several portfolios, one of which focuses primarily on innovation and technology transfer (I&TT). This portfolio committee is responsible for activities relating to technology transfer, innovation, and the management of IP, and has concentrated its efforts on capacity building for IP management and the technology transfer function within public research institutions, such as universities.

Through the I&TT portfolio committee, SARIMA was involved in the Intellectual Capital Forum (ICF) held in June 2003, and made a significant contribution to discussions leading up to the development of the IPR-PFRD Framework, released in 2006, and the resultant Intellectual Property Rights from Publicly Financed Research and Development Act 51 of 2008 (IPR-PFRD Act). The committee also facilitated networking events and the sharing of experiences between technology transfer professionals in SA (Southern African Research and Innovation Management Association (SARIMA), 2012).

SARIMA has since refocused its efforts into three areas, namely research management, innovation and technology transfer, and engagement in Africa. The strategic objectives and planned activities of the research management focus area include networking and partnerships, advocacy and awareness of issues relating to research and innovation. A specific effort on Africa is planned to strengthen research management on the continent, whilst financial sustainability is listed as a crucial element in reaching more achievements and supporting growth in the future (Southern African Research & Innovation Management Association (SARIMA), 2017).

SARIMA's role in SA is not to be underestimated, as it played an important role in raising awareness of the need for well-trained university technology transfer managers at SA universities. Being part of the network of non-profit organisations in SA that promotes technology transfer, SARIMA contributes to the overall enabling environment for university technology transfer. An enabling environment is inclusive and comprises many role players, such as the government, universities, science councils, technology developers, and businesses in commerce and industry.

4.3.5 Centre for Science, Technology and Innovation Indicators (CESTii) survey of TT in SA

The SA National Survey of IP and TT at Publicly Funded Research Institutions (2008 to 2014) was the initial standard survey. The survey was undertaken as a project of SARIMA, NIPMO and DST, with project implementation by the Centre for Science, Technology and Innovation Indicators (CESTii) at the Human Sciences Research Council (HSRC).

Fieldwork for the baseline survey project started in April 2015 and ended in November 2015. The survey gathered information from a seven-year period, 2008 to 2014. The aim of the project was to set an initial starting point of statistical data of TTOs in SA, their performance at public research institutions, and the type of results that emanate from technology transfer efforts (Republic of South Africa: Department of Science and Technology, National Intellectual Property Management Office (NIPMO), Human Sciences Research Council (HSRC), Centre for Science Technology and Innovation Indicators (CeSTII) & Southern African Research and Innovation Management Association (SARIMA), 2017). The survey offers information to the SA government and its role-players about the effects of the enactment of the IPR-PFRD Act. The range of the survey comprised 33 institutions, including the 23 higher education institutions and 10 Schedule 1 institutions denoted as science councils.

The questionnaire used in the survey was designed to measure a bold set of parameters (RSA: DST *et al.*, 2017). These parameters were based on surveys undertook in other countries, whilst incorporating SA specific contextual issues, for instance gauging current capability and capacity to perform TT activities. Notably and important for this study, RSA: DST *et al.* (2017) list the following inhibiting factors noted by participants in their survey: (1) low awareness amongst research staff of the value of disclosing and managing IP; (2) lack of funding to expand TT activities; (3) shortage of funding for IP registration costs, and (4) insufficient access to specialist resources.

Inputs used by RSA: DST *et al.* (2017) in their study comprised human resources (capability, scope, talents, experience and qualifications), R&D expenditure, TTO running expenses, legal expenses, seed funding provided for projects managed by the TTO, and the management structure of TT functions. The TTO activities considered in the survey were IP management and other commercialisation efforts. The output and outcomes of TT activities gauged were proceeds from protected IP, such as patents and license agreements; licensing income; outright sale of IP; and spin-out companies formed.

The outcome of the survey indicates that the policy changes and new IPR legislation in SA has had the desired effect of increasing the disclosure rates of new inventions emanating from publicly financed research activities. The mandatory establishment of TTOs (more fully discussed in section 4.7) at HEIs in SA also positively impacted on the conversion rate of successfully commercialised technologies. The support from funding vehicles and government agencies such as NIPMO, THRIP and TIA seems crucially important in contributing to the increased success rate of the commercialisation of new technologies emanating from publicly financed research activities. Results from the survey clearly suggest that the commitment from the SA government in providing appropriate legislation through the IPR-PFRD Act, strengthening funding for IP protection and commercialisation, as well as financing increased human capacity resources at TTOs, has had a positive impact on the TT industry in SA.

The next sections depict the legislative, policy, funding and human resources environments as dimensions of university TT, derived from the conceptual analysis in Chapter 3.

4.4 The legislative environment for TT at universities

The protection of IP has influenced international trade in an increasing manner. The Paris Convention was signed in 1883 (World Intellectual Property Organization (WIPO), 1883) and dealt with three issues:

- Firstly, contracting countries to the Paris Convention must provide the same protection to citizens of other countries as it would to its own citizens for IP created by them.

- Secondly, the right of priority means that contracting countries may apply for protection of patents (within 12 months) and trademarks and industrial design (within 6 months) in any other contracting country.
- Thirdly, common rules state that patents and trademarks granted in one contracting country are independent from its registration in another contracting country (WIPO, 1883).

Since 1947, the General Agreement on Tariffs and Trade (GATT) has regulated international free trade. Until the mid-1980s, GATT was not directly concerned with IP issues, but since then it has become clear that an agreement on IP was necessary, as differences in the treatment of IP were becoming a source of conflict between countries. The result was an agreement called the Trade Related Aspects of Intellectual Property Rights (referred to as the TRIPS Agreement) that was signed on 15 April 1994 (Lehman, 2001). TRIPS is administered by the World Trade Organisation (WTO) and sets out minimum standards of IP protection for all member countries of the WTO (Lehman, 2001). Article 67 of TRIPS requires that the United States and other developed countries provide technical and financial assistance to help developing countries build modern IP systems, as the World Intellectual Property Organisation (WIPO) wants to level the playing fields and make trade easier between member countries (Lehman, 2001).

During the 1940s and 1950s, debates around the assignments of patents emanating from research paid for by public funds largely ignored universities in the United States (Bremer, 2001). However, since 1968, Institutional Patent Agreements (IPAs) were established by the Department of Health, Education and Welfare, as well as the National Science Foundation (NSF) in the United States. These IPAs gave universities the right to retain the titles of patents arising from using public funds (Bremer, 2001).

The most well developed and explicit example of how a piece of legislation has affected the legislative environment for technology transfer is the case of the Bayh–Dole Act in the United States discussed in the next section.

4.4.1 The USA Bayh–Dole Act of 1980.

Enacted on 12 December 1980, Public Law 96-517, the Patent and Trademark Law Amendment Act of 1980 (commonly known as the Bayh–Dole Act of 1980) resulted in a uniform patent policy among the many federal agencies that funded research in the United States (Congress of the United States of America, 1980). Bayh–Dole enabled small businesses and non-profit organisations, including universities, to retain title to new inventions that emanated from federally funded research. This legislation was co-sponsored by Senators Birch Bayh and Robert Dole at the time. The major aims of Bayh–Dole were to:

- enable non-profit organisations, including universities, and small businesses to elect to retain title to inventions developed with federal funds;
- encourage universities to collaborate with businesses in commerce and industry and to promote the utilisation of inventions arising from federal funding;
- enable universities to file patents on inventions they elect to own (they were expected to do so);
- enable universities to engage in licensing activities, as universities are expected to give preference to license agreements with small business enterprises;
- enable universities to participate fully in all aspects of TT activities; and
- share the proceeds from the commercialisation of intellectual property with their academic staff as inventors (Congress of the United States of America, 1980).

The Bayh–Dole Act has been credited with creating the biotechnology industry. However, critics such as Bremer (2001) as well as Arno and Davis (2002) signal that excessive patenting of research results by universities delays the publication of these results. This has increased conflicts of interest for academic researchers, and is an unintended consequence of the Bayh–Dole Act.

Additional shifts in United States policy towards stronger protection of IPRs supported Bayh–Dole at the time and contributed to an upsurge in patent applications from US universities during the early 1980s (Mowery *et al.*, 2001). Of these policies, the establishment of the US Court of Appeals under Chief Judge Howard Markey in 1982 was instrumental (Mowery *et al.*, 2001). In 1982, this Court has upheld patent rights in approximately 80% of the cases argued before it, compared to 30% prior to 1980 (Katz & Ordover, 1990). Empirical evidence provided by Henderson *et al.* (1998) supports the view that, in addition to Bayh–Dole, changes in federal law (such as the Stevenson–Wydler Act of 1980) increased industry funding towards university R&D and the establishment of university TTOs. The result was a sharp increase in the number of patents owned by universities (Katz & Ordover, 1990; Mowery *et al.*, 2001).

Furthermore, prior to Bayh–Dole, there was no national policy in the United States dealing with the ownership of university inventions developed by using government funding (Bremer, 2001). Federal agencies rarely licensed inventions exclusively, trying to make them available as widely as possible. This left the inventors completely out of the commercialisation process. As a result, the federal government held title to approximately 28 000 patents before 1980, of which less than 5% were licensed to businesses in commerce and industry (Bremer, 2001). This situation changed significantly after the enactment of Bayh–Dole, as many universities started to manage their own patents and licensing activities after its enactment (Bremer, 2001).

Mowery *et al.* (2001) conclude that several factors stimulated the upsurge in patenting and licensing at US universities. Of these factors, the increase in importance of biotechnology as a productive field of research and the tightening of IPRs, which elevated the economic value of patents, had the biggest effect, according to these authors. Mowery *et al.* (2001) further attest that increased federal funding for biomedical research and the passing of a series of laws by the US Congress in addition to Bayh–Dole, led to intensified efforts by universities to commercialise their IP assets.

Still, the question remains whether Bayh–Dole led to numerous new inventions that might otherwise not have been made. Supporters of Bayh–Dole (Jensen & Thursby, 2001; Mowery *et al.*, 2001) argue that patenting of university inventions and the consequent licensing thereof increases the rate of commercialisation, as industry has better information available on new inventions through the efforts of university TTOs. Under Bayh–Dole, the US Congress determined that private ownership of inventions, motivated by financial gain, would lead to more effective commercialisation of federally funded research through technology transfer (Bremer, 2001; Mowery *et al.*, 2001).

Conversely, critics such as Bremer's (2001) as well as Arno and Davis (2002) argue that exclusive licenses are not needed for technology transfer and that university administrators and academic staff are shifting research to chase profits. Critics are also of the view that the increase in patenting activity involves low-quality patents and that incentives are not needed for the commercialisation of high-quality patents and inventions. They further argue that involvement by academic staff in the commercialisation activities may divert their attention from more basic research and teaching (Jensen & Thursby, 2001).

Evidence presented by Mowery *et al.* (2001) in comparing three universities, namely Columbia University, the University of California, and Stanford University, also suggests that Bayh–Dole itself had little effect on the content of academic research and that university research shifted independently of Bayh–Dole. Bremer (2001:1) refers to the "dichotomy on disposition of rights to inventions and the lack of understanding of the operation and contribution of the patent system to the benefit of the public". Arno and Davis (2002) echo Bremer's (2001) sentiments, and as example note that Bayh–Dole is not enforced by the US government when it comes to providing new drugs produced with the help of federal funds. The production of these drugs are said to lead to huge profits for pharmaceutical manufacturers, while the public, who have contributed to its invention through paying taxes, finally pay twice for it. Arno and Davis (2002) further attest that, although Bayh–Dole maintains that new drugs invented wholly or in part with federal funds should be made available to the public at reasonable prices, the prices of prescription drugs are increasing steadily and pharmaceutical companies succeed in using Bayh–Dole to gain unfair prices for their products.

Yet, the effects of the implementation of Bayh–Dole in the United States have been considerable in terms of increasing the growth of patenting and licensing of federally funded university developed technologies (Goldfarb & Henrekson, 2003). Inventions disclosed increased by 84%, new patent applications by 238%, license agreements concluded by 161%, and royalty income by 520% in real terms of the 84 US universities responding to the AUTM surveys from 1991 to 2000 (Thursby & Thursby, 2003). Since 1980, 4 320 new companies have been started based on a license from universities, of which 450 companies were formed in 2002 (Association of University Technology Managers (AUTM), 2003). Of these spin-out companies, 2 741 were still operating at the end of 2002 (AUTM, 2003). According to annual surveys conducted by AUTM, US universities had more than 26 000 active licenses, while gross licensing income was $1.267 billion, as reported by 218 institutions during the fiscal year 2002. Hence, these figures support the notion that university technology transfer in the United States dramatically improved under Bayh–Dole.

Shane (2004) examined the share of patents from US universities, from 1969 through 1996, and across 117 lines of businesses. In addition to the above mentioned findings by Mowery *et al.* (2001), Shane argues that Bayh–Dole led to a shift in university patenting towards fields in which licensing is an effective mechanism for acquiring new technical knowledge:

> Because universities exploit their inventions primarily through the licensing of technology … the incentive to become more commercially focused led universities to concentrate their patenting in fields in which knowledge is transferred effectively through licensing (Shane, 2004:128).

However, Mowery (2004) asserts that many of the patent holders who were most active after 1980 were already patenting inventions from government-funded research in the period between 1970 and 1980. He claims, therefore, that the effects of Bayh–Dole are overstated, and the credit given to it over-emphasised. Mowery (2004) consequently advocates for open partnerships, the free sharing of information, and royalty-free licensing and believes that this will ensure a broader dissemination of university inventions into society.

Bayh *et al*, (2004), on the other hand, lists several factors which contributed to the success of Bayh–Dole and the transfer of technology under it, namely that

- there was continued support for basic research by the federal government;
- ownership of inventions was held by universities and not by government;
- the academic staff as inventors remained in the picture and stood to gain personally from their inventions; and
- there was uniformity in treating intellectual property rights generated with federal funds, irrespective of which federal agency supplied the funding.

Bayh *et al*, (2004) further argues that the success of the implementation of Bayh–Dole was achieved without cost to the taxpayer, whilst the estimated economic benefits being added to the US economy were many billions of dollars. Bayh *et al*, (2004) concurs with Siegel *et al.* (2004) on economic development, and claims that the partnership between academia and businesses in commerce and industry in the United States has seen technology transfer from US universities to industry contributing $38 billion in 1999, creating over 300 000 jobs and forming hundreds of new spin-out companies. In terms of Bayh–Dole, the US government also retained a non-exclusive license to practice the patent throughout the world and march-in rights to intervene if no or little effort is being made to commercialise a particular technology. Proponents of Bayh–Dole, like Garduño (2004b), argue that many results from federally funded research would have remained idle in university laboratories in the absence of Bayh–Dole.

Still, results from work performed by Dai *et al.* (2005) confirm that, although Bayh–Dole led to increased patenting by universities in the United States between 1982 and 1997, it did not lead to increased research activity at universities. Dai *et al.* (2005) therefore maintain that Bayh–Dole succeeded to increase university technology transfer, but has not led to increased funding by the US government for applied research.

However, Bayh–Dole accomplished two goals in awarding property rights to universities. Firstly, it encouraged hundreds of universities in the United States to establish TTOs, thereby relieving inventors from having to develop legal and business expertise themselves. Secondly, inventors could avoid the risks relating to the costs of patenting, marketing, and licensing, as these were now incurred by the university TTOs (Sampat, 2006).

Shane and Somaya (2007) considered the effects of patent litigation on the licensing efforts of US universities. The authors claim that patent litigation might be an unintended consequence of Bayh–Dole. According to them, patent litigation has had an adverse effect on technology being licensed by universities, as it prevented the marketing efforts of staff employed by TTOs. Nonetheless, despite patent litigation and some problems with under-staffed TTOs, there is clear evidence from the literature that Bayh–Dole has had a profound effect on the way that US universities view their IP assets created by their academic staff.

A significant number of spin-out companies were formed during the first 18 years under Bayh–Dole, based on licenses obtained from US universities (Reichelt, 2007). These spin-out companies, apart from paying royalties to universities, have fueled regional economic growth in the United States and aided economic development through job creation and paying of taxes to local authorities (Reichelt, 2007). Early estimates calculated the total economic effect of technology transfer from US universities at $428 billion by 1998 (Reichelt, 2007). Hence, from the evidence provided in the literature, there can be no doubt that Bayh–Dole succeeded in its aims.

4.4.2 The IPRs from Publicly Financed Research ("IPR-PFRD") Framework in SA

Until recently, SA had no law equivalent to the Bayh-Dole Act of 1980 that addresses the ownership of IP created by using public funds. Universities in SA were left to either develop their own IP policies, or have no policy at all, which resulted in some universities having rights to the ownership of IP, while others left it in the hands of individual academic staff members to own and commercialise. According to Garduño (2004a), not claiming ownership of intellectual property rights (IPR) is a critical flaw in the institutional framework in SA, as it removes the incentive and economic benefits of universities engaging in technology-transfer activities. Garduño (2004a) believes that without this incentive, SA universities would not be eager to allocate resources to promote technology transfer activities. The resultant lack of eagerness by universities, in turn, might discourage entrepreneurial behaviour among academic staff. Garduño (2004a) does not suggest the homogenisation of IPR policies at SA universities, but does suggest that universities consider modifying their IPR policies to create incentives for both universities and academic staff to actively participate in the technology transfer process.

The DST in SA was keenly aware of the importance of the Bayh-Dole Act in the United States and its role in stimulating the exploitation of university IP since 1980 (Republic of South Africa: Department of Science and Technology, 2006). DTI, as the authors of the IPR-PFRD Framework, cited evidence to support their claim that 40% of SA patents filed in the United States were owned by non-SA entities, and said that they believed that this was due to a lack of an unambiguous IPR policy in SA for IP created through public funds. Both Heher (2006) and HESA (2007) noted the low levels of patenting by SA universities at the time and claimed that there was a need for legislation similar to the Bayh-Dole Act to promote certainty and protection of the ownership of IPR at SA universities.

Consequently, DST developed and proposed a framework for enabling legislation that would reflect global best practices and that would be in line with what was called for in SA's R&D Strategy of 2002. Efforts by DST culminated in the Intellectual Property Rights from Publicly Financed Research Framework in 2006 (IPR-PFRD Framework). The framework advocated for a single agency to administer the protection and exploitation of IP derived from publicly funded research in SA, and claimed that the SA government could play a significant role in creating an enabling environment for the commercialisation of the results of publicly funded research in SA (RSA: DST, 2006). Included in the new framework were requirements such as:

- benefit sharing between universities and academic staff as inventors,
- a duty placed on universities to protect IP and then to exploit it commercially,
- a centrally managed agency (like the National Intellectual Property Management Office (NIPMO) created by government to whom all publicly financed institutions must report on IP matters,
- walk-in rights for the new agency for IP that is not being commercialised, and
- preferred licensing of IP to local SMMEs in SA (RSA: DST, 2006).

The framework also promoted the setting up of IP management offices, better known as technology transfer offices (TTOs), with IPR policies at SA universities. The duties of such TTOs would include:

- receiving invention disclosures and ascertain their patentability,
- acquiring patents,
- concluding license agreements,
- building research affiliations with businesses in commerce and industry, and
- managing benefit sharing with academic staff to use the IP (RSA: DST, 2006).

The framework also noted the need for effective monitoring, evaluation and performance assessment of the TTOs at SA universities to satisfy the requirement for accountability to the SA government and society (RSA: DST, 2006). Key statistics to be assessed included IP disclosures, new patents filed, licensing income earned, contributions to social development through licensing activities, new and incremental innovations, spin-out companies established, and employment opportunities created (RSA: DST, 2006). These measurement statistics were also cited by Heher (2006) as critical in determining the success of technology transfer activities.

An approach to benefit sharing was offered by the framework for royalty income generated from licensing agreements, equity participation, or the outright sale of IP by universities. Inventors were to receive 30% (to be distributed equally if there are more than one inventor), the department at the university within which the discovery occurred and the central university administration will each receive 30%, with the balance of 10% being allocated to the TTO to recover its costs (RSA: DST, 2006). DST (RSA: DST, 2006) agrees with Garduño (2004a) that licensing is the most significant and preferred method of technology transfer from university research laboratories to businesses in commerce and industry. Universities bridge the gap between research results and commercial success by engaging in licensing activities on behalf of their academic staff that create new technologies (RSA: DST, 2006). DST proposed a preference for using non-exclusive licensing and performance clauses in exclusive licensing agreements.

According to Wolson (2007), the IPR-PFRD Framework drew heavily on the Bayh-Dole Act in the United States and proposed a new approach to improve the very low levels of patenting in SA experienced over the ten years prior to 2006. Wolson (2007) and SARIMA (2012) noted the bias towards licensing in the framework, and the preference for licensing to Broad-Based Black Economic Empowerment (B-BBEE) businesses. BEE is a key part of the SA government's strategy to extend the participation of black people in the SA economy, alleviate poverty, and advance education to previously disadvantaged people. The purpose of promoting BEE in SA is to correct the wrongdoings of the past, when prior to 1994 back people were prevented from participating freely in the economy and sharing in the benefits that economic growth can bring.

Often, prospective licensees cannot be found to further develop or incorporate new technologies. In such cases, the IPR-PFRD Framework suggests that SA universities consider forming a spin-out company with input from the academic staff member and to find a suitable entrepreneur to manage the newly created company.

The IPR-PFRD Framework discussed in this section was the forerunner of the IPR-PFRD Act. This Act was promulgated on 22 December 2008 and is more fully explained in the next section.

4.4.3 The Intellectual Property Rights from Publicly Financed Research and Development Act 51 of 2008 ("IPR-PFRD ACT") in SA

Following from the IPR-PFRD Framework, the IPR-PFRD Act was promulgated in the SA Government Gazette in 2008 and came into effect on 2 August 2010. This new law governs IPR generated from publicly funded R&D in SA and follows the approach proposed by DST in the IPR-PFRD Framework of 2006, as discussed in the previous section.

The main aims of the IPR-PFRD Act are to:

- ensure the effective utilisation of IP created by publicly financed R&D activities in SA,
- establish NIPMO,
- establish an Intellectual Property Fund,
- provide for the setting up of TTOs at SA universities and research institutions, and
- provide for matters connected thereto (RSA: DST, 2006).

More specifically, Section 2(1) of the IPR-PFRD Act states that the object of the Act is to "make provision that IP emanating from publicly financed R&D is identified, protected, utilised and commercialised for the benefit of the people of the Republic, whether it be for social, economic, military or any other benefit".

The Act refers to recipients of public funding in SA and Section 2(2) of the Act requires universities to:

- assess, record and report on the benefit to society of publicly funded R&D,
- protect IP emanating from its campuses,
- identify commercialisation opportunities for the IP it protects,
- acknowledge and reward human ingenuity and creativity,
- allocate preferential access to SMMEs and B-BBEE businesses,
- allow publication by academic staff of their findings after disclosure, and
- where necessary, to allow the government to exercise walk-in rights to use the IP in the best interest of all citizens of SA (RSA: DST, 2006).

Section 3 of the Act assigns universities the right of ownership to the IP created by using public funding. SA universities must inform NIPMO if it decides not to retain ownership of a particular piece of IP created on its campus so that NIPMO may decide whether to acquire and protect the said piece of IP. If NIPMO decides not to acquire the IP, then it must notify the university concerned, who must then offer it back to the academic staff member. The following responsibilities were allocated to recipients (SA universities) with regard to the management of IP created in terms of Section 5(1) of the Act. A university must:

- establish procedures for the identification, protection (after assessment), development, management and commercialisation of IP;
- provide effective processes for the disclosure of IP by academic staff (within 90 days of identification of the IP) and its protection before the results are made public;
- negotiate and enter into transactions with third parties and manage income so received, as well as manage the benefit sharing arrangements of academic staff as inventors of the IP; and
- report to NIPMO twice a year on all matters relating to IP contemplated in the Act and provide reasons for IP that is not commercialised (RSA:DST, 2006).

Universities are thus given direction by the IPR-PFRD Act when negotiating agreements on the commercialisation of the IP assets they hold. Preference is given to organisations wishing to use the IP for accruing benefits to the economy and improving the quality of lives of SA's citizens. Holders of exclusive licences must agree where possible to develop, produce, and commercialise the IP in SA. If they fail to do so, the SA government has walk-in rights to the IP. If the holder of an exclusive licence is unable to continue the proper commercialisation of the protected IP, then NIPMO can ask for the exclusive license to be changed to a non-exclusive licence. The SA government will also have an irrevocable and royalty-free license to use the IP anywhere in the world for issues relating to health, security, or other matters of emergency. If IP is assigned to an SMME or university spin-out company in exchange for shareholding and that business or spin-out is liquidated, then the IP which becomes available will revert back to the university (RSA:DST, 2006).

In terms of Section 10 of the IPR-PFRD Act, the creators of IP (and their heirs) at SA universities are granted the rights to a portion of the income derived by the institution from commercialisation efforts of their invention. The following distribution rates apply:

- The IP creator is entitled to at least 20% of the first R1m of the gross income received or such higher amount as the Minister may prescribe.
- Thereafter, the IP creator is entitled to at least 30% of the net revenues which amass to the university.

- The benefits received by creators and or their heirs must be shared in equal amounts, unless agreed differently between them or in accordance with university's policy.
- The 20% initial sharing from the first R1m of proceeds is a preference distribution ahead of any other claims that the university may have.
- The university may allocate the balance as it deems appropriate, but some of the proceeds must be allocated to:
    - funding further research and development expenses,
    - funding operational expenses of the TTO, and
    - legal protection of the IP emanating from the university (RSA: DST, 2006).

As Sibanda (2009) indicates, the IPR-PFRD Act requires SA universities to establish TTOs and suggests the formation of regional technology transfer offices. These TTOs should be stationed at the university with the highest research outputs within a region. In this way, scarce human resources would be shared in a region where universities have lower research outputs.

In determining whether particular IP generated at universities in SA falls within the scope of the IPR-PFRD Act, one needs to consider the date of creation of the IP. The IPR-PFRD Act does not apply to IP created prior to 2 August 2010, but does apply to IP created after that date, even if it was based on background IP created prior to that date. The IPR-PFRD Act requires the completion of a number of statutory forms to be submitted to NIPMO, should universities encounter an issue that requires NIPMO's approval, as set out in the Act (Southern African Research and Innovation Management Association (SARIMA), 2012).

As noted by Alessandrini *et al.* (2013), sound collaborations exist in SA between universities and businesses in commerce and industry. Moreover, the IPR-PFRD Act covers co-operation between universities and private organisations. If a private organisation (such as a business in commerce and industry) provides resources, background IP, or funding leading to joint creatorship of the resultant IP, then they may co-own the newly created IP. Of note is the condition that the parties reach an agreement on the commercialisation of the newly created IP, and that the academic staff of the university should be adequately compensated through benefit sharing if the IP concerned falls within the ambit of the Act (RSA: DST, 2006).

The following section reports on the IPR-PFRD Act of 2008. The Bayh–Dole Act of 1980 provided certainty of the ownership of IP resulting from publicly funded research in the USA. SA universities were lacking the same clarity and certainty until the IPR-PFRD Act of 2008 was promulgated in 2010. Although the protection of IP rights in SA is advanced when measured by international standards (Alessandrini *et al.* 2013), it is undermined by the patent office's operating as a non-examination office. University TTOs must refer any uncertainty or dispute arising from the interpretation or application of the Act to NIPMO. The act is prescriptive to all participants active in R&D at SA universities. Only if funding was provided on a full cost recovery basis will the IP belong to the funder of research.

As researcher, I agree with the notion that legislation is required to remove uncertainties with regard to the ownership of IP emanating from publicly funded research. I believe that a fair and just system needs to be established for multiplication and production of the new technology inventions by university academics and students. Within such system, entrepreneurs should be adequately compensated and rewarded for the risks they take in the commercialisation effort, which may exceed the costs of research activities.

Although Jensen and Thursby (2001) assert that commercialisation activities may divert the attention of academics from more basic research and teaching, I do not believe that this is the case for all university researchers. The results from interviews held with academic staff and students in the target group as part of this study will show to what extent (if any) academics as inventors are detracted from conducting more research and from teaching activities.

As with Bayh–Dole in the USA, the new IPR-PFRD Act of 2008 in SA has accomplished two goals in awarding IP to SA universities. Firstly, it mandated all SA universities that did not have TTOs yet to do so, which spared inventors from having to acquire legal and business expertise themselves. Secondly, inventors could avoid the risks of patenting costs, marketing, and licensing fees, as these were now paid for by the university TTO.

Simelane (2013) claims that the current environment for innovation seeks to promote knowledge development for the purpose of promoting academic excellence. This is supported by the requirement that academics need to publish, supervise, and deliver a specified number of postgraduate students within a given time period. The author points out that all these requirements are central to obtaining an NRF rating. As it appears, little emphasis is placed on the generation of patentable knowledge.

Staphorst, Holland, Pretorius and Pretorius (2015), when considering the impact of the new IPR act in SA on research alliances, found that the extra administrative and operational costs, due to the establishment and monitoring of complicated contractual R&D agreements for universities, are major deterrents similar to Bayh-Dole-like IPRs legislative rules. The implication for universities is the establishment of TTOs for monitoring and the correct and diligent application of the new act. University TTOs have to ensure sufficient human resource capacity and systems to comply with the provisions of the act and to promote adherence to the act by all university staff and students. I see the new IPR act as a positive development, as it levels the playing field and provides certainty regarding the ownership of research and development conducted at SA publicly funded universities.

Following from the legal milieu in this section is the policy environment stated in the next section, which impacts on university inventions, and ultimately the TTO function and the outputs from TT activities as depicted by the conceptual analysis in section 3.3.

4.5 The funding environment for university TT

4.5.1 SA's funding for R&D at universities and TTO commercialisation

SA's funding for R&D at universities

HSRC (2013) quoted figures from their summary of the 2009/2010 R&D survey stating that only 0.87% or R20.9 billion of SA's GDP was spent on R&D activities during that year, and R21billion or 0.92% of GDP for the previous year, 2008/2009. This decrease is mainly attributed to the effects of the global financial crises over this period, which affected almost all countries (Centre for Science Technology and Innovation Indicators (CeSTII), 2013). For the year 2015/2016, HSRC (2017) reported in its same annual survey a figure of 0.80% or R32.337 billion of SA's GDP that was spent on R&D activities, compared to R29.345billion or 0.77% of GDP for the previous year, 2014/2015. The three years prior to that were similar, at 0.73% of GDP. One must remember that SA's GDP decreased from 1.7% in 2014 to 1.3% in 2015 (HSRC, 2017). Evidently, SA has gone backwards, as the percentage of 0.80% is lower than the 0.92% figure achieved for the year

2008/2009 year (HSRC, 2013) and compares poorly and is significantly lower than the 2.7% on average spent by most developed nations of the world.

The figures quoted above imply that applied research conducted by SA universities is mostly funded by businesses in commerce and industry, whilst basic research is still predominantly funded from government sources. The resultant effect is that the ownership of IP created through applied research lies with businesses in commerce and industry and that of basic research with universities. Thus, it is important for SA universities to correctly measure and claim part ownership of IP developed (from applied research activities) in exchange for the background intellectual property they provide (from basic research activities). Once the IP has been protected, private equity investors, and venture capital and angel investors can step in to commercialise the effort of technologies emanating from SA universities.

Figure 4.1 below indicates how gross expenditure on research and development (GERD) as a ratio of GDP in SA has moved between 1993 and 2015. Funding for R&D in SA has grown over this period, but not as planned. Measured in rand terms for 2010, GERD has more than doubled over this time, but SA's proportion of global R&D expenditure was a mere 0,3% in 2013, compared to Brazil and India's increases in their ratio's of 2,2% and 3,2%, respectively (RSA: DTI, 2017b).

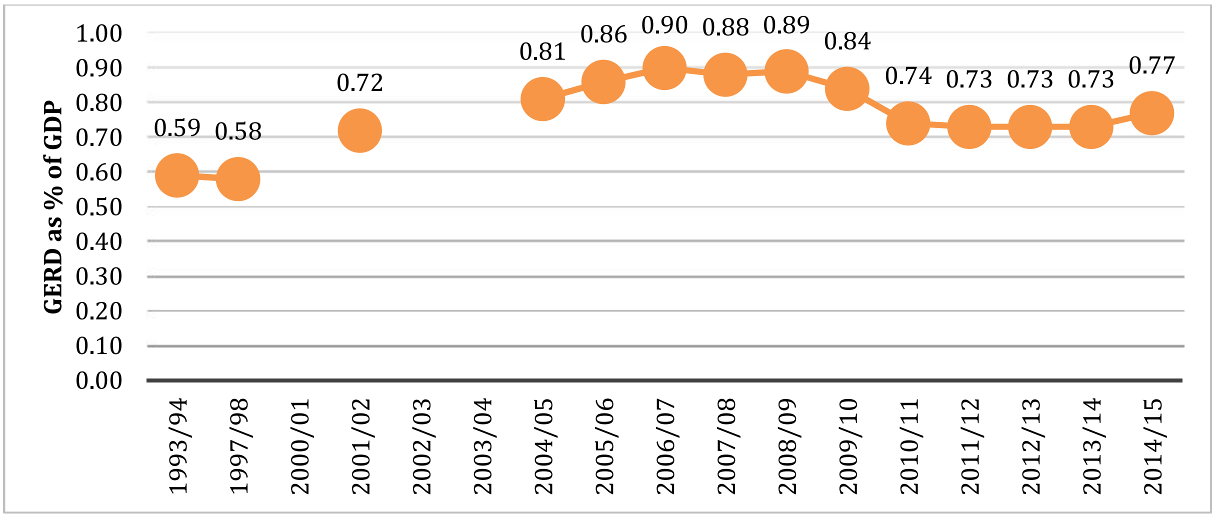


Figure 4.1: Gross expenditure on research and development as a percentage of GDP, in 2010 constant rands (data not available for 2000/01, 2002/03, and 2003/04)
Source: (RSA: DTI, 2017b)

Figure 4.2 displays a specific strong disparity between SA and South Korea. The latter country achieved almost 10 times the GERD per capita, compared to SA in 2007. South Korea's GERD per capita almost doubled from 2007 to 2013, whilst SA's GERD per capita decreased over the same period. In 2013, South Korea's proportion of GERD over their GDP was 4,2%, contrasted to SA's figure of a paltry 0,7% (RSA: DTI, 2017b).

Indicator	Year	SA	Brazil	India	China	Russia	Korea	Mexico
Share of global GDP	2007	0,7	3,0	5,4	11,5	2,8	1,8	2,0
	2013	0,7	3,0	6,7	16,1	2,5	1,8	1,8
GERD in $PPP billion (purchasing power parity)	2007	4,6	23,9	31,1	116,0	22,2	38,8	5,3
	2013	4,2	30,2	42,8	290,1	24,8	64,7	7,9
Share of world GERD (%)	2007	0,4	2,1	2,7	10,2	2,0	3,4	0,5
	2013	0,3	2,2	3,2	19,6	1,7	4,4	0,5
GERD % of GDP	2007	0,9	1,1	2,5	0,8	1,1	3,0	0,4
	2013	0,7	1,2	2,9	0,8	1,1	4,2	0,5
GERD per capita in $PPP	2007	92,9	126,6	26,8	87,0	154,7	815,6	46,6
	2013	80,5	157,5	35,0	209,3	173,5	1 312,7	65,0

Figure 4.2: Selected international comparisons on indicators of R&D intensity
Source: (RSA: DTI, 2017b)

Available data depicted in Figures 4.1 and 4.2 above indicate that the NSI in SA is significantly short funded when considering gross expenditure on R&D as a percentage of GDP and comparing it to other developed and emerging countries of the world.

R&D tax incentive

The main aim of this incentive is to encourage South African companies to invest in scientific or technological research and development. The section 11D Research and Development Incentive (R&D) was introduced into the Income Tax Act in 2006 to replace the previous research and development rule that existed in terms of section 11B. Section 11D allows for:

- a deduction equal to 150% of expenditure incurred directly for Research & Development and
- an accelerated depreciation deduction (that is, 50:30:20) for capital expenditure incurred on machinery or plant used for R&D (SARS, 2017).

The tax incentives are considerable and RSA: DST (2012b) claims that "…the South African incentive for R&D is one of the most generous offered by a government".

Nevertheless, the uptake has been somewhat limited. Between 2006 and 2014, the total number of companies that accessed the incentive was 810 (Technology Innovation Agency (TIA), 2013b). Approximately 45% of the companies had an annual turnover of below R40 million, defined as SMMEs in the National Small Business Act, Act No 102 of 1996. More than 80% of applicants are from two sectors, namely manufacturing and financial intermediation that included real estate and business services (TIA 2013).

There have been concerns about delays and the complexity of accessing the incentives, and thus various changes have been made to speed up processes and make them more efficient. A number of improvements were effected in 2012, including a new approval process and other measures to enhance the impact of the incentive. These changes were published in the Tax Laws Amendment Act, 2011 (Act No. 24 of 2011). Prior to 1 October 2012, forms were submitted retrospectively and after this date R&D activities were subject to preapproval. In 2013/14, it was reported that there was a significant backlog, and measures were put in place to clear this (Department of Science and Technology, 2013). The DST target is now expected to provide decisions on preapprovals within 90 days of receiving applications (Department of Science and Technology, 2013).

However, there is still a considerable backlog. The most recent National Treasury Budget Review (Republic of South Africa: National Treasury, 2015:145) reports:

> …. the backlog in the approval process is creating difficulties, especially for smaller businesses, which have to wait months for approval. Measures will be considered to ensure that taxpayers are not disadvantaged by undue delays by the adjudication committee. The issue of third-party funding for R&D activities will also be considered.

DST reported to parliament that the tax revenue foregone due to the R&D tax incentive was estimated to be R2 billion for the period 2005/06 to 2009/10 (Republic of South Africa: Department of Science and Technology, 2012c). Moreover, the R&D expenditure supported was R12 billion, of which R10 billion was eligible for the tax incentive. Thus, the tax relief offered is extensive (R2 billion on allowable expenditures of R10 billion).

A key performance metric is the additional R&D investment that resulted from the tax incentive, as compared with the cost of the incentive, where the latter is measured as tax foregone. Only 23.1% of the companies participating in the R&D tax incentive responded to the question on how much they had increased their R&D expenditure. They indicated a total of R374 million (2.9%) as a result of the incentive, leaving no clear estimate of the additional R&D investment occurring (RSA: DST, 2012c). This admittedly very partial data might indicate that the increased R&D resulting from the tax incentive is limited relative to the tax foregone.

The R&D tax incentive consumes considerable resources, and is a major instrument designed to enhance R&D on the part of the private sector, as well as to promote collaboration between companies and other R&D performers. RSA: DTI (2017b) attests that DST received a total of 189 applications from 147 companies for the period 2015/16. The applications covered 953 projects, encompassing R3.9 billion of R&D expenses. A total of 86 businesses applied for the first time, which increase to 962 the total number of businesses partaking in the tax incentive scheme since the start thereof in November 2006 (RSA: DTI, 2017b).

TTO funding for commercialisation activities

In addition to funding for research at SA public universities, funding is also required for providing the TTO function itself. Wolson (2007) asserts that the Innovation Fund (later incorporated into TIA) through IFCO, transformed itself to operate as a typical venture capital investor, as it applied investment criteria used by venture capitalists in evaluating proposals. Through IFCO, the SA government provided much needed seed funding to universities and start-up businesses in the development of early-stage technologies (Kruss, 2008)

Sibanda (2009) reports that DST, within the IF, set up a Patent Support Fund to subsidise patent costs for SA universities and a Patent Incentive Fund to entice researchers to protect their knowledge that has commercial potential. In order to receive this funding, SA universities had to have an IP policy that shared proceeds from IP commercialisation with academic staff and students. Within ten years of its inception, the IF had invested R1.2 billion in 270 projects (South Africa, 2013).

IFCO also managed a number of human capital development programmes such as the Candidate Patent Attorney Programme, the Commercialisation Managers Development Programme and the TTO support programme (Republic of South Africa, 2013). A number of SA universities also benefitted from these programmes. The Innovation Fund subscribed to patent- and marketing databases that could be used by universities at no charge or at reduced rates, and also provided financial support for the establishment of TTOs at SA universities.

Data gathered during the SA National Survey of IP and TT at Publicly Funded Research Institutions (RSA: DST *et al.*, 2017) indicate that the growth in TT operational expenses incurred at public research institutions is maintained by the TTO Support Fund that is granted to these institutions by NIPMO to fund capacity development. The cumulative figure added up to R75m for all participating institutions from 2011 to 2014. Funding requirements were indicated in the survey as the most critical impediment to grow TT activities at institutions to reach critical mass and to pay for IP registration costs (RSA: DST *et al.*, 2017).

Along with the R&D tax incentive, the funding formula for universities that was started in 2003 constructively contributed to research production in the higher education sector. RSA: DTI (2017b) claims that this support will continue as long as the focus remain to be on generating quality research outputs delivered by scientists performing inter, multi and transdisciplinary work. The next section deliberates on private equity, venture capital and angel investors as sources of funding for new inventions, products and services emanating from universities in SA.

4.5.2 Private equity, venture capital and angel investors

Funding for early-stage technologies is necessary for its successful development. Venture capital is provided by venture capital (VC) companies that focus on providing finance for spin-out companies in exchange for obtaining a shareholding (equity) in the company.

Some universities in the United States, such as Stanford University, understand the role that seed funding plays, and have established their own VC funds from revenue received from other TT activities (Tornatzky *et al.*, 2002). Similarly, North Carolina State University created a fund called Centennial Venture Partners (CVP) in 1998 (Tornatzky *et al.*, 2002). This fund, capitalised initially with $10 million, is managed outside the university and targets technology owned by the university and alumni of the university (Tornatzky *et al.*, 2002). Matching funding was secured that allowed CVP to invest in 15 spin-out companies in its first two years of operation, which resulted in 240 permanent jobs being created (Tornatzky *et al.*, 2002). Contrary to these examples in the United States, markets for venture capital in Europe and elsewhere globally remain low, compared to the United States where diverse sources exist for seed funding, including a strong venture capital industry and many wealthy individuals acting as angel investors.

Shane (2002) found that entrepreneurs often use the university TTO to help gain access to angel investors and VC firms. Venture capital and angel investors are particularly helpful, as technologies transferred to entrepreneurial companies often require greater financial investment to unlock the potential value of such technologies through commercialisation efforts (Shane, 2002). Universities often use their TTOs as brokers to the VC and angel investor community (Garduño, 2004b). The University of Maryland in the United States, for example, holds a ‘Technology Transfer Boot Camp’ every year to allow students and academic staff members to meet with VCs and angel investors providing seed funding (Garduño, 2004b). The VC industry in the United States played a significant role in the success of early-stage start-up and university spin-out companies by investing more than $1.3 billion in such companies during the year 2000 (Garduño, 2004a). Venture capital firms and/or angel investors often participate in the management of the new company initially and assist in building the management teams.

Unlike the United States, where venture capital has been used effectively to stimulate the formation of new high-technology spin-out companies from universities, the prospects for VC industries are limited in most developing countries, due to their underdeveloped financial-services sectors. Investment in high-technology start-up companies takes many years before positive cash flows are generated, and it is therefore considered risky. By their nature, VC investors are aggressive in their approach and seek high returns for the risks they take investing in technologically based start-up companies (Koekemoer & Kachieng’a, 2002).

Garduño (2004a) suggests that one of the reasons behind the low level of funding towards early-stage development in SA is also that the market for investments has a preference for safer, shorter-term transactions. He asserts that another reason why venture capitalists avoid early-stage funding in SA is the apparent lack of skills of fund managers to evaluate and support such new university spin-out companies. This lack of experienced fund managers has resulted in weak networks in SA, compared to the strong networks available to venture capital companies in the United States. Hence, Garduño (2004a) argues that SA universities should actively explore the international market to provide the much needed capital. Lotz and Buys (2005) report that venture capital fills the gap between the initial funders of new technologies and the commercial banks with strict lending criteria that represent the more formal funding option. Lotz and Buys (2005), who researched financing trends for start-up companies in SA, found that respondents in their survey listed the lack of access to venture capital as one of the main reasons for the failure of technology-based start-up companies.

Angel funding is more readily available in countries where there are sufficient levels of personal savings. Angel investors represent wealthy individuals in society with surplus capital for which they seek investment opportunities that will offer higher returns than commercial banks typically offer on savings accounts (Wolson, 2007). There are very few angel investors in SA, and as they often do not understand biotechnology, they are wary of committing funds to its development (Wolson, 2007).

VC funding is usually associated with high-technology start-up companies that are considered to be quite risky, as they represent the early stages in the funding cycle of a new venture or product (Van Deventer & Mlambo, 2009). University spin-out companies are likewise considered to be risky and often require further funding (Sibanda, 2009). Van Deventer and Mlambo (2009), as well as Lotz and Buys (2005) confirm this and lament the lack of funding for early-stage technologies in SA. They further assert that entrepreneurs often start and then manage new companies on a shoestring budget, and then only start looking for venture capital once they are ready to grow their businesses.

The leading survey in SA on the private-equity industry is the KPMG Southern African Venture Capital and Private Equity Association's (SAVCA) annual survey. SAVCA, based on its UK counterpart the British Venture Capital Association (BVCA), classifies private equity into three sections, namely venture capital, development capital, and buy-out funding. Venture capital is divided into two further stages, namely seed capital and start-up and /or early-stage development. Seed capital is typically applied to research, evaluation, and development of the proof-of-concept prior to a business being started. Start-up and early-stage funding is used primarily for setting up a spin-out company in the first three years of its trading. The venture-capital market in SA in 2012 comprised only 0.10% of GDP, which was lower than the venture capital market of Brazil, which represented 0.18% of their GDP for that year. By contrast, the venture-capital markets as percentage of a country's GDP for developed countries such as the United States and the United Kingdom were 0.86% and 1.05% respectively (KPMG & South African Venture Capital and Private Equity Association (SAVCA), 2013).

SAVCA's annual survey for 2016 reported compound annual growth of 11.6% in funds under management since the survey started in 1999 until December 2015. The report by SAVCA quoted the total value of investments made into early-stage and new start-up companies in SA for the year ending 31 December 2015 as R29.0 billion (2014:R11.8 billion) (KPMG & South African Venture Capital and Private Equity Association (SAVCA), 2016). Capital raising efforts culminated in the growth of total funds under management, adding up to R165.3 billion at the end of 2015, compared to R150.3 billion at the end of 2015, and excludes funds under management by the Public Investment Corporation (PIC) (KPMG & South African Venture Capital and Private Equity Association (SAVCA), 2016).

Since 2006, though, the SA government has filled the funding gap by providing early-stage funding through the establishment of the Innovation Fund. The Innovation Fund initiated a number of funding schemes aimed at funding early-stage technologies in SA. These initiatives, such as TAP and MiTech, were consolidated in the Intellectual Property Fund in 2011, after the enforcement of the 2008 IPR-PFRD Act in 2010. As stated in section 4.2.3 above, the Innovation Fund was amalgamated with TIA and three new risk funding schemes were initiated by TIA during the 2013/14 financial year. RSA: DST *et al.* (2017) noted that seed funding allocated to HEIs in SA increased between 2012 and 2014 as a result of the creation of these funding schemes by TIA.

The three risk funding schemes support the funding of early stage technological development designs that have the potential for commercial exploitation and consists of a seed fund, technology creation fund, and a commercialisation support fund (RSA: DST, 2018). The seed fund helps researchers from HEIs, science councils, and SMMEs to promote their research projects to the stages of proof of concept and prototypes that can be applied in creating future sellable products. The technology creation fund supports inventors to promote new technologies alongside the value chain for innovation, from the proof of concept phase to the practical display and validation, while the commercialisation fund aids inventors in resting market readiness by linking the inventors to businesses in commerce and industry and investment prospects (RSA: DST, 2018).

Funding for research has a direct influence on the strength of the NSI and its ability to promote SA's NDP by changing the economy, advancing growth, growing the employment rate, and having a positive socio-economic impact (RSA: DTI, 2017b). The lack of growth and development of university spin-out companies as part of the SMME sector in SA can be due to an underdeveloped funding environment. The low levels of funding on R&D in SA, as shown by the proportion of its GDP, is a concern. It is consistently under 1%, compared to the norm average of 2.7% of other countries in the world. Preferences of investors who choose to finance existing companies, rather than start-up businesses such as university spin-out companies, often limit the growth opportunities further.

The SA government is trying to stimulate expenditure on R&D activities through the R&D tax incentive and seed funds managed by TIA, as discussed in this section. Private equity investments, venture capital investments, and angel investors as funding mechanism were briefly discussed. It is imperative that these actors invest in new technologies emanating from SA universities via the TT process. The next section considers human resources as the fifth enabler listed per the conceptual framework developed for this study.

4.6 Human resources

4.6.1 Incentives for academic staff to engage in university TT

Jensen and Thursby (2001) surveyed 62 universities in the US and found that more than 75% of licensed technologies were no more than a proof of concept, and that the commercial potential of such licences are unknown, as the invention is in such an early stage of development. Jensen and Thursby (2001) agree with Goldfarb and Henrekson (2003) that continued participation by academic staff as inventors exponentially increases the probability of the commercial success of university generated IP. To ensure the involvement of the inventor, outcome-based payments such as royalties from licensing provide the best incentive, as they directly link the inventor's income to additional effort in the commercialisation process. Evidence obtained by Jensen and Thursby (2001) indicates that only 12% of inventions were ready for commercial application when the licence agreement was concluded, and only 8% were ready for the manufacturing process.

Colyvas *et al.* (2002) found that the most common reason for the continued involvement of academic staff in the further development of licensed technology is the fact that the technology is often in its early stages. Being critical, the authors argue that the disclosure of new inventions by academic staff at universities comes at the expense of fewer research publications, as time is diverted away from writing books and articles. Contrary to the argument by Colyvas *et al.* (2002) that TT activities distract academics from publishing, Thursby and Thursby (2005) found evidence in their survey that the publications by academic staff involved in university TT activities actually increased and in some cases almost doubled. Thursby and Thursby (2003) also observed that the notable increase in university patenting since the early 1980s is attributed to the financial gain that academic staff obtained from inventions made by them.

Lach and Schankerman (2004) concur with Shane (2002) and provide evidence to indicate that an academic staff member as inventor should share in incentives from licence agreements and in equity participation of university spin-out companies formed from their new inventions. A royalty arrangement works best if IPRs to the invention can be asserted. These authors also agree with Goldfarb and Henrekson (2003) that equity in university spin-out companies is more important when the knowledge to be transferred is mostly tacit and other IPRs are weak. The payment of license fees to universities for inventions is shared with academics in accordance with the IP policy of the university and is tied to the commercial success of the licensee (Thursby & Thursby, 2003). If academic staff is required to assist in further development of the technology to ensure its commercial viability, then they expect to receive a bigger share of the royalties, or even equity in a spin-out company (Thursby & Thursby, 2003).

Reid (2004), when referring to Australian universities, concludes that a lot is expected from academic staff members and university management with respect to securing private sector funds for R&D. Funding for R&D expands the scope of IPRs that the university can claim were created in the course of the employment of academics. However, Reid (2004: 773) further contends that "as the body of academics becomes increasingly distinct from the entity that is 'the university', the scope for conflict between the two over IP will increase". University management needs to realise and acknowledge the fact that academic staff could both serve the public good through teaching activities and perform top-rated research, which could lead to valuable IP for which the academics need to be compensated. Without academic staff, there would be no university inventions to disclose; hence, a measure of success for university TTOs is the number of invention disclosures received by the TTO, as it indicates the level of participation by academic staff in the TT process (Thursby & Thursby, 2005).

In SA, varying incentive schemes used by SA universities may have discouraged academic staff from engaging in the commercial exploitation of their research results. Commercial exploitation of university inventions was limited, as incentives at the time were constrained by traditional academic and departmental boundaries, also referred to by Debackere and Veugelers (2005) as "professional bureaucracy". HESA (2007), referring to SA universities, reveals that sixteen of the seventeen universities surveyed in their study, which was published in 2007, offered incentives to academic staff members for delivering research publications, while only ten of them (62.5%) had incentives for filing patent applications. HESA (2007) maintains that publications offer immediate and direct financial benefits for the academic, as opposed to patents, which only start to deliver financial returns when they are commercialised, and not when the patents are first granted. Furthermore, HESA (2007) found that, although SA universities provided financial incentives to academic staff to engage in technology transfer (TT) activities, such achievements did not count for promotion purposes at the time. However, since the IPR-PFRD Act, SA universities must compensate academic staff as inventors according to predetermined formulas included in the Act.

Thursby and Thursby (2011) argue that IP disclosures are the best and most preferable way to effectively measure and test the participation of academic staff in university TT activities. Data from the 2011 AUTM survey in the United States show that 21 856 invention disclosures were received by 186 research institutions in that country at an average of 117 per institution (Association of University Technology Managers (AUTM), 2011). The ratio of disclosures that were converted to patent applications filed increased from 25.9% in 1991 to 47.4% in 2002, and to 91% in 2011, as US university TT programmes matured (Association of University Technology Managers (AUTM), 2003, 2011). Using this ratio, Thursby and Thursby (2011) derived that the propensity of academic staff at United States universities seeking commercialisation of their research results increased significantly since 1991.

SA's population comprised 0,75% of the total world population in 2014. Its research system is doing very well, considering the size of its population. Data presented by CREST indicate that the per capita research outputs of university academics raised from 0,39 in 2001 to 0,84 units of output in 2014. Nevertheless, the per capita indicator is still below par when bearing in mind that the data include master's and doctoral graduates, and that productivity is heavily tilted to research-intensive universities, where per capita outputs are more than 2 units of output (RSA: DTI, 2017b). SA's improved research outputs are mainly due to better publication levels by academics at universities. The key driver of the upturn was the performance-based funding formula launched DHET in 2003, additional financial incentives instituted by the NRF, as well as more journals included by Thompson Reuters (RSA: DTI, 2017b).

RSA: DTI (2017b) quoted DHET's Higher Education Management Information System which indicates that many academic staff at SA universities, including scores of black and women academics, are inactive in research (referred to as the "silent majority). Universities are responsible for almost 90% of all research publications, with five universities producing 60% of the research outputs. The total for all the science councils and national research facilities together equates for only roughly 8%, of which the MRC and CSIR make up 65% of the 8% figure (RSA: DTI, 2017b). Growth was achieved in masters and doctoral enrolments and graduations over and above research outputs (RSA: DTI, 2017b). The increased outputs occurred despite the number of full-time equivalent researchers increasing by a mere 17% from 2005/06.

RSA: DST (2017b) testifies that DST and DHET will cooperate on an incentive programme for science council staff to improve their research outputs and postgraduate supervision of students. Mouton (2017) cautions against the approach of expecting too much of science council staff who are carrying a large workload of performing applied and contract research activities. In addition, Mouton (2017) maintains that doctoral supervision is best performed by academic staff of universities that are entrenched in an academic culture (RSA: DTI, 2017b).

The Department of Higher Education in SA published a new policy on the evaluation of creative outputs and innovations produced by HEIs in the Government Gazette dated 28 April 2017 (Republic of South Africa: Department of Higher Education and Training, 2017). In terms of the new policy, universities from which patents and plant breeders' rights emanate will receive a subsidy reward based on 2 units. The subsidy will accrue to the university where the invention originates from and not to the individual researcher. The subsidy does not apply to contract research paid for by businesses in commerce and industry (RSA: DHET, 2017).

The incentives and remuneration on offer to academic staff are considered to be equally important to a strong institutional commitment in promoting the propensity of staff to disclose IP created by them and for them to engage further in TT activities. In addition to the commitment expected from top management within universities and incentives on offer to academic staff and students, networks are seen to be a central part of the cultural environment within which universities operate. According to Debackere and Veugelers (2005), supporting an entrepreneurial culture should take the form of adequate incentive schemes for academic staff as part of an appropriate structure. Networks leading to collaboration between universities and businesses in commerce and industry are discussed in more detail in the section below.

4.6.2 Networks seeking collaboration

Networking amongst university academic staff, business people, and government officials in a particular region, nationally or indeed internationally, is seen as very important for the successful commercialisation of university IP. Universities are ideally placed to stimulate collaborative efforts with regard to networking, as universities cooperate with other research institutions, government bodies, as well as with businesses in commerce and industry to form a series of networks. When constructed positively as part of an enabling environment, such networks can become extremely valuable to participants. Patents, for example, may become more valuable when seen not in isolation as an income-producing product earning royalties, but as a negotiation tool in research agreements with businesses in commerce and industry (Thursby *et al.*, 2001).

Henton *et al.* (2002) are of the opinion that networks within regions play a crucial role in the new knowledge economy. Firstly, Henton *et al.* (2002) contend that place has become even more important in the new economy, as skilled and knowledgeable people tend to locate themselves in communities that offer a good quality of life and have important social, cultural, and natural assets. Secondly, they explain that having skills and knowledge similar to those of people living in San Francisco, for example, is key to economic progress. Authors Henton *et al.* (2002) consider the success of San Francisco in making continual leaps across technology waves over four decades. These innovative leaps included integrated circuits in the 1960s, personal computers in the 1970s, software in the 1980s, and the Internet in the 1990s, giving rise to the nickname of the area, namely Silicon Valley (Henton *et al.* (2002). These advances occurred during a time of rising costs, growing competition, and rapid diffusion of technology. Henton *et al.* (2002) conclude that the answer to the success of universities in areas such as San Francisco in California and Austin in Texas lies in the dense and flexible networks of strong relationships between entrepreneurs, venture capitalists, university academic staff, patent lawyers, accountants, and others. Henton *et al.* (2002) further argue that leaders build, connect, and influence social networks to help facilitate the innovation process that leads to the TT process followed by universities.

Friedman and Silberman (2003) also argue that building personal relationships and improving the networking capabilities of academic staff are important in the TT process for universities. Building such relationships and reducing cultural barriers require time and experience. Universities that have an older and more experienced TTO with established networks will generate more and higher yielding license agreements than universities with younger and less experienced TTOs.

Network dynamics are particularly important for new university spin-out companies. The academically orientated personal network is later partly replaced with a market orientated network (Pérez & Sánchez, 2003). Pérez and Sánchez (2003) found in an exploratory study that university spin-outs are dynamic in both TT and network development just after inauguration. VC networks spanning potential suppliers, customers, and service providers, such as lawyers and accountants, also link new university spin-out companies to all these role-players (Garduño, 2004a).

In a study involving 55 interviews with various stakeholders, Siegel *et al.* (2004) found that knowledge transfer works in both directions, and not only from academic staff to industry scientists. In the study, several university academic staff indicated that formal and informal interactions with industry scientists enable them to refine their experiments and sometimes the interactions spark new ideas, leading to more scientific discoveries and more patents. Personal relationships may be more important than contractual relationships in university TT, as participants in the study considered networking between academic staff and their counterparts in commerce and industry (Siegel *et al.*, 2004) as vitally important. Other studies (Friedman & Silberman, 2003; Thursby & Thursby, 2005) also noted that the personal networks of academic staff in promoting innovation and TT between universities and businesses in commerce and industry were imperative in obtaining licensees for newly patented university technologies.

Hatakenaka (2004) concurs with Siegel *et al.* (2004) that social networks may be critical if TTOs want to be successful in their TT efforts. Social networks, unlike markets, support exchanges of information amongst people without competitive pricing and legal contracting. Hatakenaka (2004) adds that well-networked academics are at the heart of the organisational capability of universities and they are able to benefit from knowledge gained in industry, which they in turn can teach to their students. Such networked academics may be well aware of the potential applications of their discoveries by the time they construct them.

In SA, DST (Republic of South Africa: Department of Science and Technology, 2006) points to the fact that the commercialisation of IP is dependent upon constructive relationships (networks) among all role players, and stated that SA universities can exploit the commercialisation opportunities for IP and still preserve their academic integrity. In similar vein, Heher (2006) infers that strong professional networks are very important for academic staff in SA and need to be encouraged and increased.

Kruss (2008) deduces that the growth in networks for universities in SA is supported by an institutional attempt to grow research expertise and increase income derived from the so-called third income stream. Networks are formed when businesses in commerce and industry are willing to form partnerships in alliance with universities in order to satisfy their needs for obtaining knowledge and technology (Kruss, 2008). Lubango and Pouris (2009) agree with Heher (2006) that inventive academic staff members have a stronger network of collaborations that further enhance their careers and successful TT activities. Lubango and Pouris (2009) further state:

> The value of knowledge and technology produced in formal or informal networks of scientists depends on the conjoining of equipment, material resources, organisational and institutional arrangements for work and the unique scientific and technical human capital embodied in individuals.

Alessandrini *et al.* (2013) support Kruss (2008) and insist that SA universities' interest in developing a third income stream is causing SA to enter a "landmark era". The result is that SA universities are increasingly cooperating with other institutions, governmental bodies, and businesses in commerce and industry in SA, thereby forming a series of interrelated networks.

DST will, via suitable means, strengthen networks between R&D orientated government departments such as the Departments of Energy, Environmental Affairs, and HEIs to solidify support to the research effort in SA (RSA: DTI, 2017b). Research cooperation to grow networks will entail the movement of researchers between universities, science councils, and businesses in commerce and industry. RSA: DTI (2017b) maintains that such exchange of academic researchers and entrepreneurs permits for the swap of skills and knowledge whilst funding progressively move over country borders.

Networking between academics and industry counterparts seems to be a critical success factor in achieving positive results in university TT. As can be seen from the literature, networks leading to research partnerships can take many forms and comprise a flexible and easy way for universities to align with a multitude of partners in achieving a common goal. A strong regional network in which academic staff participate is supportive of new license agreements and new university spin-out companies and comprise a key element in the success and development of university IP to be commercialised. Networking is also used by university TTO management and staff, not only to connect academics and students from different faculties, but also academic researchers and scientists of government institutions and the private sector.

4.7 University technology transfer offices (TTOs)

A consequence of the Bayh–Dole Act, and its resultant increase in entrepreneurial activity at universities in patenting and licensing since 1980, has been the setting up of internal technology transfer offices (TTOs) by universities to facilitate the commercialisation of research results emanating from their campuses. In SA, apart from having mandatory IPR policies, the IPR-PFRD Act of 2008 also placed an obligation on SA universities to setup and maintain a TTO and to allocate the responsibilities for managing such an office to a person or existing unit within the university.

OECD (2003:80) defines the concept of a TTO as being:

> … those organisations or parts of an organisation which help the staff at a public research organisation [such as a university] to identify and manage the organisations' intellectual assets, including protecting intellectual property and transferring or licensing rights to other parties to enhance the prospects for further development.

Siegel *et al.* (2004) argue that the primary motive for setting up a university TTO is to safeguard the university's IP and market that IP to businesses in commerce and industry through negotiations between academic staff and entrepreneurs. Siegel *et al*. (2004) and Thursby *et al*. (2001) theorise that the involvement of the university academic often speeds up the TT process and leads to successful negotiation and conclusion of a licence agreement. However, Garduño (2004a) notes that too much involvement by entrepreneurial academics may prove problematic as, while they are experts in their profession, they often lack the business skills necessary to effectively develop the technology into a viable product capable of generating income streams. He noted the success of university TTOs in the United States in establishing spin-out companies and claims that it was their ability to match surrogate entrepreneurs with university academics that brought about the successful commercialisation.

Most TTOs are organised as a separate unit within universities, usually within a university's research administration department. Some universities work according to the 'cradle-to-grave' approach, which entails a single person to be appointed as the primary agent for each new invention. Stanford University's TTO is such an example where this person, once appointed, is responsible for all the stages in the commercialisation process, from review of the invention disclosure to securing the patent protection and then the marketing and licensing thereof. Some universities, however, prefer a team-orientated approach where a different person, with appropriate experience and skill set, handles each different phase of the commercialisation process.

Reichelt (2007) claims that the TTO forms an important link between its university staff, businesses in commerce and industry, and government institutions. TTOs can and should play a vital role in fostering university TT activities, despite operational and management issues that may be challenging at times. Managers at university TTOs should act entrepreneurially and be facilitators between the various parties involved.

HESA (2007) conducted surveys in both 2006 and 2007 and found that most SA universities had only just established TTOs prior to the implementation of the IPR-PFRD Act, and that these were under-staffed. Due to the requirements of the IPR-PFRD Act of 2008, all SA universities had to set up structures (departments or wholly owned companies) as TTOs to discharge the university's obligations and responsibilities in terms of the Act. NIPMO was encouraged to assist universities by providing financial support for setting up TTOs, coordinating their establishment, and training staff to be employed by the TTOs. Management of a TTO and its IP portfolio has become increasingly important and requires a wide range of legal, engineering, economic, financing, taxation, and accounting capabilities and expertise.

The IPR-PFRD Act lists specific functions of a typical university TTO. These functions should be conducted by suitably trained people who have "interdisciplinary knowledge, qualifications and expertise" in identifying, protecting, and commercialising university IP (Republic of South Africa, 2008:8). The list of TTO functions comprises:

- the development and use of a policy for disclosure, protection, commercial exploitation and benefit sharing arrangements on behalf of the university,
- the receipt of new disclosures of IP emanating from publicly funded R&D (research results from research performed on a full cost basis by another party is not included),
- an analysis of the disclosures received by the university to determine their commercial viability, likelihood of successful commercialisation, the existence and terms of the IPR, the protection of the said IP rights in terms of the IPR-PFRD Act,
- dealing with all aspects of transactions in the commercialisation of IP, and
- disclosing IP and liaising with NIPMO, as required by the Act (Republic of South Africa, 2008).

At the time of the HESA surveys in 2006 and 2007, the average TTO had been operating for only three years, and the average number of staff employed was 1.17. Universities without a dedicated TTO used external service providers on a case-by-case basis (Wolson, 2007). An analysis by HESA (2007) of TTOs at United States universities found that most of them are between 8 and 24 years old, the average age being 12 years, and had a median of five staff members. The authors of the report further deduced that the chances of success in university technology transfer increases as TTOs age. In the SA universities survey, HESA (2007) found that SA universities consider technology transfer to be important, but that they simply do not have the human resources to effectively mine, protect, and commercialise the IP created by their academic staff.

Wolson (2007) used anecdotal evidence gathered from TT professionals at four SA universities to conclude broadly that TTOs at SA universities have similar characteristics to those of universities around the globe. In particular

- there is a time lag between the start of a TTO and the point where it receives enough income from TT activities to cover its operational costs, and
- the performance of TTOs at different universities fluctuates widely.

Similarly, Lubango and Pouris (2009) provide evidence to support the claim that TT activities at SA universities are minimal. The authors considered the performance of TTOs at five leading SA universities, being SU, UP, UJ, UCT and NWU. The authors focussed on SA patents registered by these universities from 1996 to 2006, using data from the Companies and Intellectual Property Commission (CIPC) in Pretoria (formerly the Company and Intellectual Property Registration Office [CIPRO]), and also considered the NRF rating (if any) of the academic staff who were patent applicants.

Sibanda (2009) noted that the IPR-PFRD Act of 2008 instructed SA universities to set up TTOs and promoted the establishment of regional TTOs for smaller universities for the sake of cost-effectiveness. Lubango and Pouris (2009) found that 213 patents were obtained by the five universities during this ten-year period, of which 31% were issued to UP, followed by 26.3% to SU, 17. 4% to UJ, 17% to UCT, and 8.5% to NWU.

Data gathered during the SA National Survey of IP and TT at Publicly Funded Research Institutions (RSA: DST *et al.*, 2017) included information on contributions made (inputs), actions performed (activities), yields achieved (outputs), and results obtained (outcomes). The survey was discussed in section 4.2.5 of this study and included feedback received from 24 institutions, of which 23 had established and were running TTOs. Yearly, from 2011 to 2014, a median of 100 new technologies emanated from the 24 institutions (RSA: DST *et al.*, 2017). There was a fourfold increase in the number of licenses executed annually during this period, and interestingly, more than 88% of the licensing income was earned by the four institutions with well-established TTOs.

A total of 45 new spin-out companies were started during the seven-year period, of which 73% (33 spin-outs) were started based on publicly funded IP projects (RSA: DST *et al.*, 2017).

The total number of disclosures increased from 138 to 306 for the period under review and 86% of the 306 disclosures reported for 2014 were based on IP generated by public funds (RSA: DST *et al*, 2017). Similarly, the number of new patent applications increased from 103 in 2008 to 216 in 2014, whilst the data showed that R1.3m on average per annum of shared IP revenue was paid to creators of IP during the period under review (RSA: DST *et al.*, 2017).

Furthermore, the survey found that 53.5% of all employees working within the TTOs had four years or less experience in TT activities, which confirmed that SA had a new and small TT industry (RSA: DST *et al.*, 2017). In response to a question on skills required to fulfill the TT function, TTOs highlighted marketing and administration skills as most needed. Incubation space for new spin-out companies made available by institutions partaking in the survey increased threefold from 2008 to 2014 (RSA: DST *et al.*, 2017).

With regard to staffing of TTOs, Bansi (2016) claims that the literature shows that the number of personnel working at university TTOs does not have a bearing on the success of the commercialisation of university technologies. She asserts that having a bigger portfolio of registered patents does not necessarily result in more licenses. This statement will be tested with the researcher's own findings from interviews conducted at four universities in the Western Cape as part of a case study at each of these institutions and reflected in Chapters 6 to 9 that follow.

It should be emphasised that this section does not intend to provide a comprehensive review of the history of TT activities at all SA universities. Rather, it highlights changes in the legal environment for SA universities after the enactment in 2010 of the IPR-PFRD Act of 2008 and its subsequent effect on the establishment of TTOs at SA universities.

4.8 Conclusion

The conceptual framework contains external and internal enablers, consisting of key dimensions for university TT, which forms the basis for debates in the chapters to come and also for this chapter 4. The first dimension comprises the national and institutional policy environment as part of the enabling environment for university TT. National policy documents of SA, which includes developments in S&T policy with reference to NACI, the NRF, and TIA, are discussed. Institutional policies elaborated upon contains university IP policies.

The second dimension discussed revolves around a discussion on the devotion by university top management towards TT activities, as well as various national institutions in SA in support of TT activities at universities.

The third dimension as enabler for university TT comprises the legislative environment (both external and internal enabler) which is considered in this study, as it relates to IP protection for newly created inventions at universities. The Bayh–Dole Act in the United States, which represented a significant piece of legislation that had a profound effect on university TT in that country, is debated, followed by a deliberation of the Intellectual Property Rights from Publicly Financed Research and Development Act ("IPR-PFRD ACT") in SA**.**

The fourth dimension eluded to in this study is the funding environment. This environment contains propositions on (a) SA's funding schemes for R&D and TTO commercialisation activities, and (b) private equity, venture capital, and angel investors.

The fifth dimension as enabler involves human resources. The discussion of this dimension constitutes (a) incentives for academic staff and students and (b) networks seeking collaboration.

University TTOs, as the resultant operational units envisaged by the national and institutional polices and acting as conduit through which these enablers are directed to achieve the desired outcomes for university TT, is examined next. The examination of TTOs includes the quality and quantity of the enablers as inputs and the usual TT outputs of invention disclosures, patents, licenses and spin-out company formation. The proper functioning of these enablers assists the TTO in the discharge of its responsibilities regarding IP protection and TT activities.

Hopkins (2014) quotes ten reasons why innovation is similar to surfing, among them that most rides of a surfer are not successful, and while it looks simple, it is not.

> Watching surfers gracefully yet boldly ride monster waves is breath-taking. You see first-hand how seemingly at ease they are before and after the ride. Onshore there are plenty of high fives but there's also a cool nonchalance about them. It almost makes you think, "I could do that". Until you try it. When you emerge half-drowned, board-scraped, bruised and beaten it becomes clear…this is no amateur sport. It requires endless practice and patience. Innovation is like that too. Done well it seems simple. But underneath the simplicity is an incredible amount of hard work, smart experiments, and spills that require us to get back up on that board and go again (Hopkins, 2014).

A cultural environment reflecting a strong institutional commitment is needed that is conducive to promoting and increasing the propensity of academic staff to disclose their findings and to seek commercialisation thereof. References were made to the commitment of the central management within universities, financial incentives for academic staff and networks maintained by them to foster technology transfer. A strong commitment by the central university management has shown to be beneficial to university technology transfer (Henton *et al.*, 2002).

Surveys of TTOs in the United States (Jensen & Thursby, 2001) revealed that the commercialisation of university research findings require the continuing involvement of academic inventors as participants. In one survey, Jensen and Thursby (2001) found evidence that at least 71% of inventions require further involvement by the academic researcher if they are to be successfully commercialised. Thursby and Thursby (2003) found that academic staff expected to be adequately compensated when adding value through the ongoing development of technologies destined for the marketplace. Many respondents in a study by Siegel *et al.* (2004) asserted that activities in technology transfer should have a greater weight in promotion and tenure decisions of academic staff. Debackere and Veugelers (2005), Pérez and Sánchez (2003) and Henton *et al.* (2002) all agreed that many informal contacts and personal networks between academic staff of universities and scientists in commerce and industry support the multitude of formal relationships involved in the innovation process. Innovation supports the TT process, as it adds to prior research results to create more valuable intellectual property assets, or even products.

Some international agreements on the protection of IP were quoted in section 4.3 before an in-depth analysis of the effects of the promulgation of the Bayh–Dole Act of 1980 in the United States as part of the legislative environment was provided. The success of the implementation of Bayh–Dole was examined with reference to proponents and critics of the act. Various studies (Goldfarb & Henrekson, 2003; Sampat, 2006) supported the notion that Bayh–Dole and other legislation in the United States promoted the protection of university IP and aided the legislative environment that was required to fuel commercialisation efforts of US universities. The certainty offered by the implementation of Bayh–Dole allowed academic staff at US universities to benefit financially from their inventions through the process of university technology transfer. Consequently, university technology transfer in the United States thrived since the implementation of Bayh–Dole and led to a surge in patent applications (Association of University Technology Managers (AUTM), 2011, 2014; Garduño, 2004a; Thursby & Thursby, 2003).

Due to Bayh–Dole, universities adopted IP policies to regulate TT activities on their campuses. The IP policies were enforced by university technology transfer offices in the United States and were set up to safeguard and facilitate the commercialisation of new inventions of academics and students. Because of the success of Bayh–Dole, many countries across the world enacted similar laws and universities in those countries adopted comparable IP policies. Recent developments in South Africa with regard to intellectual property rights from publicly funded research at universities will be considered comprehensively in Chapter 5.

The funding environment, as the third key enabler, was discussed with reference to funding for research and the need for seed funding for early-stage technologies. Seed funding is primarily provided by venture capitalists and angel investors. Basic research, which forms the building blocks for applied research, is mostly funded by government (Dai *et al.*, 2005), whilst applied research is mainly funded by businesses in commerce and industry who seek to obtain direct financial benefit at the earliest opportunity. Garduño (2004b) opines that developing countries spend much less on basic and applied research than developed countries and, as a result, universities in developing countries often struggle to find licensees or buyers for their patented technology. Hence, Garduño (2004b) proposes that developing countries should prefer creating spin-out companies in the absence of a market to license such technologies from their universities. Heher (2006) supports the idea of creating spin-out companies in what he calls the economic model. Funding for early-stage technologies provided by venture capital companies and angel investors has proved to be important for the success in the transfer of university technologies in the United States for which licensees could not easily be found. Often, a patent or particular know-how is commercialised by university spin-out companies set up for this purpose. Funds invested by venture capitalists and/or angel investors are used to bolster the success of these newly created spin-out companies.

Heher (2005, 2006) discussed benchmark data from the United States, Canada, the United Kingdom, Europe and Australia. The data used illustrated that TT activities can be a major source of income for universities globally if blockbuster patents or inventions were established. However, most TTOs at universities break even or make losses, and the same may be true for SA universities in the future. Heher (2006), like many other authors, points to the lack of funding for fundamental (basic) research in SA by the SA government and argues that such funding should be increased significantly. Technology transfer at SA universities is the subject matter of Chapter 5 of this study, where it is elucidated in all of the sections.

Chapter 5: Research design and methodology of the study

5.1 Introduction

The purpose of this study was to gain a better understanding of the concept of IP in general and the importance of effective commercialisation for SA universities. Academic staff, students, and university TT managers could benefit from this study by evaluating their own structures and procedures. This chapter comprises the research design and methodology used for the study to address the research objectives and answer the main empirical research question.

The main research question of this study is addressed by determining how effective four SA universities have been in commercialising their IP assets through the use of TT practices. These universities are Stellenbosch University (SU), Cape Town University (UCT), the University of the Western Cape (UWC), and Cape Peninsula University of Technology (CPUT), all located in the Western Cape, SA, which is a developing country. This section provides the reader with a brief introduction to Chapter 5 and sets the scene for the sections to come.

5.2 Deciding on an appropriate research design

The research paradigm of this study is descriptive and explanatory. The phenomenon is being studied within the context of historical, social, political, and economic conditions. A research design is described by Mouton (2001:55) as a "plan" or "blueprint" of how the intended study will be conducted. Similarly, Yin (2009:24) asserts that a research design is "*the logic that links the data to be collected to the initial questions of the study*". (Yin, 2014:28) later added:

> Colloquially, a research design is a logical plan for getting from here to there, where here may be defined as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions.

Mouton (2001) highlights the differences between research designs and research methodology. Research design, he asserts, focuses on the kind of study being planned, while the research methodology focuses on the process to be followed and the tools to be used. Mouton states that the point of departure for research designs is a research problem (or question), whereas the starting point for the research methodology is the specific tasks (such as data collection) to be done. Mouton (2001) further advocates that research designs concentrate on what kind of evidence is needed to address the research question, while the research methodology focuses on the specific steps in the research process and the impartial measures that should be used to lead to valid conclusions.

In this study, textual and numeric primary and secondary data were used as part of an empirical ethnographic research inquiry strategy. The inquiry strategy used multiple, embedded case studies and a mix of qualitative and quantitative research approaches for describing and analysing existing data. Mouton (2001:149) describes case studies as part of an ethnographic research approach as those studies that "... aim to provide an in-depth description of a small number (less than 50) of cases". In this study, we evaluate and describe TT practices at four universities as HEIs that are involved in TT activities in the Western Cape, SA.

The results of the TT activities from 2008 to 2015 for the four universities were obtained as secondary quantitative data and then used in a descriptive analysis of each university. Primary data was collected from the universities by developing a qualitative survey questionnaire that was used as questions for interviewees to evaluate the effective use of TT practices by the TTOs of the four universities. The resultant overall research design is descriptive and evaluative in nature, using inductive reasoning. The chosen data are functional and represent the latest information available.

Secondary data were obtained from scholars who have published in this field. The data were used particularly in the literature review chapters. The use of secondary data provides a useful background and historical data of the subject matter. It is also inexpensive, reliable, and can easily be used in data analysis. The limitation of using secondary data is that it may not be applicable to the specific population being studied.

The case-study evaluations followed a two-stage design approach. The first phase used secondary data sources, mainly from a national TT survey conducted by the Centre for Science, Technology and Innovation Indicators (CeSTII) of the Human Sciences Research Council (HSRC) in March 2016, HEMIS (Higher Education Management Information System) records, and HSRC National R&D Surveys for the years 2008 to 2014. Data from the year 2015 were obtained from the four universities and analysed to describe the performance of technology transfer activities at these four universities. The design for stage 2 entailed an analysis and evaluation of semi-structured open-ended questions, used in sixteen interviews conducted at the four universities. The reasons for selecting the four universities as part of an embedded, multiple case-study design were:

- These universities are prime examples for examining technology-transfer activities as their research outputs place them among the top universities in SA.
- Two of the four universities are considered historically advantaged universities and the other two are regarded as historically disadvantaged universities.
- The cases could be studied in depth.
- Frequent contact was possible with the staff at the TTOs of these universities.
- The researcher resides in the Western Cape, where the four universities are located.
- The researcher had personal experience of the subject matter, having worked in the TTO of Stellenbosch University from the start of 2000 to the end of 2005.

The results obtained from the four case studies were used to evaluate the effectiveness of TT activities at these universities against the main aims set by the IPR-PFRD Act. Empirical research conducted by Scherer and Harhoff (2000) indicated that a small number of inventions may account for almost all the total economic value being created for a university. Due to the nature of innovation and the reported skewness of the results of the performance of university TTOs in developed and developing countries (Scherer & Harhoff, 2000), it was expected that the results for the four universities could be similarly skewed. Differences in the cultural history and economic background of historically advantaged universities compared to historically disadvantaged universities were very likely to accentuate this skewness.

A mix of research methods was used in this study, which culminated in the four embedded multiple case studies. Mixed methods research considers many perspectives and includes both qualitative and quantitative research approaches (Johnson, Onwuegbuzie & Turner, 2007). Johnson *et al*. (2007) define mixed research methods as "*an intellectual and practical synthesis based on qualitative and quantitative research*". Yin (2009) argues that mixed method research allows researchers to answer more involved research questions and compile stronger evidence than when using a single method.

The strength of case studies is that they provide the reader with detailed quantitative and qualitative information, over many years, about the phenomenon being studied. Case studies are often used in explanatory research and can assist in generating new ideas. Case studies are also versatile and flexible, and are used extensively within the social sciences and education (Rule & Vaughn, 2011). Another benefit and strength of case studies is that insights gained during the study can be used for further research.

The main weaknesses of using case studies as research design are that the results can often not be generalised to a wider population, and that researcher bias may influence the outcome. Case studies are mostly difficult to replicate and can also be time consuming. Compared to surveys, which are usually quantitative in nature, case studies are often characterised as qualitative and small-scale (Rule & Vaughn, 2011).

Alessandrini *et al.* (2013) collected data by way of a survey questionnaire as well as structured face-to-face interviews with dedicated TT managers at thirteen SA universities. The authors found that participants were suffering from a degree of survey-fatigue, following the drafting and implementation of the IPR-PFRD Act 51 of 2008 in SA in 2010. Alessandrini *et al.* (2013) structured their questionnaire to evaluate three issues for university TTOs in SA, namely:

- organisational structures,
- factors influencing the success of technology transfer in SA, and
- the current measurements of success.

Yin (2014:4) asserts that case-study research is the most suitable method to use in answering "how" or "why" research questions about a contemporary set of events over which we have little or no control. Yin (2014:16) considered many definitions for case studies and finally concludes in the first instance that a case study is an empirical inquiry that:

- investigates a contemporary phenomenon in depth and within its real-life context, especially when
- the boundaries between phenomenon and context are not clear.

Moreover, the case study inquiry:

- copes with the technically distinctive situation in which there will be many more variables of interest than data points,
- relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and
- benefits from the prior development of theoretical propositions to guide data collection and analysis (Yin, 2014:17).

A case study is a holistic design and can be presented, either as a design variant where little or no sub-units can be identified, or as an embedded case-study design (Yin, 2014) when either quantitative data or qualitative information gathered is "embedded within a larger design" (Creswell, 2014:16). Yin (2014) mentions that the short-comings of a holistic design are that the study may firstly be performed in an overly abstract manner and not measure enough data. Secondly, the character of the case study may change during the course of the study without the knowledge of the researcher. Yin (2014) also notes that the drawback of an embedded design is that the focus of the researcher may remain on the sub-unit level and neglect to return to the broader level of analysis.

Creswell (2014:228) refers to an *embedded mixed methods design* as one that "nests one or more forms of data (quantitative or qualitative or both) within a larger design". Yin (2014:238) similarly states that an embedded unit of analysis comprises "a unit lesser than the main unit of analysis, from which case study data are collected". In this study, the university TTO forms the unit of analysis from which data are obtained, and which is directly related to the quality and quantity of research being conducted by staff and students within the larger university campus.

Finally, Yin (2014) notes that evaluative case studies are used to clarify the circumstances in cases where the subject field being studied has no obvious result. The author also notes that evidence from multiple cases is frequently reckoned to be more convincing than that from single case studies. The embedded mixed-method research paradigm of using both quantitative data and qualitative questions (Creswell, 2014) posed to the TTOs of Western Cape universities in SA, and culminating in four separate, embedded case studies, was considered to be the most appropriate research design for this study. The case studies first describe the institutional history and research environment at each institution and then evaluate the effectiveness of technology transfer practices followed by the respective TTOs at each of the four universities. The next section describes how the research design is implemented using methodological processes.

5.3 Methodology followed in the application of the research design

5.3.1 Research instruments chosen to obtain data for analysis

This methodology section explains the detail of how the research design was applied and executed. It comprises the justification for the selection of research instruments, data, and the analysis of that data. The aim of this section is to convince the reader that the chosen research instruments, the data collected, and the analysis thereof were sufficient to answer the main research question. It must be noted that the unit of analysis is the TTO at each of the four SA universities in the Western Cape, and not the units of data that were collected using one or more of the research instruments that are described below.

Following from the discussion and the selection of the research design above, this section describes the use of the chosen research design to answer the research objectives and the main research question. Notably, this section deals primarily with research instruments used in "*the measurement of key variables of the study*" (Mouton, 2001:123).

Apart from data collected from secondary sources, (data obtained from university publications, HSRC surveys, and scholarly articles published in accredited journals), the following research instruments were chosen and utilised in the four embedded case studies for this descriptive and evaluative study. The quantitative data obtained informed the interview schedule questions and both sets were used as the main research instruments of this study. Quantitative data, covering the seven years from 2008 to 2014, were obtained from CeSTII with the permission of the four participating universities, while data from the year 2015 were obtained from the four universities directly. All the data were compared to HEMIS reports and HSRC reports. A number of open-ended qualitative questions were also posed to top management and researchers at each of the four universities. The interview schedules were compiled after the quantitative data were obtained and analysed.

The principle agents and institutions for university technology transfer were identified by Siegel and Phan (2005) as being university scientists, industry scientists interacting with them, industry-university research centres, university TTOs, science parks, incubators, and venture capital firms. The authors noted the output of TT activities as being invention disclosures, patents filed and registered, licensing agreements, licensing revenue earned, research productivity of university and industry scientists, spin-out company formation, survival of spin-out companies, and employment creation.

Due to the significance of patent statistics, the number of patent applications filed in SA, Patent Co-operation Treaty (PCT) patents filed in PCT member countries, and foreign patents filed were included in the list of the secondary quantitative data sets obtained from the HSRC reports. Other quantitative data items, apart from the output statistics of TT, include the total number of students, academic staff, and publications by academics in peer-reviewed journals and the total expenditure of each participating university on R&D costs. The data for these categories were obtained from the CesTII survey reports, HEMIS records, and SA national surveys of research and experimental development that are compiled annually.

The purpose of data gathered from the quantitative data sources was to obtain recent TT output statistics from the four participating universities and the performance of their TTOs. The quantitative data items, when considered together, were selected to best evaluate the TTOs at the chosen universities. The results of the quantitative data collected from the secondary data sources were considered to be reliable, as the data originated from data submitted by the TTOs of the four universities to CeSTII early in 2016. The results were analysed, interpreted and evaluated to enable the researcher to finalise the interview questions and to draw conclusions and make recommendations to best address the research objectives and the main research question of this study.

The qualitative questions posed to staff of the universities pertain to the enabling environment and effective use of TT practices by the university TTOs. The open-ended qualitative questions were answered by top management, academics, and researchers of the four universities. The qualitative questions posed during in-person interviews provided participants with an opportunity to expand on issues relating to their experience of TTO practices employed at their university.

A flaw of qualitative questionnaires is that the questions may be biased in favour of the participant. Conversely, the strength of these specific questions was that they are in line with questions from similar studies at universities across the globe and was explicitly chosen to avoid any potential bias to participants. Another weakness of the questions chosen is that they may not fully cover all the activities typically performed by staff in a TTO. However, the questions were considered to be adequate for drawing reliable conclusions in support of the quantitative data obtained. Data used in the study are discussed in the next section.

5.3.2 Data used in this study

Secondary quantitative data gathered as the first research instrument represents the actual performances of the selected universities over eight years, from 2008 to 2015. The collection of the said data was limited to available secondary data in the public domain plus key primary-data performance indicators obtained from CesTII, HEMIS, and HSRC reports. Of the four selected universities, two universities had had established TTOs for many years, while the remaining two had launched their university TTOs only recently.

The collection of quantitative data was limited to eight years, starting from 2008, as it made no sense to go back further, considering that two of the four universities only recently established since the start op their TTO operation. Data for these two universities, being the University of the Western Cape and the Cape Peninsula University of Technology, was for the most recent years up to 2015, as they do not have data going back to 2008. Thus, the period of eight years was considered to be sufficient for drawing meaningful conclusions from the results. At least two of the four universities have TTOs that are similar in age and size. Moreover, the quality of the secondary data was expected to be valid and reliable, as it was obtained from reputable information systems providers and national surveys conducted by reputable government institutions in SA. The quantitative data obtained via CesTII is considered equally reliable, as it was submitted by the participating universities to CesTII directly.

In addition to the quantitative statistics obtained, in-person interviews were used to solicit answers to the open-ended qualitative questions from top management and senior research staff members at these universities. It was anticipated that the answers from the qualitative questions could be used to draw reliable conclusions for all four participating universities.

Although the data collected by both the research instruments could not claim to be representative of the entire population of TTOs in SA, the data should accurately display the characteristics of TT practices used by the participating universities. These four universities do represent a significant portion of the total research being conducted at SA universities when measured according to the combined total R&D expenditure at these universities. Despite their limitations, the quantitative data obtained and the in-person interviews as research instruments were considered adequate to arrive at valid and useful conclusions for this study. Other sources of evidence were also used to inform the case studies. These sources included, but are not limited to, documentation, archival records, direct observations, and more in-depth interviews with support staff at the TTOs of the respective universities.

5.3.3 Analysis of the data of key technology transfer variables

The data collected from the quantitative data sourced for the eight years starting from 2008 to 2015 was checked for reliability before being analysed and used to calculate key ratios for each university. Once analysed, the evidence gathered for each university and the ratios that were calculated were used to inform the qualitative interview questions and to evaluate and ascertain the relative performance of TT activities of the participating universities.

Whereas some questions were closed, most were open-ended, which allowed respondents to express themselves freely. Answers received from the qualitative interview questions were checked to ensure that participants had understood each question that was asked. Differences in the institutional commitment as part of the enabling environment were anticipated to significantly affect a university's performance in TT activities and may explain variations in the data received from the four participating universities. In addition, differences between the incentives offered to academic staff of the participating universities were also noted and examined.

One of the shortcomings of obtaining the secondary quantitative data is that we do not interact with or observe the respondent in the answering of the questions. Once the data of participating universities were attained, it was evaluated to see if there were any common trends which could be of value to these universities collectively, seeing that they are in close proximity to each other. As with many other research methods, the organising and documenting of data collected for a case study should culminate in a case-study database (Yin, 2014). A database was therefore compiled for recording the data acquired for each of the four universities.

This section highlighted the data collection and data analysis for this study. Secondary data were acquired from reliable sources and primary data from interviews as part of an embedded, multiple-case study, mixed-method approach. Next, the limitations of using a mixed-method research design for this study is evaluated.

5.4 Limitation of the use of research instruments and data collected

A limitation of the use of quantitative data obtained is that the trends obtained from the data for each university may be misleading, since there is a time lag between the setting up of TTOs by universities and the results they achieved in their TT commercialisation effort. The time lag usually occurs due to TTOs first having to gain the trust of academic staff in the commercialisation process before they are likely to disclose their novel research findings.

Another limitation of the quantitative data obtained is that a key variable could have been left out when compiling the list of data items. However, the researcher is confident that the list is complete and adequate for the purpose of answering the research objectives and the main research question of this study.

A limitation of the qualitative interview questions is that the questions may be seen to be biased towards the two larger research orientated universities in the group of four universities chosen. The rationale for choosing these questions is simply that they originate from the large volume of literature available globally on this topic and ought to lead to reliable answers for this study. On a broader level, the fact that SU and UCT, as two of the largest and historically advantaged universities in SA, were used as part of the multiple-case study approach may influence its relevance and comparability to the other two previously disadvantaged universities, being UWC and CPUT, located in the same geographical region.

Most previously disadvantaged universities in SA only recently started commercialising IP emanating from their campuses and have fairly inexperienced staff at their newly created TTOs. Many authors (Alessandrini *et al.*, 2013; Heher, 2006; Wolson, 2007) argue that a strong pipeline of new-invention disclosures received over many years is necessary for a steady stream of income to be generated by a university. It is evident that SU and UCT, being the two larger universities and having some of the oldest TTOs in SA, would benefit from having longer pipelines of invention disclosures. However, it remains to be seen from the research results if this is true and to what extent (if any) the older TTOs received more disclosures than the younger ones in recent years. Of particular interest will be to see what impact (if any) the enactment of the IPR-PFRD Act had on TT activities at the four universities since implementation of the act in 2010.

5.5 Interviews with academic inventors and university top management

5.5.1 Selection of interviewees

A total of twenty academic staff members as researchers and top management officials were approached at the four universities to avail themselves to answer the qualitative questionnaire of which sixteen (80%) agreed to be interviewed and were interviewed. The chosen interviewees represented a wide range of age demographics and included young researchers as well as seasoned, well respected academics that are experts in their fields of study.

5.5.2 Interview questions

The interview questions were developed to cover the four broad themes. The first three areas focused on the enabling environment necessary for effective TT and dealt with the cultural, legislative, and economic aspects affecting university TT. Five dimensions were discussed with interviewees as derived from the conceptual analysis in section 3.3 of this study. The first dimension considers the policy environment affecting university TT in SA. The second dimension relates to the institutional commitment. The third dimension involves the legal setting and consists of questions pertaining to IP policy, the IPR-PFRD act, and TTO support services. The fourth dimension embraces the funding environs that encompass questions relating to funding for TTO commercialisation activities and TT as income driver. The fifth theme includes human resources and is followed lastly by general questions concerning TT practices.

All questions formulated and interviews conducted were directed in English. The specific questions posed to both top management and academic staff at the respective universities are:

The policy dimension

1) IP Policy

a) Are you aware of the university's IP policy and its contents?

b) If YES, what are your views on the policy?

The institutional commitment

1. Commitment by university management

a) Would you describe the institutional commitment from the central university management (top management) towards TT activities on your campus as strong or weak?

b) How is institutional commitment demonstrated at your university?

c) (1) What motivated you to commercialise your research results?

   (2) What motivated the university to engage in TT activities?

d) How are the services of the TTO advertised/promoted on campus?

2. Organisational challenges

a) What are the managerial challenges to TT at your university?

b) How can organisational factors and managerial behaviours be changed to better facilitate effective TT practices at your university?

3) TTO relationship

a) Would you describe the relationship between you and TTO staff of the university as trustworthy?

b) How can the relationship be improved?

c) Are you satisfied with the services offered by the TTO?

The legal dimension

1) IPR-PFRD Act 51 of 2008

a) Are you aware of the IPR-PFRD Act 51 of 2008 in SA that now compels universities to protect newly created IP and commercialise it?

b) If YES, what is your opinion on the act?

2) Legal and TTO support services

a) How would you describe the legal and support services that you receive from the university TTO?

b) Are there areas where you feel that TTO staff could have done better in safeguarding IP created by academics and/or its commercialisation?

c) Would you recommend the TTO's services to fellow academics and students? Why/why not?

The Funding dimension

1. Funding for research

a) Describe the efforts by academics to secure funding for new research projects.

b) Should the university or the TTO staff assist academics to secure funds for research?

2. Funding for start-up businesses

How, if at all, does the university TTO stimulate interaction between academics and the following interest groups?

a) entrepreneurs

b) venture capitalists

c) angel investors

d) governmental funding agencies

3. TT as income driver

a) Do you believe that TT can be a major source of income for academics, the department where the academic resides, and the university?

b) Do you believe that the financial gains from TT activities should benefit the inventors mostly, or should it mostly benefit the public at large, which includes the university?

The Human resource dimension

1. Incentives

a) Have TT activities affected the promotion of academics or their career trajectory at the university? If so, how is it affected?

b) What other incentives (if any) are used to motivate academics to engage in TT activities?

c) Which rewards would you like to see implemented to increase the willingness of academics to disclose new findings and seek commercialisation for those findings?

2. Networks/linkages

How does the university TTO stimulate your interaction with the following groups to develop linkages?

a) other academics and students

b) governmental scientists and laboratories

c) businesses in commerce and industry

The Technology transfer office

1. TT practices

a) How do you define success in university technology transfer activities?

b) Which activity of TT are the academics mostly involved with (e.g. patenting, licencing or spin-out company formation)?

c) What do you like or dislike most regarding TT practices? Why?

2. Successful TT participation

a) What do the successes that you as academic/your university have achieved in TT mean to you?

b) What type of advice and support received from the TTO was most helpful to you? Why?

5.5.3 Procedure followed

Each selected academic staff member as researcher or top management official at the selected universities received a request via e-mail for a face-to-face interview. The reason for the interview was briefly described and a 40-minute time slot, suitable to the respondent's timetable and availability, was requested.

At the start of each interview the academic staff member/top management official was thanked for making time available to partake in this study. None of the participants objected to the interview being recorded. The voice recorder of a digital device generating electronic (wave sound) files was used to record the interviews. The interviews lasted between 30-40 minutes with the average duration being 35 minutes. All sixteen interviews were conducted in English and during normal office hours. A number of interviews had to be rescheduled as unforeseen circumstances prevented the particular academic staff member/top management official from completing the interview as planned. The interviews were conducted between September 2016 and March 2017.

5.5.4 Analysis of Interviews

The electronic files of the interviews were transcribed verbatim in MS Word. The resultant transcripts ranged between fifteen to twenty pages per interview. In examining the text of each transcript, consideration was given to identifying the five dimensions described above. Often, answers provided by the participants led to follow-up questions posed. The answers to these questions were also studied for its contribution and possible inclusion in the overall analysis. Answers were copied and pasted in a new MS Word document, from where it was incorporated into fuller descriptions to inform the case study chapters of the four chosen universities. Respondents for all interviews were identified by a combination of alpha numeric references to retain anonymity where their answers were quoted as text in this study.

5.6 Conclusion

This chapter discussed the research design and research methodology followed in the study. The type of research design selected is descriptive and explanatory, and uses an embedded, mixed-method approach, comprising both quantitative and qualitative aspects that resulted in four separate (multiple) case studies (one for each participating university in the Western Cape, SA). Secondary quantitative data was obtained from a CesTII survey report conducted in 2016, the participating universities, HEMIS records, and HSRC National R&D Surveys of R&D for the years 2008 to 2015 and were used throughout sections of the case study chapters. The secondary data obtained and in-person interviews were used as research instruments for this study. The strengths, weaknesses and limitations of the research design, research instruments, and the data collected were stated and discussed. The chosen interviewees represented university staff from top management and university academics that are respected experts in their fields and who have had experience in TT activities on their campus.

The quantitative data obtained and in-person interviews were analysed and evaluated to inform the major part of the research design, which comprised multiple case studies of the performance of the TTOs as an embedded unit of analysis within each of the four selected universities. Section 5.3.2 describes the types of data collected and also the method of collection, whilst section 5.4 highlights the limitations of the use of the research instruments selected and of collected data. Section 5.5 explains the selection of interviewees, the interview process, and the interview questions in detail.

Chapter 6: Stellenbosch University (SU) – A case study

6.1 Brief history and research capacity

Mentioned in the annual report of Stellenbosch University in 1997 was a wine yeast called VIN13 that was developed by the department of Microbiology at the university as well as the Hysucat patent system developed by the department of Mechanical Engeneering (US, 1997). This was before the technology transfer office was established by the university in 1999 and signified the very early beginnings for the university of protecting its IP and then seeking to commercialise it (SU, 1997).

The mission of the university at the start of the new millennium stated:

> In a spirit of academic freedom and of the universal quest for truth and knowledge, the University as an academic institution sets itself the aim, through critical and rational thought, ... of being relevant to the needs of the community, taking into consideration the needs of SA in particular and of Africa and the world in general (Stellenbosch University (SU), 2000:9).

SU changed its slogan in 2000 to read "your knowledge partner", whilst the motto on its coat of arms remained to be “*Pectora roborant cultus recti”* meaning "A true education builds inner strength" (Stellenbosch University (SU), 2002).

Prof Chris H Brink was appointed the new Rector and Vice-Chancellor from 1 January 2002 and he reshuffled the management team. Prof Liesbeth Botha was appointed as Manager: Innovation and headed the team that was responsible for the commercialisation of the university’s knowledge base (SU, 2002). The year 2002 saw increased enrolments for postgraduate students from Africa and contributed to the percentage of black, Indian, and coloured students increasing from 27.5% in 2001 to 29.4% of the total number of registered students in 2002 (SU, 2002). SU gained a reputation for being an excellent research partner and in the six years leading up to 2002, SU received most of the funding from the NRF under the THRIP funding scheme (SU, 2002). Good progress was made in the development and promotion of the Stellenbosch Institute for Advanced Study (STIAS) which attracts renowned specialist academics and scholars from around the world

Looking back further, the university was initially called the Stellenbosch College and was founded in 1881 with only 4 professors giving lectures (Thom, 2005). The college first awarded diplomas to students in 1884 and the name of the college was changed shortly afterwards to the Victoria College with permission from her majesty the Queen of England (Thom, 2005). Scholars could matriculate at the institution and pursue tertiary studies, but from 1900 only tertiary studies were offered. The initial mission of the college was to teach education and produce teachers of high caliber for SA. Mr Jannie H Marais bequeathed £100,000 to the College with his passing in 1915, which laid the foundation for the establishment of a fully-fledged university (Thom, 2005). The then Union of SA Parliament proclaimed Act no 13 of 1916 (known as the University Act) that paved the way for the renaming of the Victoria College to Stellenbosch University (SU) and the conversion of the college to a university. On 2 April 1918, a number of laws regulating Higher Education in SA came into effect, which finally established SU along with UCT and UNISA as the only universities of higher learning at the time (Thom, 2005).

Research profile at SU

SU is positioning itself to be the foremost research-intensive university on the African continent. The university aligned its research efforts to SA national and international development objectives in striving to be a planner of hope for SA and Africa (SU, 2010). By 2013, SU had over 10 000 postgraduate students, representing 35% of the total student body (Stellenbosch University (SU), 2013). During the 2013 academic year, the university also had 316 scientists rated by the NRF of which 12 were A-rated scientists, whilst over 2 500 active research contracts were active that included more than 70 joint projects with national science councils in SA (SU, 2013a). In 2013, SU's student population reached 28 000 (including 3 000 foreign students), and the university had an instructional staff component of 939 and some 50 research and service units (SU, 2013b).

Figure 6.1 depicts that the total R&D expenditure at SU increased by 171.4% for the years 2008 to 2015, compared to an increase of 24.1% of instructional staff (Figure 6.2) over the same period.

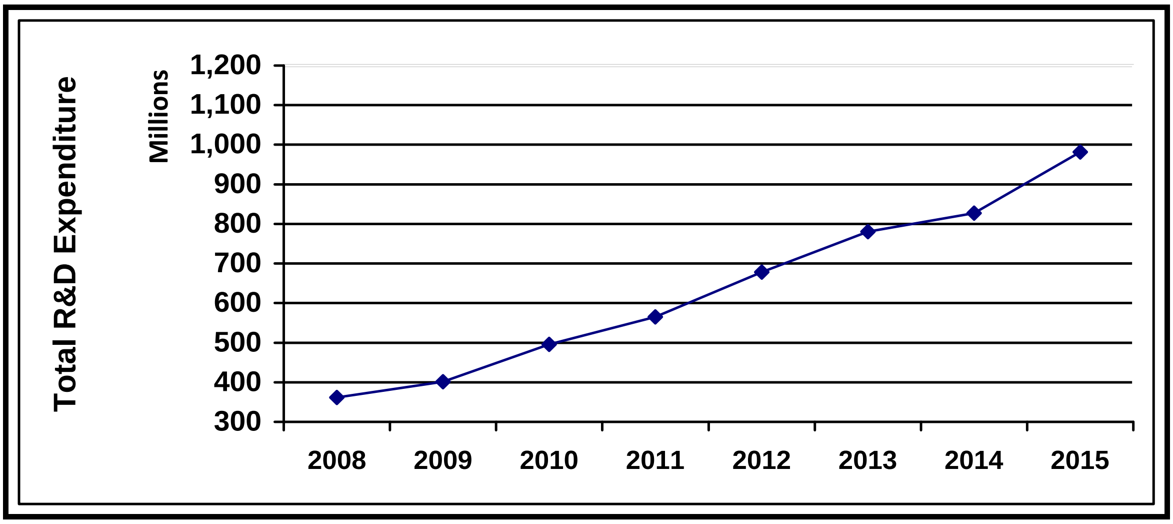


FIGURE 6.1: SU TOTAL RESEARCH AND DEVELOPMENT EXPENDITURE
Source: SA National R&D Survey Reports (2008 to 2015)

Figure 6.2 shows the increase (30.7%) in the student population that have fulfilled the requirements for a degree at the university for the years 2008 to 2015, from 5 978 to 7 816, whilst the number of instructional staff members increased modestly (by 24.1%) from 867 in 2008 to reach 1 076 by the year 2015.

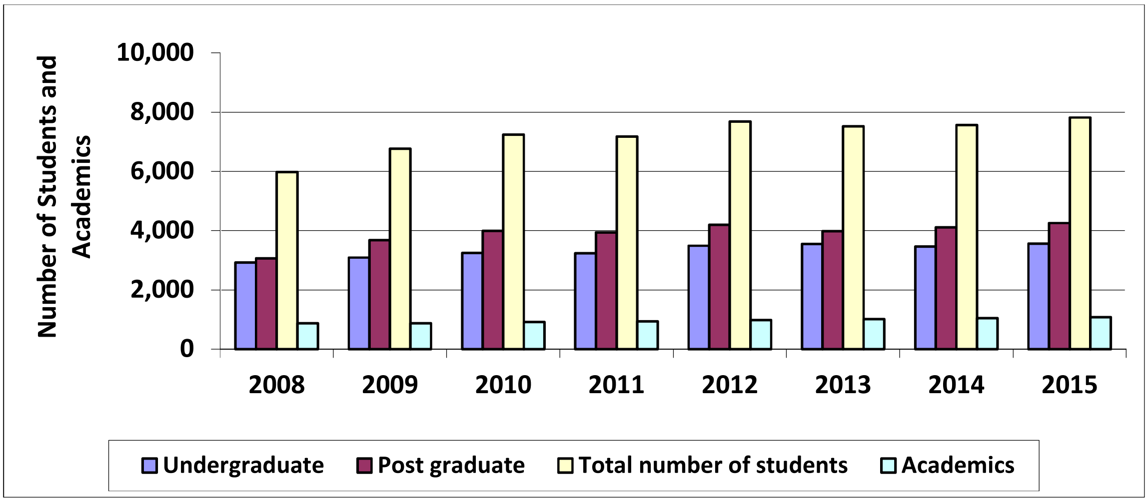


FIGURE 6.2: SU TOTAL NUMBER OF STUDENTS AND INSTRUCTIONAL STAFF
Source: HEMIS Tables (Republic of South Africa: Department of Higher Education and Training, 2015).

The period from 2008 to 2015 was selected for the unit of analysis for the study. Looking beyond the period ending 2015 for SU, however, one finds that the number of staff members at SU that obtained NRF evaluation status reached 457 by May 2018 representing 95% growth in this figure from 2008 to 2018 and making it one of the key research orientated universities in SA (Stellenbosch University (SU), 2018b). Postgraduate students at SU comprised 33% of the student population, which included more than 3 000 foreign nationals from over 100 countries registered as students for the academic year 2017, of which 97% came from African countries (SU, 2018b).

Research infrastructure: Centres of Excellence and SARChi Chairs

At the forefront of SU's research distinction and global engagement are the university's centres of excellences (CoEs). The levels of funding for research chairs were R2.5m and R1.5m per annum initially for Tier 1 and Tier 2 correspondingly (National Research Foundation (NRF), 2015). The funding provided was meant for the salary of the chair holder, postdoctoral fellowships, postgraduate student bursaries, operating costs, small items of equipment, and limited administrative and technical support, within predetermined confines. The intervention was intended to lure new research capacity into public universities, and to retain those researchers that are already at the universities. Another aim was to attract about 60% of research candidates from other countries and the remaining 40% from within SA. Foreign candidates may include African scholars and SA citizens in other countries (NRF, 2015).

The DST CoEs at SU are the Centre for Invasion Biology (CIB), the Centre for Epidemiological Modelling and Analysis (SACEMA), the Centre for Biomedical TB Research (CBTBR), and the Centre for Scientometrics and Science Policy (SciSTIP) (Stellenbosch University (SU), 2017a). The other three national centres include the DST-NRF Centre for Renewable and Sustainable Energy Studies (CRSES), the Stellenbosch University Water Institute (SUWI), and the National Institute for Theoretical Physics (NiThep) (SU, 2017a). SU was awarded five new research chairs in 2015 through SARChI, funded by DST. The research chairs hosted by SU are strategically positioned around specific research areas where SU is seen as a leader in the field and where existing resources and capacity exist for a focused knowledge and human resource intervention (SU, 2017a). By 2017, SU held 38 chairs, of which 24 are within SARChI, funded by DST through the NRF (Stellenbosch University (SU), 2017b).

Output: Research publications

Mouton (2014) intimates that research outputs are a very good indicator of research activities for a university. Mouton (2014) also records the distinction between full paper and fractional counts as being tied to single or multi-authored research articles. In the case of full paper counts, each paper is counted as a unit, whether it has one or many authors (Mouton, 2014). Fractional counts, on the other hand, take into account the fact that a paper could have one or many authors and only those authors linked to SA universities are included. Full paper counts are used when compiling international ranking lists and fractional units are used by DHET in SA to apply the research funding framework (Mouton, 2014).

TABLE 6.1: SU NUMBER OF RESEARCH PUBLICATIONS IN PEER-REVIEWED JOURNALS

	2008	2009	2010	2011	2012	2013	2014	2015
Articles	879.6	947.2	894.9	1,048.1	1,158.7	1,244.9	1,334.6	1,256.0
Books / Chapters	24.7	53.8	54.9	34.2	91.6	105.4	116.3	78.0
Conference Proceedings	44.2	50.5	85.0	66.0	73.1	126.7	103.5	82.6
Masters Graduates	542	540	613	638	939	840	883	924
Doctoral Graduates	120	139	174	150	240	225	234	267

Source: HEMIS Tables (DHET, 2015)

Table 6.1 shows that the number of research article publications appearing in peer-reviewed journals rose by 42.8% from 2008 to 2015. Over the same period, the number of books and chapters increased by 216%, conference proceedings by 87%, master's graduates by 70.5%, and doctoral graduates by 122.5%. The combined net overall increase for all these publications was 62% for SU, whilst the number of instructional staff merely rose by 24.1% over the same eight year period. There was a decline in the number of articles, books/chapters, and conference proceedings from 2014 to 2015, but overall these figures indicates the extent to which efforts exerted by SU academic staff have excelled meaningfully during this period.

Other outputs: Technology Transfer outputs (patents/ licenses/ spin-out companies)

The invention disclosures received and patents registered by SU provided a strong base from where licensing opportunities are sought. Figure 6.3 shows the performance of SU from 2008 to 2015 by denoting invention disclosures, patent application, and patents granted.

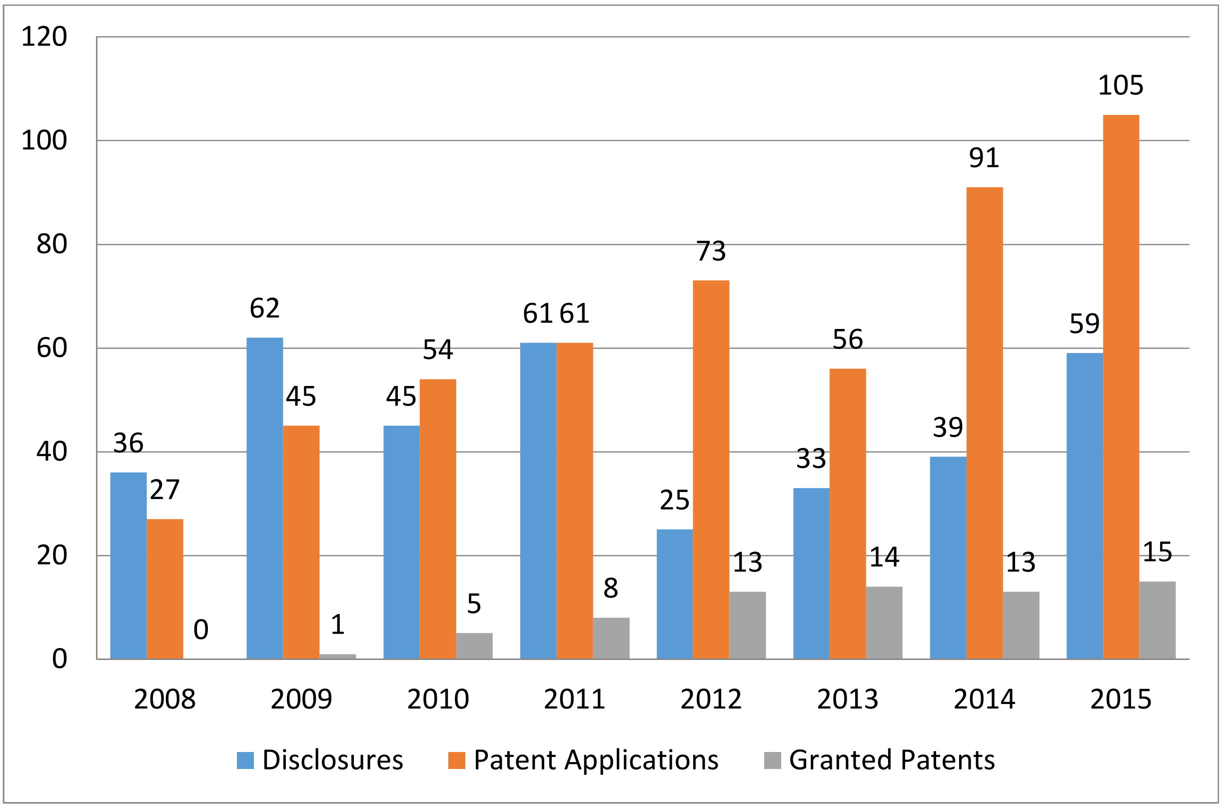


FIGURE 6.3: SU INVENTION DISCLOSURES, PATENT APPLICATIONS & PATENTS GRANTED
Source: DST et al. (2017)

The data in Figure 6.3 reflects new invention disclosures from the SU campus that started at 36 for 2008 and increased to 61 by 2011, before dropping to 25 in 2012 and then increasing again to 59 for the year 2015. Total patent applications were solid at 64 on average per year, starting off at 27 for 2008 and ending at 105 for 2015. Patents granted are much lower on average per year, indicating that not many technologies are ready for patent protection and is also indicative of SU's cautious approach to spending money on patent registrations.

TABLE 6.2: SU TOTAL COMMERCIALISATION INCOME FROM IP

	Licensing R	Sale of IP R	Spin-off Companies R	Cumulative Active R
2008	1,378,305	0	70,000	1,448,305
2009	896,800	0	175,000	1,071,800
2010	1,085,318	0	350,000	1,435,318
2011	4,472,257	552,250	525,000	5,549,507
2012	1,528,042	627,837	1,050,000	3,205,879
2013	3,016,925	545,150	350,000	3,912,075
2014	2,521,902	512,023	350,000	3,383,925
2015	5,928,691	0	437,500	6,366,191
Total	**20,828,240**	**2,237,260**	**3,307,500**	**26,373,000**

Source: Stellenbosch University (2017a)

The total income derived from commercialisation activities increased steadily over the years from 2008 to 2015 per Table 6.2 and indicate that the TTO at SU is maturing and succeeding in generating income from research activities. The good growth of income earned from IP commercialisation can be attributed to the long pipeline of inventions built since 1999.

TABLE 6.3: SU LICENSE AGREEMENTS EXECUTED

	Non-exclusive	Exclusive	Total Executed	Cumulative Active
2008	4	1	5	7
2009	1	4	5	12
2010	2	1	3	15
2011	2	5	7	22
2012	3	4	7	0
2013	9	10	19	0
2014	6	1	7	0
2015	0	0	0	0
Total	**21**	**25**	**46**	

License agreements concluded by SU increased steadily per table 6.3 and SU benefits from a long pipeline of invention disclosures. Patents awarded and licensing revenue earned are the indicators most commonly used when measuring the performance of TT at universities.

National and institutional policies affecting university TT is stated as the first enabler as per the conceptual framework for this study and is dicussed next followed by the institutional commitment which includes the devotion by university top management towards TT activities.

6.2 Institutional policies

Research policy

SU has opted to strive to be a research-intensive university. This decision appears strongly in the University's vision statement that details its objectives. The motto "your knowledge partner" was embraced by the institution after a strategic planning session was held in 1999 (SU, 2008).

Hence the most recent research policy statement of SU demonstrates the focus placed on research as a key function of its academic duty and denotes the university's undertaking to:

a) actively participate in the NSI and be aware of the applicable government policies;
b) support research efforts in SA and globally;
c) grow competence in areas where top rated research expertise is based;
d) adhere to international standards of excellence in research, considering the specific prospects and confines of SA; and
e) certify that research conducted at SU conforms to globally acknowledged standards of moral governance (SU, 2008).

SU's research policy promotes and directs research activities within central management and within separate faculties, departments, centres, and institutions that comply with the primary principles of research integrity. SU considers research to include the regular grouping and collating of information that will broaden the corpus of scientific knowledge (SU, 2008).

Furthermore, SU requires that targets are set for all academic staff. Whilst such targets will give precedence to academic work, good quality research outputs will be required, as well as involvement in community service projects. Academic staff and students of the University are also urged to keep abreast of new research methods and to be aware of the relevant research policies and programmes of other international institutions (SU, 2008). SU expects academic staff to keep strong professional relationships with other researchers in SA and international scholars through partaking in research networks and to source funding to sustain their research efforts. Staff members are further compelled to follow the institution's policy regarding contract research by complying with the contractual obligations of research agreements and to protect and commercialise IP emanating from research (SU, 2008).

SU is dedicated to R&D that may bring about new knowledge, innovations, and goods, thereby releasing the commercial potential of its created IP to the benefit of the university and the wider community (SU, 2009c). The University operates according to a value system that is described in its Strategic Framework which has been embraced by the University population. SU also has an Assurance and Promotion of Ethically Accountable Research Policy that is directed by three ethics committees covering humans, animals, and environmental issues (Stellenbosch University, 2013b).

IP policy

Innovus is tasked with protecting the IP of SU. Staff and students of SU are obliged to support Innovus in discharging its duties in the exploitation of IP generated, whether through licensing, sale of IP rights, or the formation of spin-out companies. Usually, staff members are required to participate in the commercialisation activities. Innovus, as the TTO of SU, will explore a business idea or IP that was created by a staff member or student when the IP is disclosed to it. If SU, represented by Innovus, resolves not to pursue the commercial exploitation of the disclosed IP, then the particular staff member or student is free to seek commercial exploitation of the concept or IP for his or her own benefit (SU, 2009c).

Academic staff and students at SU must realise that their IP have commercial value and it should not be shared with fellow staff members or business acquaintances. Research contracts that are concluded on the basis of not being fully funded by external funders must be carefully considered as it pertains to SU's publicly funded R&D. Any transfer or sharing of IP rights with other businesses in commerce and industry that originates from partly funded research agreements must be sanctioned by NIPMO prior to dissemination and must also be approved by the responsible person from SU who will ensure adherence to the legal requirements (SU, 2009c).

Interviewees responded positively to a question on whether they are aware of the university's IP policy and its contents. Interviewee S1 attested:

> I think it's a really forward thinking policy. I think it is something that is intended to stimulate disclosure of IP and working with the university to exploit IP rather than encumber it. So obviously I'm quite happy with that.

The views of interviewees on the IP policy of SU were mixed. Although mostly positive, a few concerns were raised by respondents S1 and S2.

> The things that I don't like about the IP policy are typically things that are legislated. Things such as opening a small repository of research software. However, the IP policy states that it needs to be approved by the TTO. Academics find that stifling to their academic freedom of sharing their research results (S1).

> I'm unhappy about the fact that the proceeds from commercialisation is equally spread around, and the cost centre from where the original development occurred gets the least amount of money. From my perspective the one single area that should get the most amount of money is the cost centre in which the research was developed (S2).

Results of the interviews conducted reveal that SU staff and students are aware of the IP policy of SU, its contents, and the impact of the policy on their research results. This section briefly stated a few applicable institutional policies of SU that pertain to TT at the University and is followed by a segment on institutional commitment by university top management towards TT activities.

6.3 Institutional commitment by top management at SU towards TT

The first indication of a culture that supports IP commercialisation was evident at SU when the university adopted an IP policy in 1999, long before the enactment of SA's own IPR-PFRD Act which was mainly based on the Bayh-Dole Act in the Unites States. A question to consider is if the same commitment is prevalent today as was back then in 1999 and whether the Act has had an effect (if any) on the institutional commitment towards IP commercialisation at SU.

This was one of the questions the researcher set out to answer through in-person interviews held with academic staff and top management at SU. In response to a question whether participants in the survey experienced institutional commitment as weak or strong, the reply was mostly uniform in confirming a strong institutional commitment at SU. Actual responses from interviewees were as follows:

> Strong in the sense of support, certainly yes. We got very good support in starting the company from top management. Most of them were aware of what we're doing and supporting what we're doing and even invested strategic funds in the start-up, which is unusual for a university (S1).
>
> Strong. I've had support in my activities from the likes of Prof Leopoldt van Huyssteen, Prof Eugene Cloete, and I mean, they're senior directors at the university. So yes, top management are in full support of what we do (S3).
>
> I think it's strong. I mean, the university as a research university has a big commitment through their establishment of a company like Innovus (S5).

One of the interviewees (an academic staff member) was somewhat critical in claiming that the message of IP commercialisation at SU often does not filter through to lower levels of management.

> So, yes, you have Innovus on the one side, which is very keen and committed to TT, but from a Dean's perspective and from the central university perspective that message does not really resonate for me throughout the different layers. But that's my perception (S2).

The representative from top management (S4) was unequivocal in asserting:

> Our commitment is very high and it is shown through Innovus as our wholly owned company of SU doing TT. Then we have the LaunchLab acting as incubator that is also a 100% wholly owned company. Results of this commitment is reflected in the rapid increase in the number of PCT applications by SU (S4).

Both respondents S4 and S5 indicated that the commitment expressed by SU's management was demonstrated through continued support for Innovus, Science Cafés, and the LaunchLab (S4 & S5). Organisational challenges were addressed next as part of the survey questions. Participants had to identify managerial challenges experienced by them, and responded as follows:

> Much of the complexity of starting a high technology company was shouldered by the TTO at SU. We as academic co-founders could focus on developing the product and taking the product to market. All of the complexity of dealing with the CIPC and with corporate lawyers was managed by the university TTO (S1).

Interviewee S2 listed a few problems that they experienced in the past five to ten years, but which had been ironed out. Participant S3 echoed as follows:

> It is much better now, but I think there was a lot of friction from the academics in the early days to TT and this whole thing of patenting versus publishing.

Capacity to promote TT was a problem noted by the representative from top management (S4).

> I think we've set it up in a way where unrealistic expectations were created. We are getting innovation onto the agenda of faculty management meetings to measure innovation so that it is promoted in the faculties at grassroots level.

The same interviewee also asserted that capacity to deal with the approval of research contracts is problematic. This function is not under the control of the TTO, but by delaying the pipeline of new inventions from growing faster it has an impact on the TT process.

> I think capacity is often an issue when getting research contracts signed so that the research can actually starts. Due to capacity constraints it sometimes takes very long to get research contracts signed. Innovus doesn't want to be involved until it becomes commercialisable (S4).

In response to a question on how organisational factors and managerial behaviours can be changed to better facilitate effective TT practices at their university, participants responded as follows:

> The most difficult process was negotiating the structure of the company. We went into that process with very little guidance around what a typical shareholding should be for the university as a shareholder in the company. Royalties versus shareholding, how that is structured and how it should be negotiated (S1).
>
> I think having a person which is less busy on Innovus's side would be better for us, specifically Mrs Doris Peters who helps us a lot (S2).
>
> Educate the professors on the relevance of patents and how it works. Give them workshops on how to commercialise technology or what the process is of say filing for a PCT patent. It's as simple as that (S3).
>
> We want to get innovation uppermost in the minds of academics and students as well as the dean and his management team. It's about creating the idea, the focus, the expectation and then providing supporting and enabling environment to the inventors (S4).
>
> I think fostering a culture of innovation should start at undergraduate level where a module, like entrepreneurship should be taught as compulsory unit to any student who goes through any bachelor degree (S5).

The results of the interviews conducted shows that SU staff and students consider the institutional commitment from SU top management to be mostly strong and supportive of TT activities at the university. An academic interviewee was critical in claiming that the message promoting university TT at SU is less supportive coming from the Dean through the various layers of management to reach the academics. A participant noted friction between patenting efforts and publishing of research results that was prevalent in the early days of TT at SU but which have been resolved since. Another respondent noted the rate of approval of research contracts as problematic. The approval of new R&D contracts is not performed by the TTO at SU but by the Division for Research Development. The delays do influence the time it takes to create and commercialise IP from the SU campus and better coordination between the TTO and the Division for Research Development is required to improve the turnaround time of document flow between the two units.

Finally, some criticism was levelled against staff members working in the TTO and their capacity to deliver TT activities as they are simply too busy at times to attend to the needs of academic staff and students as inventors. The capacity constraints can be viewed against an ever increasing rate of disclosure of new inventions at SU for which Innovus has to provide services to and fund the cost of protection of the resultant IP (where applicable). Innovus has to teach existing staff members to cope with the increased workload whilst at the same time recruit new staff members to manage the growth in deal flow. The next section considers IP protection as the subsequent enabler under examination.

6.4 Intellectual property protection

Prof Christo Viljoen was tasked to compile an IP policy for SU soon after the inception of the Office for Intellectual Property (OIP) in 1999. He completed the IP policy after thorough research and consultation with universities abroad (mainly in the USA). This IP policy was formally approved at a meeting of the executive committee of the university council on 22 April 1999 with the proviso that the policy be amended when required (Stellenbosch University (SU), 1999). Consequently, SU and UCT were the first two universities in SA to protect IP emerging from research conducted on their campuses.

The employment contracts of SU employees were changed due to the adoption of the IP policy. The proposed changes affected the ownership of new inventions made by university academic staff in the course of their employment at SU. All university employees had to adhere to the IP policy adopted earlier in 1999 and had to complete invention disclosure forms and submit these to the OIP for consideration and exploitation (SU, 1999).

This section aims to highlight two aspects namely the historical course of the development of the IP policy at SU and to quote the latest statistics of TT outputs achieved by SU. No reference to any respondent interviewed in this case study at SU is made in this section.

The adopted IP policy of SU aimed to develop an institutional commitment that would promote an environment in which knowledge can be found, protected and disseminated for the public good. The commercialisation of IP, and TT as a function, are considered a key segment of SU's commitment to apply the benefits derived from such IP for the betterment of society (SU, 2009c).

Staff and students of SU are urged to acquaint themselves with the IP policy and to make sure that they comply with the provisions contained in it. The IP policy applies to all campuses of SU, temporary and permanent employees on its payroll, contract workers, all registered students, postdoctoral fellows, and visiting lecturers. The policy also effects research clients and research partners of SU (SU, 2009c).

Income earned from the commercialisation of IP, to be split amongst creators and SU, includes non-refundable royalties, shareholding in spin-out companies, dividends, fees, and commissions, but excludes donations received (SU, 2009c). Income received and allotted to the inventor's milieu can only be used to further research and may not be expended by any individual for personal gain. SU controls these funds as per the 2008 IPR-PFRD Act and the stipulations of the SA Revenue Service regarding the treatment of this income (SU, 2009c)

With its submission of responses on the draft IPR-PFRD Framework of 2006, SU was instrumental in the formulation of the new IPR-PFRD Act of 2008 that led to the finalisation of the new IPR-PFRD Act. SU has amended its IP policy in February 2010 to be fully compliant to the provisions of the IPR-PFRD Act. The distribution of the proceeds derived from the commercialisation of new inventions are now done in accordance with section 10 of the said Act. The updated policy, effective from December 2010, is available on the university's website where it is easily accessible to all academic staff and students.

Accomplishments, patent costs incurred and patent statistics

During 2003, 17 new discoveries were reported to the OIP as TTO of which 14 were patented (Stellenbosch University (SU), 2003). At the time, seven spin-out companies existed on campus, two of which were paying dividends to its shareholders. VIN13 was reported to be the most successful licensing agreement at that point. This wine yeast, developed by Prof Sakkie Pretorius was manufactured by Anchor Yeast (Stellenbosch University (SU), 2003).

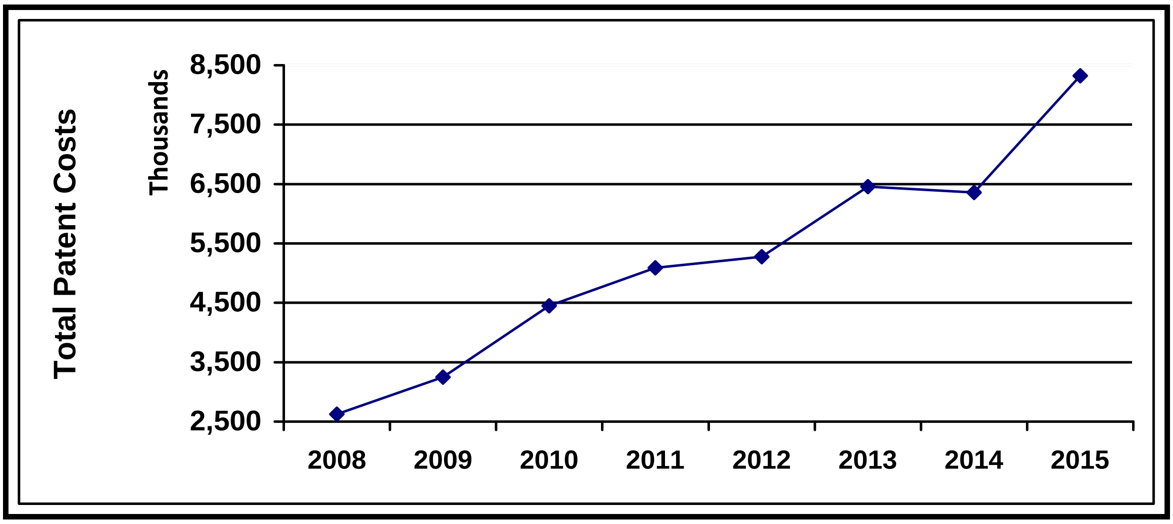


FIGURE 6.4: SU TOTAL PATENT COSTS
Sources: RSA: DST *et al*, (2017) for years up to 2014 and SU (2017c) for 2015.

Disclosures grew steadily over the years since and added up to 301 in total (38 on average per annum) for the period 2008 to 2015, whilst cumulated patent costs incurred by the TTO amounted to R30.9 million from 2008 to 2014 (RSA: DST *et al*, (2017) and reached a high of R8.3m for 2015 (SU, 2018a), as illustrated in Figure 6.4. The total expenditure on patenting costs rose from R2.625m in 2008 to R8.321m in 2015. Thus, patenting costs incurred by SU grew considerably by 317% over this period, which is significant even after inflation has been discounted.

A total of 364 patent applications were filed by SU from 2008 to 2014. That included 136 SA patents, 70 PCT patents and 158 foreign patents (DST *et al*, 2017). For the period 2009 to 2015, the PCT patents published by SU amounted to 84, as depicted in Figure 6.5 below.

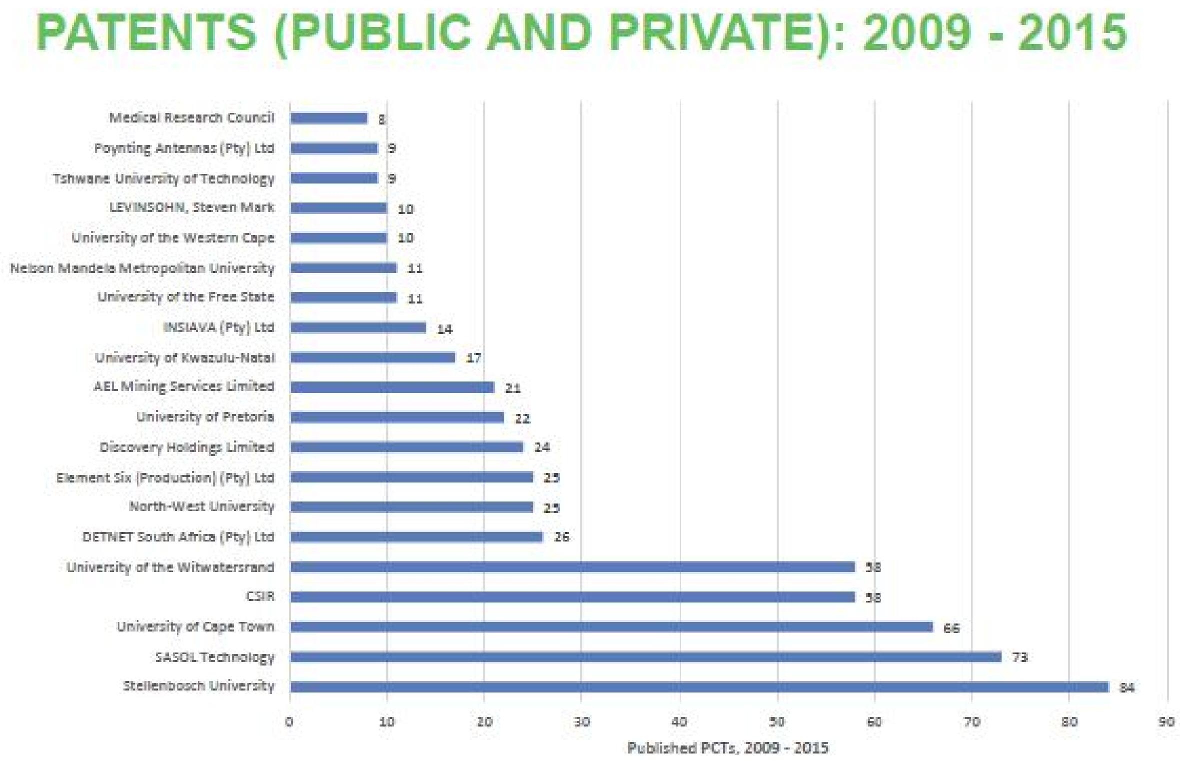


FIGURE 6.5: COMBINED PCT PATENTS OBTAINED 2009 TO 2015
Source: Stellenbosch University (2016a)

SU (2016) reports that the 84 PCT patents issued to it between 2009 and 2015 signifies the largest number of PCT patents held at then by any organisation in SA, including companies in commerce and industry. Sasol came second with 73 PCT patents and UCT third with 66 PCT patents, followed by the rest as it tailors off.

During discussions, all interviewees confirmed that they knew about the IPR-PFRD Act of 2008 in SA that now compels universities to protect newly created IP and to commercialise it. Interviewee S1 felt that the act is comprehensive, whilst both interviewees S2 and S3 asserted that the promulgation of the act is a very good development for SA universities. Yet, S3 cautioned that the application of the provisions of the act needs to be managed well.

This section examined the legal environment at SU relating to TT and briefly quoted statistics of its IP protection effort. From the above, it is clear that SU is making progress when one considers the number of PCT patents registered between 2009 and 2015. This section is followed by a segment on funding for TTO commercialisation activities.

6.5 Funding for TTO commercialisation activities

TIA's Seed Fund commenced during 2014 to provide HEIs and science councils in SA with initial funding to enable them to develop their ideas into commercial applications. An amount of R25m was made available by TIA for investments into new start-up ventures (UCT, 2015c). Stellenbosch University inventions also benefitted from TIA's Seed Fund. The fund assist inventors at SU to develop their research results into prototypes, proof their concepts and create business plans to commercialise the new technology. Prospective funding is limited to R500 000 and takes the form of a non-repayable grant to further protectable IP along the path of commercialisation (SU, 2018c). The funding can be used for production of samples in the marketing effort, performing field studies, technological evaluation studies and consulting experts in the particular technological field. Salaries may be paid to external consultants and SU students as technical assistants (SU, 2018c).

Funding for TTO commercialisation activities was seen by an interviewee as an example of institutional commitment exerted by the top management of SU. Responding to a question whether TTO commercialisation activities are supported by SU, some interviewees commented as follows:

> We were in the process of spinning out from the university. We received seed funding initially through TIA's seed fund programme that helped us to take the lab results to the market by developing a product. We were raising funds for the next stage and had an investment deal that was shaping up. The deal fell through and we were cash strapped and the university stepped in and committed funding for the next round. They were willing to buy shares in the company and top management was instrumental in making that happen (S1).

> I was busy with my PhD, and we had already filed provisional patents for technology developed as part of the PhD when I moved to Johannesburg, got married and started a job. I proposed to the university that I will set up a lab in my garage at home and they approved. I actually did five years of lab work in my garage in Boksburg because senior management at SU were supporting it and provided funding for it (S3).

The questions posed to interviewees during the in-person interviews focused around the efforts of the participants to secure funding for research projects and to obtain financial support for TTO commercialisation activities. Often funding agencies allow the academic researchers to use some of the research funding awarded to them as capital to acquire equipment that can be used in the early stated of commercialisation of the research results. Specific comments from interviewees were as follows:

> That's why we formed the Media Lab. We were in an environment where I and the co-founder of the business had no access to research funding. So, we went out and obtained more funding from Naspers by pooling our research efforts together (S1).
>
> In our case, the funding that we receive comes from companies directly or we are self-funded, which means that I often don't have to share the IP with the University (S2).
>
> As a student, one cannot qualify directly for NRF funding. The professor gives you a bursary and in that sense the initial research work was funded by the university using public funds. I then moved to Johannesburg and I set up a laboratory. The TTO and the University via the academic department then co-contributed funding for equipment and consumables whilst later on the TTO paid part of my salary (S3).
>
> The problem is finding funding to take our innovations further towards commercialisation. We try to get venture capitalists to partner with SU. We also populate the board of Innovus with representatives from Remgro, Capitec Bank and the Chairman of Sanlam, all being top-notch businessmen to advise us. Through TIA, we've secured funding for inventors and we are creating a university wide innovation fund for early stage technologies (S4).

From the above replies, it is evident that academic entrepreneurs as inventors at SU are constantly exploring various avenues for soliciting funding to advance the commercial potential of their research projects. Some of them approach industry partners, others try to fund as much of the costs themselves from within, whilst one respondent plead with the university department within which their project resides. The comment from the management representative (S4) of SU is noteworthy as the person attest to the fact that SU actively seeks to find additional sources of funding for the commercialisation of research projects emanating from the SU campus.

Mixed responses were received to a question on whether the university TTO should assist academic staff in securing funding for research or funding for TTO commercialisation efforts.

> No, I think that's the purpose of the division of research development and over the past couple of years, there emerged quite a strong split between the activities of Innovus and research development office (S1).
>
> The TTO did assist me last year in getting TIA seed funding to start the commercialisation process (S2).
>
> They did help me tremendously (S3)
>
> .
>
> We are working with L'Oreal at the moment. They had a need to develop something that would treat effluent in a decentralised fashion in a hair salon. We partnered with them and signed a non-disclosure agreement. The work was started and the technology is now mature. The head of their sustainability programme of L'Oreal visited our research lab. She examined the equipment and was thrilled with the research results. She said okay, how do we get this into each one of L'Oreal's salons around the world? (S4)
>
> No I do not think that they should assist me (S5).

The responses received from interviewees at SU were mixed. A candidate believes that the provision of funding for research projects should be the responsibility of the Division for Research whilst acknowledgement was given to Innovus for assisting founders to obtain funding from TIA for the TTO commercialisation effort pertaining to their research projects. Contrary to the other responses, interviewee S5 denotes that help is not needed and the inventor does not leave it to the university to source funding for research projects or to provide funding for the early stage commercialisation effort.

Funding for spin-out companies

During the interviews, participants were asked if the University TTO stimulates interaction between them and entrepreneurs, venture capitalists, angel investors, and governmental funding agencies. The responses were in the affirmative as follows:

> We are located in the Launch Lab that provide pitching events and entrepreneurial events and talks by people of interest to entrepreneurs. I think it is a brilliant initiative. They introduced us not just to venture capitalists, but also private investors. Our primary investor was someone who first heard about us at a Launch Lab event. Our very first seed funding was from TIA whose mandate it is to stimulate early and later stage technology innovation. We received seed funding of about R 500 000 that lasted for a year. We used it and took our research to America where our market research was completed in Hollywood and ultimately converted from the prototype into a commercial product. TIA also provided a loan to us on very favourable terms where there's no collateral and we only had to pay back the loan once the technology they sponsored has been commercialised (S1).

> I gave a talk at the Launch Lab and I get invitations specifically to speak to young entrepreneurs. At the LaunchLab I was introduced to venture capitalists, angel investors and both the IDC and TIA (S3).

Interestingly, the interviewee representing top management (S4) referred to a model used by MIT to spur the commercialisation of later stage technologies at that university in the USA.

> SU has introduced, according to an MIT model, what we call translational postdoctoral fellows. So I've identified three or four technologies which are at a late stage of development. The postdoc is then not expected to continue with research and publish papers but my expectation is that that the postdoc will be actively involved and be part of the spin-out company by the end of that postdoc. If we had this in place for the 98 PCT patents that SU have then we would have had 98 translational postdocs over the last five years and even if 40% of them were successful, it would have meant 40 new spin-out companies (S4).

> I think there's a lot of high profile people that have networks within the Launch Lab and TIA and I think the university is really trying their best to link us to entrepreneurs, venture capitalists, investors and government agencies (S5).

This section briefly refers to efforts by SU academic entrepreneurs to obtain funding for additional research to get their inventions ready for the market, funding for the TTO commercialisation effort required to take their technologies passed the prototype phase, proof of concept phase and to develop a business plan. The next section deals with human resources as the next enabler determined in the conceptual analysis for this study that is important for effective university TTO activities.

6.6 Human resources

Incentives for academic staff to engage in TT activities

Shane (2002), Goldfarb and Henrekson (2003) and Lach and Schankerman (2004) all agree and provide proof that an academic staff member as inventor should be incentivised as much as possible to engage in TT activities. It is not any different for SU and the University also acknowledges that academic staff members and students are involved and engaged in various activities that fall outside the ambit of their formal contractual bond. Moreover, SU knows that these activities may result in conflicts of interest that could be an advantage to the affected staff members or students, third parties, or the University itself. The University does have a sound conflict of interest policy that requests from the affected university staff members to fully reveal any such conflicts of interest or potential conflicts of interest (SU, 2013c).

During the interviews, participants from academic staff, students, and university management were asked what motivated them to commercialise their research results. The answers were as follows:

> I was involved in technology commercialisation for a while and when I one of my colleagues and one of our Media Lab students came across an invention that had commercial potential, we had good knowledge of what the typical route to commercialisation would be. So we disclosed the invention immediately to the TTO. The initial provisional patent was filed thereafter with the support of patent attorneys suggested by Innovus. We could identify the business potential very early, again with the support of Innovus (S1).

> I'm a plant breeder by training and I decided many years ago when I had the opportunity to stay at the University that I will be an active plant breeder. If I breed, the outcome is cultivars and if you're half decent at your job, then that needs to be put out there and commercialized (S2).

> I think I'm a little different than some other students in the sense that I've always been an inventor/entrepreneur. So I went to SU to do my PhD in the nanotechnology field and also specifically also to commercialise any findings that would be developed from my research (S3).

> The first motivation for SU is to try and create a fifth stream of income. SU wants to unlock the value of its academics and students' IP and commercialise it to create income for the university and society at large. I'll give you an example. Mostly, we think that the value lies in the patent, which is not necessarily the case. The value lies in the commercialisation of the patent. To commercialise a patent is difficult and to sell it is also difficult. You cannot easily determine the value of a patent until you have tried to derive income streams from it (S4).

> In my case we had projects that was already aimed at yielding a product. So obviously we had a company on board that was interested in the end product and commercialisation was the next logical step for us to do (S5).

These interviewees were unified in their understanding of the need to commercialise IP that originates from their research efforts. Some of them had commercialisation of their research results uppermost in their minds, even before commencing their studies at SU. Their motivation comes from an inclination to act in an entrepreneurial manner and be successful in their commercialisation strategy. Credit was given to Innovus and the supporting role that the TTO plays. The representative from top management affirmed that Innovus is committed to examining the commercial potential of every invention disclosure in accordance with the new IPR-PFRD Act. This comment from management correspond with the claim by an interviewee of the solid service offering provided by Innovus as the TTO.

Interviewees were also asked if TT activities affected their academic career path at the university and what incentives (if any) were used to motivate them to engage in TT endeavours.

> The moment you start spinning out a company, it takes some of your focus away from your research and it was part of my consideration for leaving the university. I think at one point it became clear to me that this is now the more interesting endeavour that I'm busy with (S1).

> That's a very difficult question. My wife would tell you that instead of finishing my PhD I've been breeding cultivars and putting too much time into that (S2).
>
> Academics should carry on being academics and be taught how to participate in commercial activities, adding their wisdom and knowledge by being on scientific advisory boards (S3).
>
> It's not part of the promotions criteria at present. It's not part of the definition of an academic and does not include entrepreneurship or patenting and so forth. I think it should change and we're trying to change it (S4).
>
> No, not at all (S5).

Performing cutting edge research and managing a business on a path of commercialisation is not easy. Participants interviewed alerted to this fact as motivation for leaving the employ if the university to pursue the fulltime management of a company. Alternatively academics as inventors may also decide to stay within the research institution and leave the management of a newly formed business (if this route to commercialisation is chosen above licensing) to other people capable of driving the success of the business venture. Often, inventors may also defer further studies or delay advancement of their academic careers in favour of spending time and effort in the commercialisation process of their newly created invention. When academics serve on the advisory board of new businesses, it too takes time and effort away from their research activities.

TT activities are not being considered as measurement in determining promotions for academics at SU. An interviewee noting this fact also stated that TT efforts should be recognised and thus included in annual performance review evaluations. The researcher agree that balancing research activities with commercialisation efforts is challenging and the energy required by academics to do both is considerable. It makes sense that such additional effort should be rewarded especially when clear benefits flow to SU in the form of increased reputational gains or financial rewards.

Financial rewards to motivate SU staff members and students to engage in TT endeavours indicated by interviewees were limited to those stipulated in the IP policy of the University.

Respondents also noted personal satisfaction stemming from a sense of achievement. The specific responses were:

> I think the IP policy is generous. Even if we didn't spin out the company but just licensed the patents, the IP policy in place makes it clear how the inventor will benefit. I think in a clever way, the inventor gets a lion share of the early proceeds from commercialisation as the first R1 million is split in a more favourable way for the inventor. Being able to negotiate an equity arrangement in the shareholding arrangement of the company with the university as co-founder of the business is attractive to the founders (S1).

> There's the monetary incentive, but I think the biggest incentive from my point of view is that, you can drive past your own cultivars that was planted by farmers for a few kilometers and as far as you can see there's something that you created (S2).

> I think fundamentally it comes back to just who I am. I wanted to do something that would be applicable in the real world and benefit all peoples living in SA (S3).

> We have R100 000 that we make available every year for the ten best ideas which is R10 000 per idea for students. We harvest these ideas with the help of the LaunchLab in a programme and we get lots of ideas, hundreds actually. We are thinking of R100 000 for the winning patent developed by academic staff (S4).

> For me there was no primary incentive other than to complete the project. Commercialisation was the logical conclusion of the endeavor (S5).

From the responses it seems that financial rewards and personal satisfaction were rated high by interviewees. The IP policy was seen to be unambiguous and one employee in particular was appreciative of the allocation of proceeds from commercialisation efforts that an inventor receives in terms of the policy. The interviewee from management (S4) indicated that more funding will be used in future to lobby new innovative ideas that could lead to TT activities, and ultimately to commercialisation of the research results emanating from those ideas.

Participants to the interviews were also asked which rewards they would like to see implemented to increase their willingness to disclose new findings and seek commercialisation of those findings. Interviewee S1 had no comment, but the others noted as follows:

> There's something that I like that has recently been circulated which is the awarding of publication units to for instance plant breeder's rights and patents (S2).
>
> There is a cultural bias towards not patenting, not looking at it commercially and that comes from the senior academic leaders. I think that could discourage someone and needs to change (S3).
>
> The reward should be that when a student walks onto this campus they must know that they could be the next Elon Musk. We should create this vibe and I've got a simple theory and it is as follows: We have 30 000 students and staff. Let's say 10% of them walk around with a really good idea. That's 3 000 good ideas. Let's say 10% of the 3 000 are exceptionally good ideas. That's 300. I believe that 10% of those, 30 should be new businesses. The challenge is, how do you mine that? And it's true for every university in SA. So you multiply that 30 with 20 or so universities, let's make it 600 companies. If those 600 companies employs 10 people then you create 6 000 jobs per annum (S4).
>
> I think the income distribution should just be more favourable and more recognition should be given for the risk taken, the investment made, the time, thinking about the project, and then walking the walk with the commercial company that exploits the technology. I believe that many of these ideas is held by our postgraduate students and not with the supervisors. If we want to tap into that source, then we should think differently about innovation and how we drive innovation at the university (S5).

The point raised by S2 is interesting and it will certainly spur TT and technology commercialisation if publication units are awarded to creators of new patents and inventions emanating from their research efforts. However, the comment from S3 is disconcerting as it is contrary to the enabling environment that the TTO and top management have been trying to establish over many years to increase the propensity of SU academic staff and students to disclose their research findings. The analysis and projections offered by interviewee S4 from top management is heartening and concurs with the viewpoint of Heher (2006) who asserts that the additional benefits, such as jobs created from university TT, are not recorded at the level of the institution, but rather by the local economy.

Interviewees were further asked to define success in university TT activities and they responded briefly as follows:

> In my case it is quite easy. I look at the new seed sales. We set certain targets and you can immediately see within your cultivar whether it has met its targets and whether the market is accepting the new product (S2).

> You know, it's a great aspiration, but to see 50 young entrepreneurs growing in the sciences is a lot more valuable than one Nobel Prize. So the point is get more people involve and stimulate them early on towards TT, that's what the TTO is doing with the LaunchLab very effectively. They are inspiring young scientists to do it the commercial way (S3).

> Having many success stories of entrepreneurs on campus (S4).

> Sharing in the financial benefits and recognition (S5).

Personal satisfaction and financial again seems were uppermost in the minds of two of the respondents whilst two candidates seek to promote the achievements of emerging entrepreneurs on the university campus.

In response to a question on which activity of TT they were involved in most (e.g. patent, licensing, or spin-out company), the respondents reflected that they were all involved in licensing, whilst half of them were also involved in negotiation and deal-making associated with spin-out companies. When asked what participants most liked or disliked of TT practices, the answers varied.

> What I like the most is being able to see the very first spark of an initial idea really growing and growing from proof of concept and early product prototype to the market and to when investors comes on board. Then again when the business grows with good commercial prospects and start to generate significant revenue. I think that's absolutely spectacular. That's something that you don't find in your usual research or publishing the next paper and moving incrementally forward with your research (S1).

> I hate all the admin work involved (S2).
>
> Writing a patent is difficult and I dislike it. You need to learn how to specify claims and how to work with lawyers. I like inspiring young scientists, especially scientists and engineers to think commercially, which is extremely valuable (S3).
>
> I dislike is the paperwork as we're not skilled in that as scientists (S5).

The first interviewee replied that a growing income stream from an invention is fascinating to experience and different from the usual research endevour leading to publications. This responded suggested that the act of making money may lead to personal satisfactory for the inventor rather than the money itself. Three of the four people interviewed complained about the administrative burden associated with the filing of a patent, but they do realise that it has to be done in order to unlock the potential of the disclosure for the new invention.

Participants in the interviews were also prompted on what the successes that they have achieved in university TT meant to them.

> I think there are many reasons why people join universities and become academics. For me it's a sense of discovery and learning new things and putting the new knowledge into action. Our research continues in a high pressure learning environment to solve problems. Personally I find taking an idea and to turning it into a business very gratifying (S1).
>
> Means a lot, even better if I can inspire more young students to so the same (S3).
>
> There are a few things that are better than seeing a student graduate with a PhD or Master's degree. It's incredible to help someone else achieve their goals when a commercial product is developed. It is absolutely satisfactory when you see a good idea that changes lives and someone is making a livelihood out of it and building a business and industry around it (S4).
>
> Satisfaction is to know that you started with an idea and you could finish it to become a product on a shelf somewhere. It's not something that just stays within a thesis on the bookshelf, we took it one step further (S5).

Interviewees were unified in their response to what successes in TT activities means to them. They commented that it is pleasing to see a useful product being developed from an idea and then to see that product being used to build a new business. In doing so the lives of young scientists are changed for the better and livelihoods are secured for a number of staff members being employed by the new business that assumes its role in the competitive arena of commerce and industry.

Interviewees attest to the fact that they have a liking to entrepreneurship and that it assisted them in their drive to develop new technologies and then to commercialise it. Participants were appreciative of the encouragement received from Innovus as TTO on campus. They acknowledged the fact that doing both research and starting a new business venture can be extremely demanding to say the least.

Noteworthy was the reveal that TT activities are not being used as determinant when assessing staff members during their annual performance evaluation. This fact should be made aware to university top management at SU as it may contribute further to the high levels of personal satisfaction being experienced by staff members engaging in TT activities. Interviewees were approving of the IP policy that was experienced by them as generous.

The comment by one respondent was disturbing when the person noted that there exist a prejudice towards not patenting and not seeking commerciallisation opportunities for new inventions by certain senior academic leaders. This may be a generational predisposition by older academic staff members and is something that may be explored by top management in their efforts to stimulate an environment on campus that is conducive to promoting university technology transfer.

Networks leading to collaboration

The following replies were received to a question on how the university TTO stimulates interaction between researchers and other academic staff and students, governmental scientists and laboratories, and businesses in commerce and industry:

> There's a regular event where Innovus invites academics from across faculties to the Launch Lab to observe an overview of tech transfer activities. The brunt of the day is the showcasing

> of some of the spin-outs of other academics' tech transfer activities. It is a great opportunity for academics across faculties to engage with each other. Innovus also introduced us to our first two clients. The network of funders and investors that came to us through the tech transfer office was amazing. The most valuable aspect of working with Innovus I would say is the very rich network and business connections they brought to us (S1).

> Part of our commercialisation efforts was to seek licensing opportunities through attending international conferences as part of a trip, for instance, to the Czech Republic. I attended conferences and met with many academics and it was funded by the university TTO. Innovus as TTO of SU also stimulated interaction between our research teams and both TIA and the CSIR. In addition, they paid for me to travel to Japan to pursue licensing opportunities with Panasonic (S3).

> I think they've really tried to improve and to create a network of all these initiatives around campus to get people together to discuss innovation. Innovation is often transdisciplinary that requires different people. In our field we have a flagship project in viticulture using robotics and we don't need viticulturists. We actually need engineers, nanotechnologists and those are the people that we have now interacted and networked with at the LaunchLab (S5).

The TTO and its wholly-owned subsidiary company, the LaunchLab, was perceived to be very supportive of creating a space where networking opportunities leading to collaboration initiatives can be maximised by academic staff and students of SU. The networking events stimulated interaction between academics and students as entrepreneurs, governmental scientists and laboratories, as well as representative from businesses in commerce and industry.

This section discussed human resources at SU as enabler that was identified by the conceptual analysis in chapter three as it pertains to TT activities on campus. Results from the interviews held with a number of academic staff and students of SU were presented throughout this section. The questions posed to SU respondents were focused on what motivates them to reveal their novel inventions to the TTO and which incentives would increase their propensity to reveal their findings and pursue commercialisation of the IP. The most noteworthy responses in this section grouped under a few headings were:

- *Entrepreneurial Activity*: Academic staff and students involved in TT activities reveled in the fact that they can express themselves freely by creating new products which may lead to economic development opportunities. The activities of Innovus as TTO and it 100% subsidiary the LaunchLab is commended as supportive to fostering an entrepreneurial culture on campus. Against this backdrop, it was surprising to hear one negative comment about senior academics within one faculty that was critical towards patenting and commercialisation activities. It may be professional jealousy or merely the fact that people differ or the fact that true entrepreneurial behavior is limited a few people in society. This comment seems to be isolated considering the remainder of responses from interviewees that were mainly very positive.

- *Personal satisfaction:* A number of respondents cited personal satisfaction as high on their list of accomplishments when referring to university TT. The conviction to invent new technologies and products not only for themselves but for the good of the public at large was seen as important by these academic entrepreneurs, while peer recognition was not mentioned.
- *Promoting their careers:* Being involved in TT activities did not necessarily promote the academic career path of these entrepreneurs at the University. A few interviewees pleaded that their record with regards to TT activities on campus should be acknowledged by being included in their annual performance appraisals. If publication units can be awarded for patents issued to academic inventors, as one respondent alerted to, then this will be a positive development in promoting academic careers on campus. This might also encourage more academics to spent time on writing new patent applications rather than academic papers.
- *Economic development:* The argument by a management representative that SU has 30 000 students and staff, and that if 10% (3 000) has a good idea, it is possible that 10% of that number (300) would equate to very good and commercialisable ideas, of which yet another 10% (30 ideas) should lead to new and successful spin-out companies was enlightening. The participant further assets that 6,000 new jobs may be created if each of the 30 companies were to employ 10 people and if the 30 companies per university can be multiplied by 20 of the universities in SA. As stated earlier in chapter two, Barnett (SARIMA, 2012), refers to the measurements of the economic impact of TT in SA and stated that it should not be limited to disclosures, patents, and income generated, but should extend to job creation which meets the needs of disadvantaged communities and small local economies.

- *Administrative challenges:* The administrative burden of writing detailed descriptions for new patent applications of their new inventions to comply with the legal standards was disliked more than anything else by the academics entrepreneurs. Although Innovus was applauded for easing the burden and connecting the inventors to patent attorneys, the challenge of balancing academic duties and the time it takes to write patent applications and assist in commercialisation activities was seen by many to be laborious and energy sapping.
- *Networking opportunities:* The University, represented by TTO, through the LaunchLab as incubator support unit, was seen to strongly promote networking opportunities for academic staff and students as entrepreneurs.

A key to spurring TT at SU is the role of the TTO and its management team that takes the responsibility for technology transfer at the University. The next section describes the role of the TTO at SU in more detail.

6.7 The technology transfer office (TTO)

The OIP was established towards the end of 1999 at SU after the compilation of a draft policy on the protection and commercialisation of IP by Prof HC Viljoen (SU, 1999). Professor HC Viljoen (Christo) suggested the formation of a TTO for SU to the then Rector of the university, Prof Andreas van Wyk, back in 1997 (Viljoen, 2013b). Consequently, Prof van Wyk referred this request to Prof Walter Claassen who was the then Vice-Rector for Research. Prof Claassen submitted a report motivating the establishment of such a TTO to the executive committee of SU. The report, compiled by Prof Claassen with the assistance of Prof Viljoen, laid the foundation for the establishment of the OIP (Viljoen, 2013b).

Having formally retired as Vice-Rector (Operations) on 31 March 1998, Prof Viljoen was recruited by Prof van Wyk on a fixed term contract for a five year period to start the OIP as the university's TTO (Viljoen, 2013b). Prof Viljoen compiled the IP policy for the university after extensive consultation with universities in the USA, as those universities were leading the rest of the world at the time in setting up TTOs, thanks to the Bayh-Dole Act of 1980 (Viljoen, 2013a).

The main functions of the OIP related to the registering of patents and the protection of copyright owned by the University. A process of invention disclosure and protection of IP was followed and all steps were strictly monitored by OIP staff members (SU, 2005a). The very first disclosure received by the OIP was a request for the commercialisation of a service offering which emanated from the faculty of health sciences at SU's Tygerberg campus in Bellville. The result was a spin-out company called Unistel Medical Laboratories (Pty) Ltd (UML).

Since 1999, a number of highly successful spin-out companies have been established at SU with the assistance of the OIP (later renamed to Innovus) and facilitated through Unistel Group Holdings (Pty) Ltd (UGH) which was later renamed to Innovus Technology Transfer (Pty) Ltd. UGH is a wholly-owned company of SU and was set up by the university to facilitate equity-based transactions. Similarly, shares owned directly by the university in spin-out companies were also held by another wholly-owned entity of SU, namely the Stellenbosch University Investment Trust. The purpose of UGH was to contain the financial and legal risks (if any) of the commercialisation activities of spin-out companies created at SU. The name "Unistel" was registered as trademark by SU. Following from UGH was the formation of Unistel Technology (Pty) Ltd and Unistel Properties (Pty) Ltd. Both these companies were also wholly-owned by UGH and housed assets that were commercialised by SU but that was not for sale (such as student accommodation facilities).

The commercialisation of know-how emanating from SU leading to the formation of UML was not without its challenges. A number of other academics in the same faculty were jealous and fears were raised by many in the top management of the university (executive committee members) of the possible negative effects flowing from the "corporatisation" of the university's knowledge-based assets (Viljoen, 2013a). However, the commitment from top management alleviated the fears and UML was incorporated in 1999 as the first spin-out company from SU facilitated by the OIP (Viljoen, 2013a).

The board of directors of UGH consisted of prominent businessmen and alumni of SU. UGH served as a formal structure and vehicle through which the OIP exploited the university's know-how and intellectual property arising from research and teaching activities. UGH endeavoured to use committed entrepreneurs and form joint venture alliances with companies that were active in chosen markets in its efforts to assist in the development of successful and profitable businesses.

With a new logo, revamped website (www.innovus.co.za), and newly appointed TTO manager (Ms. Anita Nel), the TTO of SU raised its profile on the campus and has enjoyed strong and continued growth since 2006. Having worked at Thawte, a SA information technology company that was created by Mark Shuttleworth and which was sold to VeriSign in 2000, Ms. Nel understood entrepreneurship and was well-equipped to lead Innovus with a renewed focus on its technology transfer mandate. In 2009, the offices of Innovus moved from the university's main administration building in Victoria Street to offices in 15 De Beer Street in Stellenbosch. The reason behind the move was for the TTO staff to be in closer proximity to the academic staff and students of SU. Since August 2009, academics of SU also have access to expert advice on legal matters and IP protection as Von Seidels IP attorneys started assisting Innovus by offering consultations every Wednesday at Innovus's premises (Stellenbosch University (SU), 2009a).

Innovus received a national prize for its efforts in innovation management in SA in May 2015. The Organisational Award for Excellence in Innovation Management was presented at the annual DST/SARIMA awards ceremony and gives recognition to excellence in research and innovation management throughout Southern Africa. Seen as a path setter in research and innovation management, Innovus was honoured for making a considerable impact on research and innovation management during 2014 (Stellenbosch University (SU), 2017a).

Results from the analysis of a survey questionnaire and an in-person interview indicate to what extent SU has succeeded in using recognised TT methods to achieve success. Interviewees were asked whether they would describe their relationship with TTO staff of the university as trustworthy. Without hesitation, all of them responded positively.

> Yes, excellent, we established a good relationship with Innovus from the outset. A few other academics distrust the TTO because they don't know whether somebody wants to take their IP. There's this fear that they are going to lose value created by them (S1).
>
> Very good, the relationship cannot really be improved further. If Doris can free up some tome then it would be great (S2).

> Absolutely. I'm satisfied that they are efficient, they're motivated, and they try their best. They do protect our IP very well. We have a good reporting structure and a solid relationship (S4).

> Yes. I have had good services from the TTO and I have commercialised three products. It would be even better if they can help us get contracts for approval back sooner (S5).

Participants to the interviews were also requested to share their observations on how they experienced the legal & TTO support services delivered to them by the university. The feedback indicated that the service levels are satisfactory.

> It's been good. It was very good for the early start-up pains. It was clear when we got to the point where the legal services employed by the university were no longer sufficient for the stage where our company was that we had to switch to our own lawyers. I think that's how it should be, but the support itself was very good (S1).

> That I can't fault. It's always great (S2).
> Very good. Through the duration of my PhD we filed three different patents, or three different suites of patents which all advanced to the PCT stage. I think it's a there are more than 30 different individual country patents right now (S3).

> Innovus is a very good model, but I reckon we should create the expertise in-house to bring the cost down substantially on outside consulting services (S4).

> I think that is excellent and I have absolute respect for them for what they do. Without them it would have been very difficult for an academic (S5).

None of the interviewees felt that TTO staff could have done better in safeguarding IP created by them or its commercialisation, and all agreed that they would strongly recommend the TTO's services to fellow academics and students. Candidate S1 summed it up as follows:

> Well, I already think it is extremely valuable having the university as a partner in your business. Our patents were fast-tracked in SA, the US, UK and I think our IP has been registered in 20 countries across the world. We don't even know about the costs behind that.

> Also, our license agreement is part of the deal so when the company has matured and an investor acquires it, the patents would go over to the company. That's brilliant, we are quite happy with that.

Participants were also asked if they believed that TT can be a major source of income for them, their department, and the university. All of them answered in the affirmative, but with the proviso that it often take a long time to grow significant income streams from new inventions.

> Yes, but it's a long term drive and it depends on where the technology is in its life cycle. I think one should be realistic about the expectations of tech transfer leading to revenue for the university. It's not a short term game (S3).

> It's difficult to say because if you look at the really successful people around the world that have done this, they've spent a huge amount of money on building TT capacity. The point is, two products basically made Apple what it is today. The iPod, which saved them and then the iPad and some of the other Apple products so you don't need a suite of products or patents to make big money (S4).

Participants as interviewees gave overwhelmingly positive feedback with regards to their relationship and the levels of service experienced by them with Innovus as the TTO of SU. A number of candidates mentioned the LaunchLab during the interview sessions. The LaunchLab is a business accelerator (incubator) and houses spin-out companies established by SU, student-owned companies, and companies established from members of the community.

The LaunchLab

Innovus established the LaunchLab (www.launchlab.co.za) in 2013. It is a joint initiative between SU and UWC. SU (2016a) deduces that participants of the incubator have the chance to commence their own businesses while creating jobs, prosperity, and knowledge.

Both spin-out and external start-up companies benefit from entrepreneurial services offered to occupants of the LaunchLab. Entrepreneurial services are offered by service providers who provide mentoring, support, or guidance to LaunchLab tenants. The LaunchLab and UWC linked up together in 2014 to present the LaunchLab's Pitching Den (SU, 2014a). The Pitching Den, which forms part of the Microsoft BizSpark sponsored *LaunchLab Ideas* programme, offers

R80 000 to the winner and encompasses three universities being Stellenbosch University, UWC and UCT (SU, 2014a). This initiative between SU and the UWC is a concerted attempt by the TTOs of the respective universities to advance entrepreneurship among its students and academic staff. Dr Sanyahumbi, Director of UWC's technology transfer office, noted that the entrepreneurial environment prospers on networks and that the partnership with the LaunchLab at SU presents unique and promising prospects to wannabe entrepreneurs. Students and staff partaking in this initiative can present their business ideas and obtain seed funding from the Western Cape Government, the Industrial Development Corporation (IDC) and Business Partners, or take part in one of the sponsored challenges outlined below (SU, 2014a).

The building project entails the refurbishment of a warehouse with a floor space of about 1 200 m². The project will cost close to R14.5 million. The refurbishment has been made possible thanks to generous contributions from the DTI Incubation Support Programme, Nedbank, and Stellenbosch University. The old warehouse, which is situated next to Stellenbosch University's Facilities Management and IT buildings, will be transformed into a dynamic business incubation space with dedicated offices, meeting rooms, and a central hot seat area. The LaunchLab will, however, not only cater for Information and Communications Technology (ICT) businesses. Two workshop or laboratory areas will allow start-ups with an electrical, mechanical, or biotechnology focus to also make the LaunchLab their new home.

License agreements

SU, through Innovus, may enter into license agreements with business in commerce and industry to take advantage of IP created by academic staff and students. Such agreements must satisfy the regulatory requirements of IP arising from publicly funded research, such as a liking for non-exclusive licensing and micro businesses.

Through Innovus, SU earns recurring income from a number of royalty-bearing license agreements in addition to receiving dividends from equity investments in spin-out companies. Technologies from various faculties are being made available and are licensed to businesses in commerce and industry in SA and abroad. One such license agreement resulted from research into a strain of wine yeast. The particular strain, branded as VIN13, has excellent fermentation properties. Developed by the Institute for Wine Biotechnology at SU, this strain of yeast is licensed exclusively and is being sold in markets throughout the world and to the local wine-producing community. VIN13 is currently being used widely in the SA wine industry and strong growth is expected in the international market. Royalties flow back to SU and to the researchers listed as inventors to the patent in accordance with the provisions of the IPR-PFRD Act of 2008.

Innovus not only manages the innovation and commercialisation activities of SU's TTO but also manages short courses offered by the university and MatieSport. The involvement of Innovus in short courses and sporting activities further raises its profile on campus. Innovus has had a number of successes in concluding license agreements. More specifically, the Innovus Instant Access™ initiative was established to enhance and expedite the use of patented technologies created by academics at SU. Since 2012, prospective licensees have admission to SU's portfolio of technologies that are available for licensing through the Innovus Instant Access™ licensing initiative as listed on its website. In terms of this initiative, an external company concludes a short and simple contract with SU that allows for the free use of patented technologies for up to three years in order to develop the technology further (SU, 2018a). It provides businesses in commerce and industry the option to use newly created technology in their operations with the least amount of effort and at no initial cost. Use of the technology is free, but a small amount of R 1000 per year as minimal license fee is payable, or 1% of the income generated by using the technology, whichever is greater. With this initiative, Innovus aims to promote stronger industry partnerships and improve competitiveness that will lead to even more job creation opportunities (SU, 2018a). A fair number of available technologies are explained and offered in Chinese on Innovus's website.

Spin-out companies

As reported earlier, the first spin-out company formed by OIP was Unistel Medical Laboratories (Pty) Ltd (UML). Founded in 1999, the company's laboratories offers a dedicated human and animal genetics testing service and is located on the campus of the Faculty of Health Sciences of SU in Bellville. The genetic testing services are offered to physicians, patients, and clients external to the university. The company's founder and managing director is Dr Munro Marx who was previously employed by the Provincial Government of the Western Cape and seconded to SU. The IP concerned was know-how gained by Dr Marx and support staff working in his research laboratory at SU. For its share in the know-how created, SU obtained an equity share of 35% in UML, which over the years has earned the university millions of rands in dividend income.

Another spin-out company formed by SU is SunSpace and Information Systems (Pty) Ltd, which originated from within the Electronic Systems Laboratory at SU. Sunspace uses IP and know-how created by that department and converts the knowledge so gained and technology created in space and information systems to provide innovative solutions for its clients. SunSpace evolved from SA's first and highly successful SUNSAT 1 multi-purpose microsatellite, built at SU. The satellite was launched in 1999 by the National Aeronautics and Space Administration (NASA) in the USA. The mission of SunSpace was to convert space and information systems research results that originated from the SUNSAT programme to commercial business solutions for scientific and engineering concerns world-wide. SA's second microsatellite was also built by SunSpace. This satellite was called SumbandileSat and was launched in September 2009 (Stellenbosch University (SU), 2009a).

Innovus signified a new era for the TTO of SU by stimulating entrepreneurial thinking amongst the academic staff and students. UGH was also renamed to Innovus Technology Transfer (Pty) Ltd in 2009. The remaining companies created from SU technologies and know-how include African SUN Media, GeoSmart, Bridgiot, Cargo Telematics, CubeSpace, Custos, GeoSun Africa, Stellenbosch Nanofiber Company, Maties Gymnasium, Sein Media, Sharksafe Barriers, SU Executive Development (USB ED), LaunchLab, and Sun Magnetics. SU, (2016a) asserts that spin-out companies formed with the assistance of Innovus support hundreds of jobs and have resulted in hundreds of millions of rands' worth of income for local businesses over the years. She further notes that 8 university spin-out companies had a combined annual turnover of R187m for the 2014 financial year (SU, 2016a).

SU has benefited from capital growth in the value of its investments in spin-out companies and through a continuing research relationship between its faculties and the spin-out companies. This relationship provides for increased research funding and student bursaries paid for by spin-out companies, which contribute to cutting-edge research facilities and skills development.

This section highlighted the establishment of the TTO of SU and some of its most successful license agreements and spin-out companies that emanated from the campus. Dr Marx, as the founder of Unistel Medical Laboratories (Pty) Ltd, has shown that know-how included in a service offering can be very profitable. Being the first spin-out company established by SU in 1999, it has delivered superior quality services and paid increasing dividends annually since its inception. Conversely, the Hysucat and Hysuwac patents did not deliver on their potential. SU invested substantial amounts of money in these patents and the commercialisation effort through Unistel Technologies. The lesson learned was that SU, through Innovus, need not act as entrepreneur itself in the commercialisation effort. At best, Innovus can contribute a small amount of seed capital to assist the inventor in proving his/her concept. It is true that spin-out companies, as a route to commercialisation, create many jobs. However, these jobs might not be sustainable if the technology is not yet proven or the markets for the technology have not been developed.

Through initiatives such as LaunchLab, entrepreneurs can be trained in the skills of running a company. Having business skills will reduce the risks considerably for entrepreneurs as business owners.

6.8 Conclusion

The brief history and research profile of SU alluded to at the start of this chapter show that the University has an excellent research base and is one of the best performing and most respected research intensive universities in SA. The high number of A-rated scientists, research chairs, and centres of excellence are testimony to this fact. Data presented in Figure 6.1 and Table 6.1 indicate that the total R&D expenditure at SU increased considerably by over 170% for the years 2008 to 2015, with a rise of just above 24% in the number of instructional staff over the same period. The combined net overall increase for total publications was 95% for SU over the same 8-year period.

SU's research policy and its IP policy were discussed as institutional policies. Results of the interviews show that SU academic staff and students are fully aware of the contents of its IP policy and the impact of this policy on their novel research findings. The IP policy was first adopted in 1999 long before the enactment in 2010 of SA's own IPR Act that was modelled on the Bayh-Dole Act in the USA.

The institutional commitment exerted by SU top management was found to be high, and it manifests according to interviewees through strong institutional support for Innovus. An academic interviewee was cynical in stating that the message advocating TT at SU is less supported by the Dean of their faculty. This comment seems to be isolated as none of the other participants reported similar issues. Capacity to deal with the approval of research contracts was seen as a problem by some interviewees. Although research contracts falls under a different unit within the university this impediment was indicated as noteworthy and cumbersome by respondents partaking in the in-person interviews.

Expenditure on patenting costs incurred by SU rose significantly from R2,6m in 2008 to R8,3m in 2015 with patent applications averaging 64 per year from 2008 to 2015 and peaking at 105 for 2015 (Figure 6.4). Patents granted were lower on an average and comprised nearly 15% of new patent applications per year, signifying a prudent approach by Innovus to registering new patents. The statistic by SU (2016) in Figure 6.5 showing that 84 PCT patents were issued to SU between 2009 and 2015 is remarkable considering that it was the largest number of PCT patents held at the time by any organisation in SA. This fact is also testimony to the entrepreneurial activity prevalent on the SU campus. Licensing income totaled R20.8m, sale of IP was R2,2m and dividend income received from spin-off companies added to R3.3m over the 8 year period (SU, 2017a). The returns from TTO commercialisation efforts can be accredited to a steadily increasing pipeline of new invention disclosure built since 1999.

Funding for TTO commercialisation activities was discussed in section 6.5. Interviewees mentioned that funding for early stage technologies is challenging, although a few gave credit to TIA for actively supporting early stage technologies. Interestingly, one interviewee representing top management made mention to a model used at MIT whereby postdoctoral fellows are used to start spin-out companies rather than having them publish a research paper as output of the postdoc. This option may be promising given the low levels of jobs currently created by the SA economy. The same representative from SU top management asserts that SU has 30 000 students and staff, and that if 10% (3 000) have a good idea, then 10% of that number (300) would represent great ideas, of which a further 10% (30 ideas) should result in new university spin-out company being established. If 30 spin-out companies can be established by each of the say 20

SA universities, then 6 000 new and sustainable jobs (30 companies x 20 universities X 10 jobs for each new company) can be created, claims this person.

Most noteworthy are the comments under human resources (section 6.6) of an interviewee who hinted at the idea of publication units that should be allocated to inventors for patents registered, rather than the publication of academic articles. If this were to be implemented then we might see a meaningful increase in invention disclosures and new patent applications at SU. The comment from one interviewee that TT activities are not being used in assessing academic staff members during their annual performance ratings was imperative. Top management might see further improved levels of staff satisfaction at SU if this suggestion can be accommodated.

Participants to the in-person interviews were mostly appreciative of the services they receive from Innovus as TTO. Criticism was pointed towards Innovus for its staff not being able to cope with the workload to deliver on TT services to staff and students. This disparaging comment needs to be considered against an ever increasing demand for additional TTO staff members due for a growing cumulative pipeline of invention disclosures. The LaunchLab was singled out as a contributor to raising the awareness of TT on campus and for stimulating interaction and networking opportunities between academics and entrepreneurs, venture capitalists, angel investors, and other governmental agencies. The next chapter details the case study of UCT as the other research-intensive university in the Western Cape Province.

Chapter 7: University of Cape Town (UCT) – A case study

7.1. Brief history and research capacity

The research profile of UCT indicates that it is one of the best universities in SA. By 2009 it was ranked 146th in the THE World Rankings and had more A-rated academic staff members than any other SA university (University of Cape Town (UCT), 2009). UCT built partnerships with many African and international institutions, resulting in the university referring to itself as an "Afropolitan" university (Cape Higher Education Consortium (CHEC), 2009). By 2013 its ranking improved to 113th in the THE World Rankings and UCT was listed for the first time as one of the top 50 clinical, pre-clinical and health universities in the world. UCT was also ranked 154th in the Quacquarelli Symonds (QS) World University Rankings for 2012/13. Moreover, it was the only university in Africa then that was within the top 300 universities listed in the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU) (University of Cape Town (UCT), 2013). UCT boasts more than 5% of the A-rated scientists in SA and has more than 60 specialist research groups providing supervision for postgraduate student work (University of Cape Town (UCT), 2015b).

Input: Expenditure on R&D and researchers

Figure 7.1 below indicates the total R&D expenditure incurred at UCT for the years 2008 to 2015.

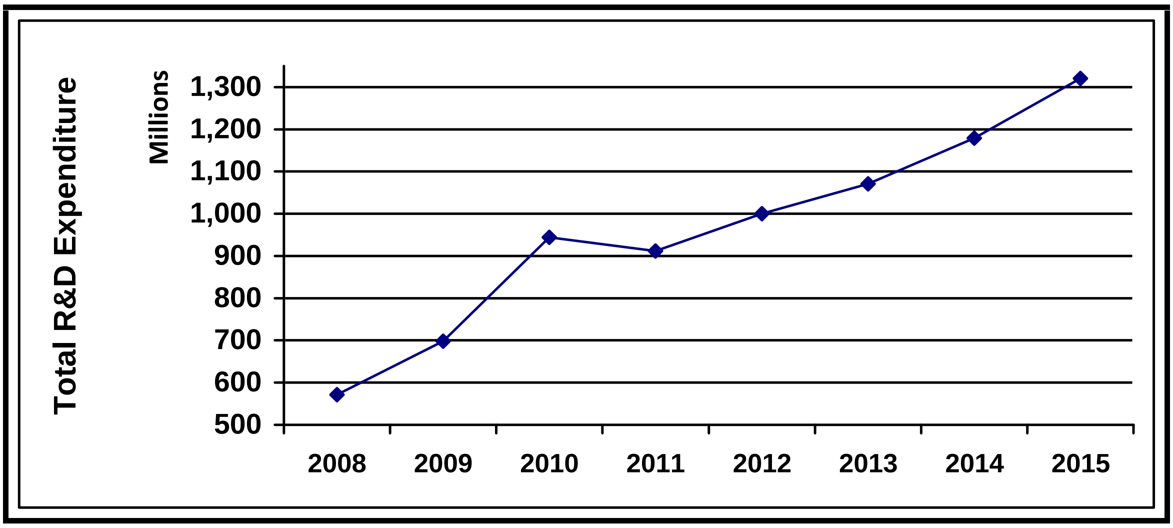


FIGURE 7.1: UCT TOTAL RESEARCH AND DEVELOPMENT EXPENDITURE
Source: SA National R&D Survey Reports (2008 to 2015).

When compared to Figure 7.2, it shows that UCT spent 131% more on R&D over this period whilst its component of instructional staff grew by 25,8%. Programmes introduced through the Centres of Excellences, SARChI, Institutional Signature Themes, and Peer-accredited Research Groupings all contribute to attracting students from all over the world. Figure 7.2 below indicates the growth in the student population that have fulfilled the requirements for a degree at UCT from 2008 to 2015. The number of students increased by 31.9%, from 5 491 students in 2008 to 7 242 by the end of 2015, whilst instructional staff members increased by 25.8%, from 937 in 2008 to 1 179 by 2015 (RSA: DHET, 2015).

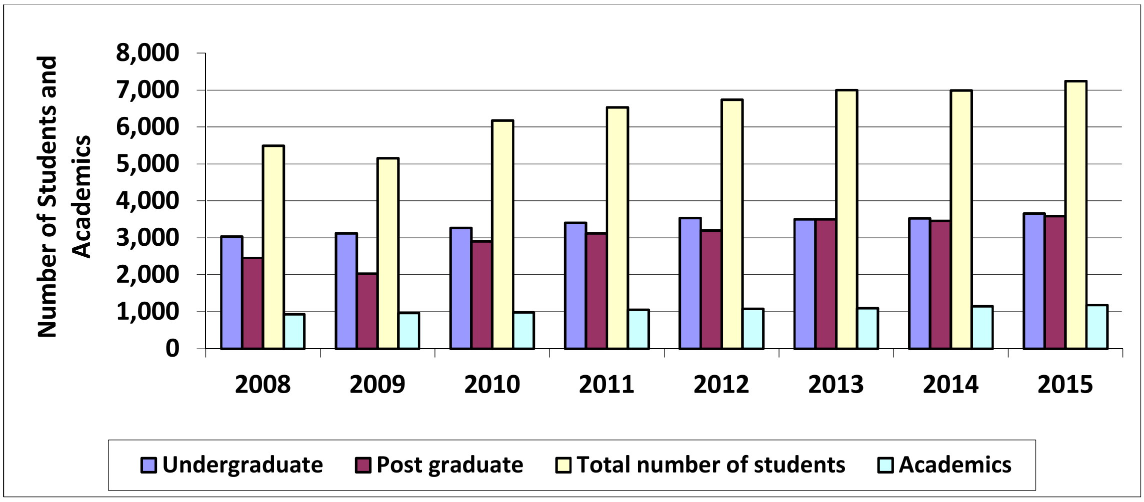


FIGURE 7.2: UCT TOTAL NUMBER OF STUDENTS AND INSTRUCTIONAL STAFF
Source: HEMIS Tables (RSA: DHET, 2015)

Research infrastructure: Centres of Excellence and SARCHi Chairs

In fulfilling and maintaining UCT's stance as an outstanding research-intensive university, several units have been formed to facilitate joint research projects in various fields. The four units driving joint research efforts at UCT are the National Centres of Excellence (CoEs), National Research Chairs, Institutional "signature themes", and Peer-accredited Research Groupings. UCT signature themes offers a structure for inter-departmental and inter-faculty research opportunities that is strategically orientated towards institutional, regional and national priorities (University of Cape Town (UCT), 2015a). The six signature themes are African Cities, Brain and Behaviour, Drug Discovery, Marine Research, Minerals to Metals, and the African Climate and Development Initiative (UCT 2015a). In addition, UCT also concluded several partnership agreements in research activities of strategic importance, located at various faculties such as the Centre for High Performance Computing, the Africa Earth Observatory Network, and the Institute of Infectious Disease and Molecular Medicine (UCT 2015a).

UCT hosts three centres of excellence funded by DST and administered by the NRF namely (1) the Centre of Excellence in Catalysis, (2) Birds as keys to Biodiversity Conservation and (3) Centre of Excellence for Biomedical Tuberculosis Research (UCT, 2019a). In addition to these centres of excellence, by 2019 a total of 42 SARChi research chairs were awarded to UCT (UCT, 2019b).

Output: Research publications

The university has six faculties, being Commerce, Engineering & the Built Environment, Law, Health Sciences, Humanities, and Science. Some of the most well-known of the 100 000 alumni of UCT include the late Professor Christiaan Barnard (heart surgeon) and three Nobel laureates, namely Sir Aaron Klug, the late Professor Alan MacLeod Cormack, and JM Coetzee. The aim of the university is for its academics to be world leaders in their fields and for UCT to be the leading research university in Africa (UCT, 2015b). Table 7.1 below lists the number of UCT research publications that appeared in peer-reviewed journals, as well as the number of master's and doctoral graduates between 2008 and 2015.

TABLE 7.1: UCT NUMBER OF RESEARCH PUBLICATIONS IN PEER-REVIEWED JOURNALS

	2008	2009	2010	2011	2012	2013	2014	2015
Articles	958.6	1038.1	1071.7	1124.0	1191.3	1315.0	1372.6	1389.4
Books / Chapters	53.9	56.6	65.0	61.5	93.4	111.6	133.8	161.5
Conference Proceedings	74.5	93.5	116.3	128.9	106.1	122.5	117.3	102.6
Master's Graduates	345	340	435	561	579	642	623	595
Doctoral Graduates	151	178	160	163	198	205	612	669

Source: HEMIS Tables (RSA: DHET, 2015)

An analysis of the number of research publications in peer-reviewed journals revealed that the total number of article publications by UCT staff grew by 45% from 2008 to 2015. Similarly, publications in books and chapters grew by 200% and conference proceedings by 38%, while master's graduates increased by 72% and doctoral graduates increased significantly by 343% during this period. These statistics highlight a significant rise in relative productivity of academic staff at UCT during this period. Good quality research outputs may lead to new invention disclosures, which are the input for promising technology transfer opportunities. The usual outputs of technology transfer efforts are patents, license agreements and spin-out companies.

Output: Technology Transfer

The invention disclosures and subsequent patents registered by RC&I at UCT provided a solid base from which licensing opportunities are explored and spin-of companies created. Figure 7.3 below depicts the performance of UCT over eight years, from 2008 to 2015, and quantifies invention disclosures, patent application and patents granted over this period.

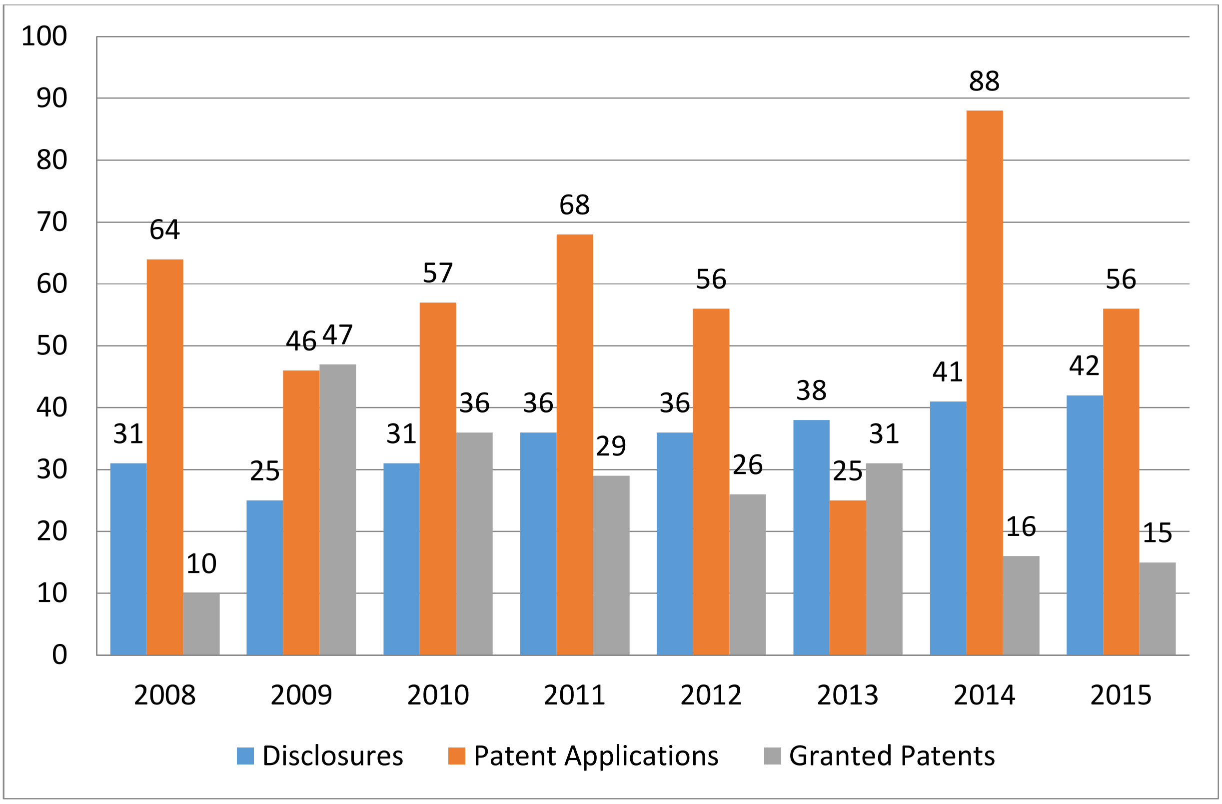


Figure 7.3: UCT Technology Transfer Outputs (excluding spin-outs)
Source: RSA: DST *et al*, (2017) for years up to 2014 and UCT (2015c) for 2015

The data depicted in Figure 7.3 show that the number of invention disclosures emanating from the UCT campus have been steady, at around 35 disclosures on average per annum over the eight years from 2008 to 2015, peaking at 42 disclosures for 2015. Patent applications were also steady at 57 on average per year, except for 2013 when it dropped to 25. In 2014, this number increased sharply to 88, and was back again at 56 in 2015. In 2009, the number of patents granted was the highest at 47, whereas the regular figure is 26 per annum. These statistics signify the cumulative effect of disclosures made by academic staff and students, patents applied for during those years, and patents finally granted in later years. There is a time lag between the initial disclosure date and the ultimate filing and granting of a patent. Income earned from the commercialisation activities of technology transfer at UCT are categorised by RC&I as being licensing income and proceeds from the outright sale of IP, as indicated in Table 7.2 below.

TABLE 7.2: UCT TOTAL COMMERCIALISATION INCOME FROM IP

	Licensing R	Sale of IP R	Cumulative Active R
2008	170,346	150,000	320,346
2009	77,310	59,184	136,494
2010	3,531,989	0	3,531,989
2011	558,545	0	558,545
2012	997,829	382,003	1,379,832
2013	1,757,948	0	1,757,948
2014	1,320,853	5,057,415	6,378,268
2015	3,734,302	38,622	3,772,924
Total	12,149,122	5,687,224	17,836,346

Source: RSA: DST *et al*, (2017) for years up to 2014 and UCT (2015c) for 2015

Table 7.2 supports the claim that revenue streams from IP commercialisation at UCT have increased significantly since 2010. It is evident that the approximately 18 year old TTO at UCT is beginning to bear fruit, as a steady pipeline of new inventions have been forthcoming, especially since the renewed focus and more practical approach were implemented in 2007. The year 2014 saw a total income from IP increasing to R6.38m, making it the best year ever for the TTO at UCT when measured in terms of revenues generated from commercialisation activities (University of Cape Town (UCT), 2015c,d).

Novel findings by academic researchers need to be disclosed before it can be protected. An institutional commitment conducive to the promotion of entrepreneurial activities on campus stimulates innovation and increases the propensity of academic staff to reveal their valuable research findings. The next section discusses institutional commitment as a key dimension at UCT which impacts on its ability to implement effective TT mechanisms. Open ended qualitative questions were posed to UCT interviewees about the university's commitment towards TT. The next section describes the institutional policies employed at UCT in relation to TT.

7.2. Institutional policies

In this section, the IP policy of UCT and the university's Innovation and Research Uptake (I&RU) policy framework are discussed in more detail, whilst its Social Responsiveness Policy Framework is briefly mentioned.

Sibanda (2009) mentions UCT's response to the IPR-PFRD Act, stating that a brief summary of the Act was distributed to new academic staff as part of their induction process. The summary explains the support services offered by the university TTO and alerts new staff to the requirements of the IPR-PFRD Act, as well as the amended IP policy of UCT that incorporates the provisions of the new Act. Sibanda (2009) also reports that (1) a standard IP clause was inserted in all postgraduate student/supervisor agreements which notify students of their duties of disclosure in terms of the IPR act, and (2) a task team consisting of members from each faculty was formed to assess the UCT IP policy and to align it to the provisions of the new IPR-PFRD.

The aim of the IP policy at UCT is to stimulate the use of research outputs in a way that will best enhance socio economic development. The policy sets rules for managing the rights and obligations of all role-players dealing with inventions at the university. The IP policy also allows for the acknowledgement of allocation of incentives for the novel findings of academic staff and students and for delivering efficient application of newly created IP (University of Cape Town (UCT), 2011). The 2011 revised and approved IP policy entitles the creator to share in the proceeds derived from the commercialisation of their IP for a long as income is generated by it.

The proceeds are distributed in various percentages to creators of IP and to third parties as co-owners, based on predetermined increment values of gross or net income. For example, gross income generated up to R250 000 will be allocated on the basis of 20% of the gross income figure, or 50% of net income figure, whichever is the most, to the creator, with the balance paid to the creator's research group. Larger amounts also include allocations to the creator's department and to UCT's central fund. The IP Advisory Committee decides on the allocation of the income for all amounts exceeding R 10 million and after the creator has received 33.3% of the net income. The allocation to the UCT central fund is destined to aid further research, to support the TTO's activities, to pay for patenting costs or benefit innovation and commercialisation, training in entrepreneurship, and IP management in general (UCT, 2011).

Interviewees replied in the affirmative when asked about the existence of UCT's IP policy and whether they support it. Interviewee U2, however, asserted that not every idea is destined to become protected IP which may lead to a commercialisable product. As inventor, this academic claims that the law from which the university's IP policy stems does not make sense, as protection for possible IP is sought too quickly before the real chances of success in commercialisation can be determined.

UCT's IP policy refers to various other policies which need to be read in conjunction with it, including the Private and Professional Work Policies, the Conflict of Interest: Principles, Policy and Rules, the Policy on the Endorsement of Products and Services by UCT and on Licensing the use of the Name, Trademarks and other Insignia of UCT, and finally the Domain Name Policy.

UCT also has a Social Responsiveness Policy Framework that was approved by its senate on 14 September 2012. For academic staff, the policy framework acknowledges the connections and interrelatedness between teaching and learning with the other primary functions of the university. The main aim of the policy is to deliver an enabling environment for promoting and increasing social responsiveness (University of Cape Town (UCT), 2012b). The TTO is specifically referred to in this policy, in that, with regard to social awareness, it must perform the role of "staff development, especially of new academics, and support related to promoting research innovation at national, local and sectoral levels" (UCT, 2012b).

UCT (University of Cape Town (UCT), 2014a) states that the university undertook many studies and arranged stakeholder contacts to formulate the acceptance of an Innovation and Research Uptake (I&RU) policy framework. The process consisted of four phases that was aimed at growing a strong understanding of good practice and creating an environment for promoting a culture of innovation at UCT. The four phases were:

(1) *Understanding the profile of innovation, its inhibitors and facilitators, at UCT*. This phase highlighted the "state of innovation at UCT" report of 2010, where an innovation profile was determined, listing the IP and innovation outputs and sketching the university's support systems for R&D and innovation.

(2) *Reviewing best practice in innovation policies of the United Kingdom and United States universities*. The main question asked in this review was: How does UCT include innovation into the conventional activities of the university. Four themes emanated from the study:

    a. Leadership support for promoting a change in culture is critically important.
    b. Similarities between teaching & learning, R&D, and social awareness need to be included in the complete research process.
    c. Creating the necessary infrastructure is key for enabling a "knowledge-push, effective engagement with stakeholders and demand-pull" (UCT, 2014c:3).
    d. Tools for monitoring and assessment of actions to follow progress need to be implemented.

(3) *Increasing the profile of innovation at UCT*. An Innovation Forum was started through which the idea of entrenching innovation more directly within the university could be tried. This process was also significant in increasing the profile of innovation at the university.

(4) *Developing an innovation policy framework for the university*.

UCT (2014c) then identified five pillars through which innovation and research uptake will be entrenched. Research uptake is how knowledge is transferred from the producers of knowledge (academic staff) to the users of knowledge (end-users, businesses in commerce and industry, or governmental agencies). Research uptake management is a focused, repetitive process that satisfies internal (academic staff and university) and external (funders and beneficiaries) participant requirements.

The first pillar of innovation and research uptake is based on establishing an enabling environment via cultural change and staff participation. This includes commitment from top management to driving the new culture, increasing the awareness of I&RU and increasing incentives to researchers that engage in I&RU activities. Another part of this pillar is an undertaking to capacity building in R&D and support staff that are appropriately skilled in I&RU activities. The second pillar comprises interactions with the outer environs. The aim is for UCT to become well connected to other innovation systems via the creation of widespread networks with role-players. The third pillar is based on combining I&RU activities into teaching and learning activities, while the fourth pillar is the inclusion of I&RU in the research process.

The fifth and last pillar is of particular importance to this study (UCT, 2014c). Called engagement in I&RU, this pillar focuses on social awareness, technology transfer, commercialisation, and entrepreneurship. This pillar has as its aim to equip I&RU via funding, infrastructure, information technology, and human resources, prominently also via the development of the capacity of personnel at the university TTO. UCT (2014c:4) reports, “The university will review support for social innovation, commercialisation, entrepreneurship and technology transfer ensuring the appropriate activities are developed along the I&RU value chain in the university.”

The policy framework described above acknowledges that there is a heightened burden on UCT to contribute meaningfully to local economic and social development and thus proposes the implantation of the five pillars into widespread I&RU activities within the University (UCT, 2014c).

This section briefly elaborated on a number of institutional policies, in particular those policies having an impact on innovation and TT at UCT and is followed below by a discussion on institutional commitment exerted by top management to promote TT activities.

7.3. Institutional commitment by top management at UCT towards TT

Differences in the culture of academics, TTO managers (as university administrators) and entrepreneurs are cited by Siegel *et al.* (2004) as being one of the major barriers to effective university technology transfer. Siegel *et al.* (2004), Alessandrini *et al.* (2013) and Bansi (2016) all noted that the role of top management is crucial in getting academics and students to increase their propensity to disclose their novel findings and seek commercialisation thereof.

A strong institutional commitment from top management within UCT and adequate rewards were seen as very important, often determining success in university TTO activities (University of Cape Town (UCT), 2007a). In response to a question on whether the institutional commitment towards TT at UCT is strong or weak, an interviewee (U1) replied unequivocally that support from central management towards TT was very strong at UCT. For interviewee U1, the institutional commitment was demonstrated by way of a favourable allocation of equity (shares) in a new spin-out company that was formed. As founders of the spin-out company, academic staff members were allowed to keep a significant portion of approximately 85% of the initial shares that were allocated and issued to shareholders. Further assistance came when the university TTO connected the spin-out company to its first major investor, the IDC. Interviewee U2 responded that their research team had very easy access to Dr Andrew Bailey, the TT manager, as well as the rest of the TTO team at UCT. This signified solid institutional commitment to them. U2 further asserted that the TTO team was always willing and able to assist in patenting new findings at very short notice and that the interaction between the TTO and academics was very professional. Interviewee U5 added that the IP Advisory Committee (IPAC) that advises on all matters relating to the commercialisation of IP at UCT was functioning very well and that the good functioning bodes well for the future.

In response to a question on what motivates academic staff members of UCT to commercialise their research results, one respondent stated:

> I was determined to get involved in some way in TT and started to serve on the board of directors of a number of companies in the biomedical engineering field. I had been a full professor for 14 years and had taken my career as far as it could go. I was an A-rated scientist and part of top management, but was looking for a new challenge in my career (U1).

Importantly, interviewee U4 observed that their faculty refunds about R400 000 per annum from the proceeds it received from cost recovery on research being conducted within their faculty back to the departmental unit and remarked that "…this is new and will allow us to appoint two Post-docs and an Admin Assistant for three years".

However, the same respondent (U4) also expressed some criticism, stating that "…the central university admin needs to contribute and further incentivise innovation on campus. They talk about it. There's lots of hand waving, but they actually don't do anything at all". The respondent further noted an apparent lack of commitment by top management in not appointing enough staff members to work in the TTO. The interviewee reckons that the TTO itself should also receive more of the proceeds from commercialisation of IP to increase its human capacity to deal with the growing needs and challenges that the TTO at UCT faces.

> The TTO started out primitive some 20 years ago. It went through a phase of rapid expansion but lately its support has plateaued and that's regrettable as the amount of research funding has doubled. The TTO is under-staffed and basically overworked at this point according to me (U4).

TTO at UCT was given the freedom to be creative in their approach to attract interest from academic staff and student towards TTO activities. The establishment of the TTO in 1999, long before the enactment of the IPR-PFRD Act of 2008 in SA, further indicate a willingness by top management of UCT to engage in something that was untested in SA at the time. The protection of IP and the commercialisation thereof through TT activities were seen by UCT as an opportunity to create social and economic benefits for all in SA (University of Cape Town (UCT), 2008a).

This section evaluated the institutional commitment prevailing at UCT towards TT. The institutional commitment exerted by top management was seen as strong by most academic staff participating in the interviews and they reported having frequent access to TTO staff. Although a comment was made by an interviewee that the human resource capacity constraints at the TTO shows a lack of commitment from the institution, one needs to consider this comment against the background of financial constraints experienced by all SA universities at present. A suggestion was made by an interviewee to allocate more proceeds from IP commercialisation directly to the TTO for it to appoint more staff members. Top management should consider this suggestion, as it may deliver increased deal flow and income from TT activities through better mining of IP assets on campus. The next section more fully describes the IP protection at UCT.

7.4. Intellectual property protection

UCT has been one of the first universities in SA to start protecting their IP emanating from its campus and engaging in technology transfer activities since 1999. By the middle of 2007, a total of 108 disclosures had been received, of which 30% did not lead to the filing of a patent (UCT, 2007b). The reasons for not acquiring patents on these disclosures included (i) a lack of the inventive step, (ii) IP being already in the public domain, (iii) not belonging to UCT, or (iv) being underdeveloped (UCT, 2007b).

Disclosures from the science faculty included therapeutic applications for cardiovascular conditions, infectious and inflammatory diseases, and cancer. These disclosures were received during the period 2001 to 2007 (UCT, 2007b). Disclosures for improvements in nanotechnology, information technology, medical devices, probiotics, and virus-defiant crops were also received (UCT, 2007b). Cumulated patent costs paid by the TTO amounted to R2.2 million by 2007, of which approximately R700 000 was recovered from the Patent Support Fund of the Innovation Fund at the time. An amount of R330 000 was also paid in the three years leading up to 2007 to 24 UCT inventors as compensation from the Innovation Fund's Patent Incentive Scheme (UCT, 2007b).

In response to the provisions and requirements of the IPR-PFRD Act of 2008, UCT took the following actions regarding its TTO activities:

- Presentations were held, and information was shared with academics and students about the implications of the Act. The audio-visual presentations were posted on its website.
- To fulfil a condition of the Act, a "full cost model" for funding research projects was prepared and put into use from 1 January 2011 for cases where external parties wish to retain all IP.
- The Leonardo database, used by UCT from 2007 to trace the progress of IP disclosed through various stages of commercialisation, was amended to incorporate new reporting requirements as set by NIPMO (University of Cape Town (UCT), 2011).

Protecting IP is costly and is often the most expensive item of the total operational expenses of a TTO. As reported in Chapter 4, the Innovation Fund (IF) in SA established a patent support fund to assist universities in SA to cope with the patent costs of new inventions. The same chapter reports on how the IF was later consolidated into TIA. Financial support to pay for patenting costs is maintained by TIA to the benefit of UCT and all SA universities. Figure 7.4 below indicates the total UCT patent costs from 2008 to 2015.

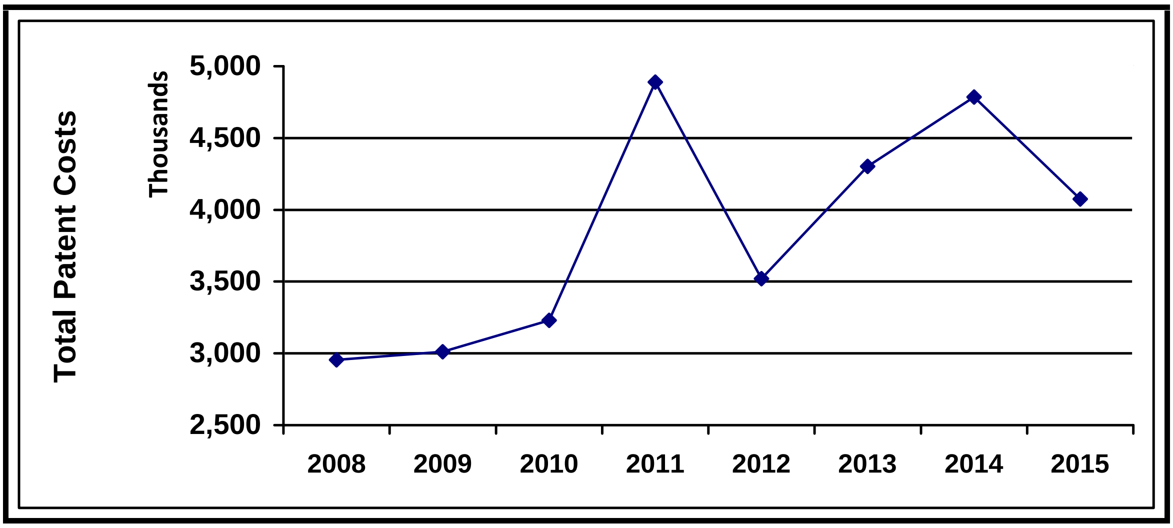


FIGURE 7.4: UCT TOTAL PATENT COSTS
Sources: RSA: DST *et al*, (2017) for years up to 2014 and UCT (2017b) for 2015.

As depicted above, the total expenditure on patenting costs rose from R2,954m in 2008 to R4,075m in 2015, with 2011, during which R4,89m was spent on registering new patents, having been the most expensive year. In total, an amount of R30,77m was spent over the eight-year period. It is likely that the IPR-PFRD Act of 2008 enacted in 2010 spurred costs incurred by UCT on patenting even further.

A total of 88 patent applications were filed by UCT in 2014, the highest ever. Most of these were national phase applications (58), paid for by partners in commerce and industry via license arrangements (University of Cape Town (UCT), 2015d). Although a high number of invention disclosures (41) were received in 2014, the conversion to provisional filing was low, due to other methods of IP protection being required (such as designs, or copyright (software), or due to more research work necessary) before filing occurs (UCT, 2015d). By the end of 2014, UCT had 152 active patents that were granted. Of these, 47 (ACE portfolio) were moved to a new spin-out company called AngioDesign during 2015, while another 62 granted patents were abandoned (allowed to lapse) at the time (UCT, 2015d).

Participants in the interviews affirmed that they knew about the IPR-PFRD Act of 2008 in SA that now compels universities to protect newly created IP and then to commercialise it. While some felt it is too early to judge the success of its implementation, others, like interviewee U2, thought that the expertise in the country is not adequate to implement the law effectively. Interviewee U2 also reiterated that there is no sense in protecting every bit of IP without knowing more about its chances of success, as it is costly. Interviewee U3 too thought that IP is too broadly defined in the Act and that it covers things to be protected that should actually not have been covered and protected. However, interviewee U04 applauded the new IPR-PFRD Act for stimulating innovation from SA universities, arguing as follows:

> There's this academic conceit that you should only work on basic research and not so much on applied research. I have received much more money by doing applied research than I ever received doing pure science (U4).

In addition, interviewee U5 underscored the commonly accepted notion in the United States that research results from publicly funded science projects should be freely available. He advocated that the rest of the world is increasingly moving towards open source and free dissemination whilst the IPR-PFRD act in SA is more restrictive (U5).

In response to a request to describe the legal and support services offered by UCT's TTO, interviewees again commended the service they received as extremely satisfactory. Commenting on areas where TTO staff could improve on, interviewee U3 noted awareness creation amongst academics that go to conferences and divulge valuable research findings before IP has been safeguarded. Furthermore, interviewee U4 observed the poor writing skills of patent lawyers in drafting patents, but admitted that is has improved hugely over the years. He indicated that two of their former students who are working for law firms are drafting patents for the TTO, which helps very much

Without any doubt, all interviewees strongly recommended the TTO's services to fellow academics and students as a critical service unit within the university that supports the effective commercialisation of IP emanating from the UCT campus.

This section considered the legal milieu at UCT as it related to TT. The pertinent issues emerging from this section are:

- The interviewees were aware of the IP policy of UCT and the IPR-PFRD Act, but felt that the protection enforced by the new Act is too strict and many pieces of IP is protected at a high cost before its commercial potential is evaluated.
- There was a comment that too much emphasis is put on academic staff to engage in IP commercialisation, while less effort is made to protect and commercialise novel findings from postgraduate students. This point is valid, but it is likely that the volume of quality research at UCT will be performed by seasoned academics or research teams consisting of postgraduate students, guided by professional academic staff.
- There was consensus that the support services from the TTO were excellent and were to be recommended to academic staff and students. The fact that the TTO at UCT has been in operation since 1999 is no doubt contributing to their good service levels, as they have learned how to maintain healthy relationships with key stakeholders in the TT process.

It is evident from this section that UCT embraced the requirements set by the new IPR-PFRD Act and succeeded in selling the legal requirements of this act to UCT staff and students, despite an opinion raised that the TTO may be too aggressive in protecting raw pieces of IP. The ability of the TTO to protect new IP emanating from UCT has contributed to the increasing number of invention disclosures. The next section denotes funding as another key dimension, as derived in the conceptual analysis for this study.

7.5. Funding for TTO commercialisation activities

Funding is an important part of any research undertaken, as without it no expenses can be incurred towards solving complex research questions and challenges. By 2007, the cumulative patent costs paid by the TTO of UCT since 2000 amounted to R2.2m, of which R 391 970 was recovered from the Patent Support Fund. Over three years prior to 2007, a further R330 000 was paid to 24 inventors who participated in the Innovation Fund's Patent Incentive Scheme (now administered by TIA) (UCT, 2007b). Once protected, newly created IP needs to be developed further to reach its full potential, often at a high cost. In its commercialisation strategy document of 2007, RC&I stated the case for the creation of pre-seed fund to provide financial assistance to early stage technologies. The aim of this fund is to bridge the funding gap in the innovation value chain before other funding resources can be approached (such as TIA, IDC, venture capitalists, etc.). Such a seed fund will be administered by RC&I and be assisted by a review panel consisting of experts from both within and outside UCT that will provide guidance and allocate funding to needy projects (UCT, 2007b).

Although R&D expenditure at UCT had increased to R547m by 2008, increases in the level of funding for TT activities did not occur (University of Cape Town (UCT), 2008b). All TTOs need funding for operating costs and to protect and exploit newly created IP in its infancy in order to enhance its sale ability. The major expenses for a TTO consist of patent registration fees and staff remuneration costs. Expenses are offset by income earned from commercialisation activities (royalties, assignment fees, sale of IP and dividends from spin-out companies), rebates received from government institutions, and awards obtained.

In a competition held during 2008 between SA's HEIs, UCT was named the best improving university in SA with regard to TT capacity, and came second overall (UCT, 2008b). The total awards in prize money received amounted to R425 000, which was spent on staff development and other TTO activities (UCT, 2008b) at the time. In 2008, RC&I launched its UCT Pre-Seed Fund which allocates funding to technologies in its initial stages to best bridge the funding gap that exists. It was hoped that the fund would move UCT's research output quicker and nearer to the market. An amount of R500 000 was made available annually by the university's Research Committee to the Pre-Seed Fund on a two-year trial basis and was split into two tiers of funding, called *Explorer* funding and *Concept* funding respectively at the time (UCT, 2008b).

Explorer funding has a limit of up to R20 000 per project over a very short period and usually pays for specialist consulting, initial business plans, obtaining market information, preparing samples, or gathering verified statistics (UCT, 2008b). More than one award may be made to the same invention to attend to various challenges. Concept funding has a higher upper limit of R100 000, which may even be exceeded should circumstances warrant it (UCT, 2008b). Funding is intended for several areas in the commercialisation value chain such as the pilot phase, building prototypes, compiling a detailed technology package, showcasing the technology, raw materials, or even parts. Ongoing funding was approved for the Pre-Seed Fund due to the success of the trial period covering the first two years since establishment (University of Cape Town (UCT), 2008b, 2009).

RC&I identified a funding need for innovation between the ranges of R500 000 to R2 000 000 (University of Cape Town (UCT), 2011) (UCT, 2011b). The limits of contributions from the Pre-Seed Fund described above were low compared to typical VC funding, which usually starts at R5m (UCT, 2011b). This funding need was addressed by RC&I through the establishment of a larger fund, called the UCT Evergreen Fund, which determines its own funding criteria and business model. The UCT Evergreen Fund was introduced in 2010 when the new IP policy was approved by UCT's senate and council (UCT, 2011b). It was envisaged that the funding will be subject to a repayment of some of the funding from the spin-out company to the fund to top up the fund once the spin-out company is operational. This fund would ensure that projects can survive financially whilst a next round of funding is sourced to enable the appointment of key staff members to run the company, making the proposition more appealing to VC inventors (UCT, 2011b).

RC&I canvasses alumni of UCT with the help of the Alumni Office to gather support in various areas, namely financial support for the Evergreen Fund; mentorship of spin-out companies; managing directors or non-executive directors for spin-out companies; and specialists partaking on patenting review committee panels (UCT, 2011b). Fundraising for the UCT Evergreen Fund coincided with a request to TIA to provide matching funding. The Evergreen Fund adds to the current base of the UCT Pre-seed Fund with the aim of assisting promising technologies to turn into solid businesses. Funding takes the form of interest-bearing loans rather than grants or acquiring an equity share in the spin-out company. The university council approved that an amount of R2m of capital, which has grown from an initial donation of about R500 000 made by Mr Richard Sonnenberg in the early 1980s, be utilised to start the fund (University of Cape Town (UCT), 2012a).

Funding from NIPMO to RC&I for additional staff has created much needed capacity within UCT's TTO. RC&I received an amount of R1 473 378 for the first year and utilised it by appointing an extra contracts manager (UCT, 2012a). This position was required due to an increased workload caused by the IPR-PFRD Act. The next year, 2013, saw NIPMO allocating another R8 320 000 of funding to RC&I for a three-year project to support specific employment positions (University of Cape Town (UCT), 2014b). This support came at the most opportune time, since constraints on the Patent Fund required a comprehensive analysis of the UCT IP portfolio (University of Cape Town (UCT), 2015c).

TIA's own Seed Fund is expected to fast track funding to projects needing less than R500 000 to expand TIA's investment portfolio and has made an important contribution to UCT's innovation capacity (University of Cape Town (UCT), 2015d). A total of 27 applications were received during 2015 to the value of R12 52m, of which 8 was supported by TIA to the sum of R3.95m (University of Cape Town (UCT), 2016b).

In response to a request to describe their efforts to secure research funding, interviewee U1 remarked that about one third of the 35 grant applications that he had written were funded. That is a good ratio and he claims:

> I have learned how to play the game. You have to know the rules and you have to know-how to play by the rules to raise the money (U1).

Interviewee U2 had a SARCHI chair that provided her with much needed baseline funding. Interviewee U4 was critical of the NRF, saying that it is not a real funding agency anymore. She indicated that her research unit rather applies for funding from the MRC, TIA, and DST in SA, as well as for funding from the European Union and some institutions within the United States.

There was a feeling amongst interviewees that the TTO should assist them in securing funding for new research projects. Interviewee U1 reckons that the Research Development Office at UCT does help a lot in securing research funding and claims that UCT is the most successful institution outside of the United States that receives United States National Institute of Health grants whether it be in Britain, Canada, Australia, or wherever. Although the TTO assisted in getting access funding applications to TIA, interviewees confirmed that they primarily seek grant funding by themselves.

UCT itself allocated some seed funding towards new businesses and promising research initiatives, but interviewees experienced that the TTO does not stimulate strong interaction between them and entrepreneurs, venture capitalists, angel investors, and other governmental funding agencies. Mostly, participants in the interviews stated that they connect with funders and/or investors through personal connections made at conferences locally and abroad.

This section can be summarised by referring to a few main findings under specified headings:

Development cost of IP: To maximise the commercial potential of newly created IP may require significant financial investment. UCT realized this fact and created a pre-seed fund to aid early stage technologies to cross the funding gap in the innovation value chain when very limited other funding options are available to academic entrepreneurs.

Funding TTO activities: Although the TTO of UCT is discussed in section 7.7, it is worth noting here that the financial support for TTO functions at UCT did not increase along with the increased R&D expenditure experienced at UCT (UCT), 2008b). The results is an inevitable reduction in available funding for new patent expenses and to add value to newly developed IP to increase its commercial potential. As much as funding is required to stimulate R&D activities and the furtherance of protected IP to get to marketable products, funding is also needed to pay for the TTO support services of the university.

Best Improving University: UCT was branded as the best improving university amongst HEI's in SA when referring to TT capacity back in 2008 (UCT, 2008b). Since then UCT has seen a remarkable growth in TT activities which has tested its capacity to deliver TT services to a growing body of entrepreneurial academic staff and students. The TTO at UCT is more fully described in section 7.7 below.

Funding mechanisms initiated: UCT's Research Committee launched its Pre-Seed Fund during 2008 that was divided into the *Explorer* fund (R20,000 per project) and *Concept* fund (R100,000 per project). The UCT Evergreen fund followed to aid auspicious technologies to become profitable business ventures by providing interest-bearing loans rather than grants to the startup spin-out companies.

Funding support from NIPMO: Funding received from NIPMO by the TTO at UCT was significant at over R1.4m during 2012 and was followed by an even greater amount of R 8.3m stretched over a three year period. The funding was specifically aimed at increasing the human capacity at the TTO within UCT to cope with an upsurge in research contracts.

Networking opportunities for funding: The interviewees testified that the TTO does not promote strong linkages between themselves and other businesses, venture capitalists, angel investors, and governmental funding agencies. Respondents being interviewed claims that they link up with additional funders and other investors through personal connections.

The next section is designated to a discussion on human resources and its role in effective TTO practices employed at UCT.

7.6. Human Resources

Incentives for academic staff to engage in TT activities

UCT (2007b) claims that TT activities at the university have the support from the DVC, but that performance measures are not adequate to motivate staff and to increase their propensity to disclose their research findings. UCT (2007b) advocates for better incentives for academic staff, which should include non-financial rewards such as sabbaticals with companies to get exposure to businesses in commerce and industry and flexible options for moving in and out of the research environment (UCT, 2007b). Non-financial rewards may also include:

- featured editorials,
- a small plaque to honour top inventions at an annual award ceremony, and
- special mention in the annual Research Report of the University (UCT, 2007b).

An *Inventors Coffee Mug* was designed to be presented to promising inventors by the TTO and two brand new publications were released during 2010. The two publications were the *UCT*

Laboratory Notebook and *Innovation at UCT 2010.* The latter publication is an annual publication which reviews UCT's IP commercialisation efforts and TT achievements over the calendar year.

Yet, the matter is certainly not as simple as that. Incentives and rewards operate in a context of opposing demands. As one of the academic interviewees phrased it:

> The tension is one of time, time commitment. There's a tension of people within academia that feel a little uncomfortable about academics who go on and make their way in the commercial world. I didn't manage that tension well and eventually I decided to take early retirement which I was eligible for. I had accomplished everything I wanted to as a professor and then wanted to become a businessman (U1).

UCT (2012b) reports that UCT allows for the creation of an esteemed social awareness reward in its Social Responsiveness Policy Framework. This can be awarded to staff members of the university in addition to other rewards for the more traditional disciplines of teaching and research. The incentive offers a strong sign to staff members of the University that the social responsiveness policy is an institutional strategy of significant importance.

Regarding the effect of TT activities on the academic promotion or career trajectory of academics at the university, academic interviewee U4 said that there is no recognition apart from publications that may arise from their research efforts, whilst a representative from management (U5) said that TT activities are now being incorporated into the annual evaluation criteria for academics in the sciences and engineering faculties. Interviewee U5 from top management also indicated that patents are now included in the criteria for ranking scientists by the NRF.

When asked which rewards inventors would like to see implemented to increase their willingness to disclose new findings and seek commercialisation, interviewee U3 from top management implied that increased exposure in annual booklets and reports plus personal recognition like the inventor's mug for first time inventors should suffice. Apart from the obvious financial incentives, such as the sharing in licensing income and growth in the value of equity held in spin-out companies, academic interviewee U1 noted peer recognition and recognition by university administrators for TT activities that is growing. He added:

> TT participation is not as highly celebrated as somebody who's, for example, an A-rated scientist. I know that because I had an A-rated rating for ten years (U1).

The respondent from top management (U3) mentioned that departmental culture often plays a role. He also mentioned the extent to which individuals as inventors motivate others once they reap the financial rewards resulting from successfully commercialised products or services. Interviewees concurred that there should be a balance between the inventors and the public at large in sharing the financial benefits from TT activities, where the one should not benefit unduly compared to the other. Management interviewee U3 summed it up as follows:

> Hopefully the public will benefit from the outcome, but I think it's important to incentivise the inventors adequately and the university. We want a fair deal for everyone, but we don't chase the money too hard. We have one arrangement where we receive about $170 000 a year from a license arrangement we have with a foreign company, which is nice, but we also have a research collaboration agreement with that same company that bring in much more money than that (U3).

Regarding the sharing of benefits from TT activities, management interviewee U5 communicated the following:

> I suppose the inventors should be the people who are the beneficiaries because if you have successful entrepreneurs you have a successful society and it helps the public at large to have successful inventors as entrepreneurs. Insofar as they use the state funds to get there, I think it is fair that some of the proceeds from commercialisation comes back to the university that enables the production of the IP (U5).

What these quotes by management interviewees U3 and U5 reveal is that there should be a good balance between the financial rewards for inventors at universities and the benefits accruing to the public at large, who ultimately fund universities in SA. Heher (2006) also suggests these additional benefits from university TT that are not recorded at the level of the institution, but rather by the local economy, such as job creation and economic growth.

Interviewees U3 and U5, representing top management, revealed that the Executive Officer of Finance has convinced the council of UCT to allocate funds from UCT's pool of investments for investment in new spin-out companies emanating from its campus. Of further importance is the statement of academic interviewee U4 that, at the time, their faculty refunded about R400 000 per annum from the proceeds it received from cost recovery on research being conducted by their centre back to the department.

Yet, academic interviewee U4 referred to the lack of capacity in the TTO and suggested that more of the share in profits from commercialisable products allocated to the central university's reserves should be allocated back to the TTO to increase human capacity in the office. Management interviewee U5's only criticism is that the TTO focuses too much on academics and not enough on postgraduate students. He reckons a lot of valuable IP generated by students is lost. Hopkins (2014) claims that intuition plays a key role in innovation.

> Talk to any great surfer and ask him how he chooses the wave to ride. He will say, "I know it when I see it." Intuition is something we are all born with. Unfortunately, traditional education usually drums it out of us by requiring evidence to support a thesis. Innovation requires listening, grabbing an inspiration and riding it where it goes. What happens next is the dots connect. For me I literally hear a bell go off when this happens. And then everything just falls into place - right people show up when I need them. You are in the slot….riding the wave.

From the above, it is clear that incentives to engage in TT activities are needed to encourage participation of academic staff in entrepreneurial activities. These incentives should include the usual direct financial benefits, which is the sharing of income derived from commercialisation activities, as well as personal appraisal on various platforms and in publications. Successful entrepreneurial academics and students are often well-connected individuals that are willing to take calculated risks. The next section discusses networks that lead to increased collaboration between researchers and other research institutions in more detail.

Networks leading to collaboration

The chief aim of RC&I at the TTO of UCT is to promote university technologies that are close to commercialisation and that may need additional funding and/or the help from alumni as mentors for new spin-out companies. To be effective in promoting the commercialisation of novel technologies, the TTO must be able to establish networks that lead to collaboration. Every year, an evening was set aside at UCT to showcase the latest discoveries and patents produced by UCT staff and students. Called Café Scientifique (UCT, 2014g), the evening was an initiative aimed at building connections between inventors and investors for academic entrepreneurs that actually have something to spin out (management interviewee U5). Café Scientifique, which was established during 2013, was set up as a local branch of an international concept (UCT, 2014g), for the purpose of promoting informal discussions around science, engineering, and innovation and to enhance wider community participation (UCT, 2014g). Four Café Scientifique events were held in 2014 during which academics interacted informally with businesses in commerce and industry whilst enjoying a glass of wine. Three of these events were subsidised by TIA and Spoor & Fisher, as a reputable firm of attorneys, was secured as a sponsor for Café Scientifique evenings held in 2015 (UCT, 2014g).

Another example of using networking to collaborate was when RC&I joined forces with the Centre for Innovation and Entrepreneurship of the UCT Graduate School of Business. Through its Director, Dr Mike Herrington, they collaborated on a number of projects. The closer ties with the business school are bearing fruitful results as more and more MBA students are used to provide expertise and connect new inventions with technology-oriented entrepreneurs.

RC&I facilitates entrepreneurship training at UCT by presenting a free course on the writing of business plans, which is aimed at postgraduate students and academic staff. Two new training courses were also introduced in 2013. The first, called IP Savvy, is an online programme consisting of modular presentations about UCT's IP Policy, invention disclosure procedures, IP protection, and the commercialisation of IP. The other course presented with the Research Contracts team is held bi-annually and is an induction course for new academics (University of Cape Town (UCT), 2012a).

On the subject of interactions with governmental scientists and laboratories, academic interviewee U1 acknowledged contact with the CSIR, but said they often compete with other universities for the same funding from DST via the NRF and TIA. Academic interviewee U2, being critical, asserted:

> We run our own lives, we're not very good at being facilitated. I can't imagine the University telling me to go and talk to them. We go to meetings and to various conferences

> internationally and nationally where we meet people from different organisations. So we create our own network in that way (U2).

Interviewee U3 mentioned a strong relationship between the university TTO and TIA and stated that TIA's seed funding of up to R500 000 per project significantly increases the prospects of success for many new ventures. He further advised, "One of the best initiatives, I think, is that TIA was established".

Interviewee U5 from top management argued that the Design School of Thinking and the Bertha Centre for Social Entrepreneurship at the UCT Business School are both units at UCT that stimulate lateral thinking and aid disruptive innovation for social benefit to society. Both these units are creating opportunities for staff and students to increase their network of contacts, which might lead to collaborations. Moreover, management interviewee U3 proclaimed that the TTO was instrumental, not only in bringing together people from various industries, but also encouraging IP lawyers to share their TT experiences and insights on IP law in regular talks.

Hopkins (2014), again comparing innovation to surfing, asserts that surfers group together to form a tight community.

> They get energy from each other. They encourage each other to keep going. They learn from others' attempts. They assuage their fears. They share a common understanding of the sacrifices involved, the injuries incurred. Innovators are like that too. Numerous forums exist that bring together change-makers from across multiple industries. We hear from the best, we meet new potential partners, we leave refreshed and reinvigorated to push harder.

During the interviews, participants confirmed strong, positive, and trustworthy relationships between themselves and the TTO staff members at UCT, which did not need to be improved upon further. This is beneficial for the TTO at UCT, as trusting relationships are particularly important for successful university TT, as confirmed by Henton *et al.* (2002).

This section considered human resources at UCT in relation to TT. It specifically explored how incentives on offer by UCT can and should be used to increase the propensity of academic staff and students to disclose their novel findings and seek commercialisation. The most important findings from this section can be summarised under the following headings:

- *Entrepreneurial activity:* Entrepreneurially orientated academic staff and students are motivated to disclose their research findings because they are seeking to grow and succeed in areas outside the realm of the academic pursuit of knowledge. Peer recognition and appreciation by university management for TT activities were seen as stimuli for growing involvement by academics in TT activities.
- *Networking promoting linkages:* Café Scientifique evenings held at UCT succeeded in building connections and networks between academic inventors, investors, and fellow researchers at other SA institutions.
- *Funding for research:* Interestingly, interviewees were united in claiming that UCT should not assist them to secure funding for new research projects. They ascertain that their connections with funders and/or investors are made via personal connections from attending conferences locally and abroad.
- *Income earned by Inventors:* Academic staff agreed that TT can be a major source of income for them, their department, and the university. Given the statistics from the rest of the world, this assertion may me too optimistic, as blockbuster patents delivering above average returns are scarce.
- *Faculty incentive:* The fact that one faculty at UCT returned close to R400 000 each year to the departments from where inventions originated is noteworthy. This initiative is encouraging and an example that should be followed by more faculties and other universities too, as it strengthens the capacity of entrepreneurial academics to do more quality research, which may lead to more commercialisation opportunities.

Central to any university IP policy is the TTO management function that ensures compliance to it. The next section denotes the TTO at UCT in more detail.

7.7. Technology transfer office (TTO)

The Office of Industry Liaison (OIL) at UCT was established in 1999 and report to the Deputy Vice-Chancellor (DVC) of Research and Innovation. Its main focus is to assist UCT in its aim to double its income from research funded by external parties by 2002 and to exploit the university's IP emanating from research activities. Initially, it was estimated that OIL would be self-sustainable within 5 years from income earned from commercial activities. However, the management of the TTO soon realised that there is a long lead time between new invention disclosures and income being generated from protected IP for the TTO (UCT, 2007b).

Dr Duncan Millar acted as the first director of OIL at its inception and Ms Rosemary Wilson was appointed as the first IP Manager. Research contracts were scrutinised for IP issues that might adversely impact on the university or on the ability of UCT researchers to conduct their research (UCT, 2007b). Proceeds from IP exploitation flowed back to the research community and were divided in equal shares between the researcher/s, their department, and the research funds of the university. During the first two years of operation, OIL received 6 invention disclosures and filed its first SA provisional patent for Smart Froth®. The IP was created by a combined team from the Departments of Electrical and Chemical Engineering (UCT, 2007b).

Dr Duncan Miller resigned as Director in 2000 and was replaced by Dr Tony Heher. During 2001 the name of the TTO was changed from OIL to UCT Innovation. In the following year a company called Innovation@UCT (Pty) Ltd was formed with the purpose of (i) commercialising new inventions from UCT, (ii) accommodating joint venture initiatives with key equity partners, and (iii) holding equity shares obtained in spin-out companies (University of Cape Town (UCT), 2007a, 2014b).

The TTO at UCT, was renamed to Research Contracts & Intellectual Property Services (RCIPS) in 2007 and again to Research Contracts & Innovation (RC&I) in May 2016 (University of Cape Town (UCT), 2016a).

Soon after the name change in 2007, UCT re-assessed its approach to the commercialisation of IP and a renewed focus added impetus to its TT efforts. A strategy document was compiled and a scorecard was used to list strengths and weaknesses of the commercialisation efforts since the start of the university TTO in 1999 (University of Cape Town (UCT), 2007a). Some of the strategies for improving the awareness of IP issues and the prospects of commercialisation on the campus included the compilation of an IP information booklet, a redesign of the TTO website, presentations delivered on IP protection, development of the UCT IP policy, presentation of seminars, publication of a regular newsletter, and the use of "IP Scouts" to mine the campus for valuable pieces of IP (UCT 2007).

Although several promising patents were registered, UCT did not actively seek licensing agreements at the time, but decided to become much more active in unlocking the commercial potential of inventions emanating from its campus (UCT, 2007b). A “Stage-Gate” model was developed to determine the needs for the commercial success of new inventions, such as market research, prototypes, patent registration requirements, countries to be considered, commercial partners, and an initial business plan. The Stage-Gate model highlights the need for extra research and development (if any) prior to the commercialisation phase of an invention. IP identification scouts, mentored by RC&I, were appointed to assist in mining university departments and identify valuable IP and commercialisation opportunities (UCT, 2007b).

UCT staff from the TTO visited Oxford University’s TTO for training, which gave them useful insight into their own processes. For the UCT staff members, it was comforting to learn that many of the systems and processes for the successful management of IP and technology transfer had been put in place at UCT already and simply needed to be expanded upon (UCT, 2009). The important areas of delivery for the measurement of RC&I’s performance and its own processes were:

- delivering an efficient, professional advisory and management service to UCT researchers;
- covering research and professional service contracts;
- administering all research and research-related professional contracts;
- providing intellectual property advisory and management services to the research community; and
- proactively facilitating and promoting technology transfer, innovation, and research commercialisation (UCT, 2011:7).

Innovation@UCT (Pty) Ltd was made dormant during the same year and UCT now holds equity stakes in spin-out companies directly. The year 2008 saw 31 new invention disclosures which led to the filing of 27 provisional patents (University of Cape Town (UCT), 2014a). More joint IP ownership, option, assignment, and license agreements were signed in 2008 than in all previous years put together. UCT received a certificate of recognition for coming second in a country-wide IF competition for the most innovative HEI in SA and was chosen as the best in the segment for growing technology transfer capacity (UCT 2014a).

A total of 36 new invention disclosures were received in 2012, which was the same as in 2011, and 14 of these disclosures were from first time UCT inventors and resulted in 19 new patent holders from 26 patents granted on these inventions (UCT, 2014a). An IP Advisory Committee (IPAC) was formed, consisting of the Registrar, DVC (Research), the Executive Director Finance, the Director of RC&I, and the IP Manager, who would decide on a number of IP issues and the split of royalty income and consider the participation of UCT (if any) in newly created spin-out companies.

From 2002 to 2013, the TTO at UCT recorded a total of 238 invention disclosures that were received, filed 464 patent applications in various countries around the world, and had secured 199 patents (UCT, 2014a). The protected IP led to 101 license and/or assignment agreements and resulted in 13 spin-out companies. UCT has not had a blockbuster invention yet, but many of their inventions have already added significantly to the advancement of society (UCT, 2014a). The TTO at UCT is not yet financially self-sustainable, but it is getting closer with a pipeline of disclosures over many years leading to increased licence agreements and income from commercialisation activities (University of Cape Town (UCT), 2015e).

Answers to the questions put to interviewees regarding organisational and managerial challenges for UCT's TTO were limited mainly to capacity constraints within the TTO. Interviewee U2 highlighted this by saying:

> I think that SA universities doesn't have the capacity to manage IP to its fullest potential. At UCT they do their best but I think that if there were more people in the office they would do much better (U2).

Interviewee U3 gave a perspective from top management, blaming funding restrictions. He added that if NIPMO did not fund some posts in the TTO, UCT would have been in trouble. Another interviewee, U5, also observed, "The more support people you have in the TTO, the more efficient services the TTO will be able to deliver." Interviewee U4 was judicious in noticing the following:

> The lack of sufficient staff in the TTO is problematic and so are academics who are woefully unaware of TT and its potential benefits. The engineers are more clued up and much more into consulting and interacting with businesses in commerce and industry whereas the pure scientists are mostly ignorant (U4).

Interviewees agreed that the human capacity in the TTO office needed to be increased, but interviewee U2 was more vocal in her reply, claiming the following:

> Academics don't make products very well. If we had a biotech company that was owned by the university and it was run by the right biotech people, it would have been much better. It's a different skill set to move into full commercialisation. At Oxford University they have their own vaccine factory and they produce vaccines themselves. If we want to do that, we've got to find a commercial partner and pay them to do that. In SA, the pipeline is long for new medical products and the main problem is that there's little or no cohesion between the various funding agencies. They give out little bits of money to many applicants but no coherent focused strategy to get new products to the market (U2).

The discussion in this section drew upon the history of the establishment of the TTO at UCT and its achievements in protecting and commercialising IP of the University. It set the scene for the next section, which considers commercialisation activities in more detail. License agreements and spin-out company formation will be looked at in particular as two of the main outputs from TTO activities.

Commercialisation activities

The year 2010 saw commercialisation revenues reported by RC&I at UCT exceeding the R1m mark for the first time (University of Cape Town (UCT), 2010). Table 7.3 reflects the list of top ten inventors at UCT by the end of 2010, determined by the total number of cumulative patent applications for each one.

TABLE 7.3: TOP TEN UCT INVENTORS BY PATENT APPLICATIONS

Rank	Inventor	Department	Faculty	Patent Applications
1	Prof Edward Rybicki	Molecular & Cell Biology	Science	95
2	Prof Anna-Lise Williamson	IIDMM	Health Sciences	53
3	Dr Arvind Varsani	Molecular & Cell Biology	Science	48
4	Prof Ed Sturrock	IIDMM	Health Sciences	43
5	Prof Margit Harting	Physics	Science	39
6	Prof David Britton	Physics	Science	39
7	Assoc Prof Carolyn Williamson	IIDMM	Health Sciences	24
8	Prof Kelly Chibale	Chemistry	Science	23
9	Assoc Prof Dee Bradshaw	Chemical Engineering	EBE	20
10	Dr Aloysius Nchinda	Chemistry	Science	15

Source: UCT (2010)

An early example of the commercialisation of an invention by a UCT academic was the CAT (computed axial tomography) scan that was developed at Tufts University in the United Kingdom by SA physicist Prof Allan Cormack in collaboration with Godfrey Hounsfield of EMI Laboratories. Cormack's interest in X-ray imaging of soft tissues or layers of tissue of differing densities was rewarded when he and Hounsfield received the Nobel Prize in Physiology in 1979. Cormack provided the mathematical technique for the CAT scan, in which an X-ray source and electronic detectors are rotated in relation to the body and the resulting data is analysed by a computer to produce a sharp map of human tissues within a cross-section of the body. Much of Prof Cormack's research was performed in SA in the 1950s (University of Cape Town (UCT), 2015f).

Through commercialising IP emanating from UCT's campus, RC&I seeks to promote the expansion of the economy and advance job creation by developing small businesses.

Technologies are carefully selected and vigorously licensed by RC&I to markets all over the world to ensure that SA citizens ultimately profit from inventions that have been commercialised (University of Cape Town (UCT), 2018).

Providing a definition of success in university TT activities, interviewee U1 was philosophical, stating the following:

> There are many students who were able to get Masters' degrees and PhD degrees in developing some of the IP that emanated from our technology. Those are successes but they're not quite as strong to me. Success is not just getting a patent or starting a spin-out company. Success is also not raising the money to allow that company to spin-out from the university. Success ultimately for me is that the technology and the company thrives and revenue streams starts to flow abundantly (U1).

Interviewee U3 said that the objective of the University is for its TTO to perform 10% better than the average TTO at universities around the globe, measured in terms of total research income. He also noted that the disclosure rate of UCT are in line with what it should be, compared to the total research income received, but that UCT does not file as many patents and has become stricter on filing patents. Interviewee U3 also observed that success to the university in TT activities should involve the establishment of an enabling environment where academic staff and students want to protect their IP and want to seek its commercialisation. In addition, interviewee U4 cited the ability to create something new and then to earn recurring income from that invention as the most gratifying aspect of TT.

The question on what interviewees most like or dislike about TT practices rendered interesting responses. Interviewee U1 said the best of it is the opportunity to do something interesting that he is passionate about. The extraordinary frustrating part, U1 claimed, is raising money by having to knock on doors and saying, "Hey, we've got this great technology, don't you think you ought to come along and invest in it?" However, he added that he has long since accepted that it's part and parcel of TT.

Interviewee U3, an MBA graduate far removed from practising science, indicated that he enjoyed being close to and exposed to other entrepreneurial businesses, negotiations and the effect of TT on people. He declared that he likes people operating in this environment that are willing to share information and dislikes academics who believe that their IP is worth more than it is and who want more money for it than they deserve. Furthermore, interviewee U4 disliked the repetitive nature of revisiting the same information contained in lengthy patent applications and continued as follows:

> As a scientist, you don't want to be doing that. You want to be doing experiments for new technologies all the time. I like creating something useful that somebody actually wants to license (U4).

Most interviewees commented on what successes achieved in TT means to them. Interviewee U1 stated that it is the sense of accomplishment from being able to create something new that many other and bigger companies could not. For example, he attests:

> Big companies have tried and failed or built prototypes but could not take it further. We not only did so using very limited funds, but we've run two successful clinical trials. When I saw the data then it gave me real satisfaction. The next step will be when our technology leads to the saving of women's lives through the early detection of cancer. That's when I'll know we've really done well and the decision to change my career path was the right one (U1).

For interviewees U2 and U4 success in TT activities means getting recognition for being an inventor. Interviewee U4 summed it up as follows:

> I Like the Deputy Vice Chancellor's award for achievement in innovation. It came with no money and there was only about 40 people in the room. It was completely unexpected and it's the first awarded given to any inventors at UCT (U4).

Interviewee U5 likes to see academics step out of their comfort zone and walk the road, beyond just the idea, which does not always come naturally for academics. Yet, he dislikes inventors who do not know when to hand the idea over to the business people to run with.

Finally, interviewees were asked what type of advice and support from the TTO was most helpful to them. For most it was the legal aspects of drafting contracts, but at a much more personal level, interviewee U1 testified, “It was the unwavering support of the enterprise and the belief they instill in me for my ability to commercialise the research findings.”

Interviewee U3 discerned that the best advice to academics from the university TTO concerned slight changes in the research effort, which leads to more focused research efforts. The result delivers more patents culminating in commercial products whilst the inventor can still do the publishing later.

Academics as inventors were optimistic in response to a question whether TT can be a major source of income for them, their department, and the university. In positive fashion they asserted that bigger income yields are possible if the entrepreneurial and innovation environment is well managed. Interviewee U3 looked at the bigger picture from a central university management perspective and stated categorically, “I think history has shown all over the world, if you don’t have a big block buster, you will have some income but it is not that the university can depend on that money.”

This section provided insight into what leads to successful TT at UCT. Overall, the staff and students at UCT are satisfied with the level of service they are receiving from the university TTO. Applied research to satisfy specific needs of the economy resulting in patents seems to be the easiest to extract value from for the benefit of the University and all its stakeholders.

License agreements

At UCT, 11 licensing agreements were entered into between 2000 and 2007, of which some were assigned for no financial consideration or for once-off payments. The accumulated income in license fees was R300 000 then and the average time from invention disclosure to earning income (if any) was 7 to 8 years (UCT, 2007b).

During 2009, meaningful time was spent by RC&I on the commercialisation of UCT’s IP portfolio, specifically on licensing and developing new business plans. Two major licensing agreements were negotiated with global corporations in that year, which contributed to noteworthy revenues received from upfront payments and royalties (University of Cape Town (UCT), 2010). By the end of 2010, the biggest contributor to the number of license agreements was the Poison’s Database developed by the Department of Pediatrics at UCT (UCT 2010). The database of poisons was the most fruitful of UCT's IP in generating license agreements. An online platform replaced the outdated CD-based distribution system and enabled general practitioners to enter the database from their mobile devices. As part of this development, RC&I reassessed license and confidentiality agreements and provided support with registering a trademark and domain name for the new brand called AfriTox^{TM} (University of Cape Town (UCT), 2012a).

RSA: DST *et al*. (2017) reveals that UCT had executed a total of 17 active licenses by 2014, as indicated by Table 7.4 below. The cumulative active licenses at the end of each year since 2008 are as follows:

TABLE 7.4: UCT LICENSE AGREEMENTS EXECUTED

	Cumulative Active Licenses
2008	5
2009	4
2010	6
2011	10
2012	27
2013	14
2014	17
2015	27

Source: DST et al, (2017) for years up to 2014 and UCT (2015e) for 2015

A significant licensing deal was concluded with new spin-out company AngioDesign (Pty) Ltd which was incorporated in the UK. The initial upfront royalty payment compensated UCT for the several million rands spent on the protection of the IP. Provision was made for further landmark payments as the angiotensin converting enzyme (ACE) inhibitor drugs move closer to full commercialisation in its chosen market segment (UCT, 2015g).

Spin-out companies

Heher (2006) supported the creation of spin-out companies in his economic model. However, it was Wolson (2007) who claimed that the lack of access to knowledgeable entrepreneurs limits the commercialisation options available to university TTOs in SA. This fact needs to be remembered in the context of SA, a developing country within which UCT resides.

The first UCT spin-out company was called African Medical Imaging (Pty) Ltd (AMI) and its initial shareholders were De Beers, UCT, and iTemba LABS. Bailey (2005) reports that a total of 14 postgraduate students, of whom 12 were master's and two were doctoral students, worked on the research project and that many research outputs emanated from the research effort. These include patents, journal articles, conference papers, and student dissertations. A re-launch of AMI occurred during 2009 under the leadership of Prof Vaughan. Renamed CapeRay Medical (Pty) Ltd, the company focuses on the development of a superior mammography scanner which unites both ultrasound and low dose x-ray technology in detecting cancer. CapeRay became the first spin-out company in which UCT holds equity and the Industrial Development Corporation (IDC) invested in CapeRay the following year.

Other UCT spin-out companies include Isiqu Orthopedics (Pty) Ltd, which was founded in 2004 and designed and manufactured bone and joint implants. Cell-Life is an e-health technology development non-profit company. Cape Caretone (Pty) Ltd (founded in 2006) manufactured food additives for aquaculture and Hot Platinum (Pty)Ltd focuses on the creation and manufacture of innovative induction heating systems for processing precious and base metals (University of Cape Town (UCT), 2015c). Whereas both Isiqu and Cape Caretone do not operate anymore, the others are still active. Strait Access Technologies (Pty) Ltd (SAT) was formed in 2010 and produces heart valve devices. It became the second company in which UCT acquired equity shares in lieu of IP created. The first major licensing agreement delivering significant annual licence fee income was also concluded in 2010 with an international pharmaceutical company that lifted the total license fee income in that year to more than R3.5m (University of Cape Town (UCT), 2014b). UCT did not own equity stakes in the first four spin-out companies formed by 2007, but obtained an equity share in 7 out of the next 10 spin-out companies that was formed (UCT, 2015c). The rest of the spin-out companies operating as at the end of 2015 and the year in which they were established were:

2004 Cell-Life	- An ICT tool for monitoring HIV Aids activities
2006 Hot Platinum (Pty) Ltd	- Develops innovative platinum casting equipment
2007 Nurture Restore Innovate	- Ecological restoration systems
2009 Cape Ray Medical (Pty) Ltd	- A revolutionary breast cancer detection solution
2010 Strait Access Technologies	- Manufacturing of cardiac-related medical devices
2011 PST Sensors (Pty) Ltd	- Printed silicon electronics
2011 Seraptix CC Seraptix CC	- Biosensor / diagnostics
2011 Antrum Biotech (Pty) Ltd	- Extrapulmonary TB diagnostic test
2012 Tuluntulu (Pty) Ltd	- Live continuous broadcast to mobile devices
2013 Elemental Tech IP Holdings	- Computational Fluid Dynamics software for advanced simulation
2014 AngioDesign (Pty) Ltd	- Angiotensin Converting Enzyme (ACE) inhibitor
2014 Hyplat (Pty) Ltd	- A specialist Fuel Cell technology company
2014 DroneSAR (Pty) Ltd	- Precision agriculture based on radar using drones unmanned aerial vehicles
2015 Lumkani	- Early warning system for shack fires
2015 Attri Othopedics (Pty) Ltd	- Advanced tumor & trauma reconstruction implants

Source: UCT (2016).

AngioDesign (Pty) Ltd was incorporated in the UK to commercialise the ACE inhibitor drugs developed by UCT after the N- and C- domain crystal structures were revealed by inventors at UCT and Bath University. Unfortunately the advancement of the inhibitor drugs was halted for years in SA, due to a lack of available funding. AngioDesign obtained IP that was co-owned IP on two patents owned by Bath University and the spin-out entered into an assignment agreement with UCT, which allows for the reimbursement to UCT for patent costs and includes upfront royalty payments at various stages as the drugs progresses through clinical trials. UCT does not hold equity in this spin-out company (UCT, 2015c).

HyCat (Pty) Ltd is an IP holding company which seeks to commercialise IP emanating from the DST HySA hydrogen fuel cell Centre of Competence, which is situated in the Department of Chemical Engineering at UCT. HyCat will be significant to licensing-in IP from countries abroad and creating a basis from which SA inventions can be entrenched into. HyCat will set up the SA hydrogen fuel cell supply chain, thereby adding value to the country's platinum resources. The result will be new sustainable jobs, a robust service industry, and the creation of secondary businesses. HyCat is wholly-owned by UCT and its directors were selected by UCT (UCT, 2015c). Equity shares were also allocated to UCT in the spin-out company DroneSAR (Pty) Ltd in exchange for know-how contributed by the university. The know-how emanates from radar technologies used by the Department of Electrical Engineering.

It is estimated that the value of UCT's investments in the equity of spin-out companies was approximately R86.6m in 2015 (2014: R16.5m) (UCT, 2016). Valuations are mostly built on the last round of investment, or the number of patents that are held in the spin-out's patent portfolio prior to the raising of external funds. Benefits accruing to UCT and the inventors will be in the form of dividends declared by the spin-outs or the disposal of equity currently owned and housed by UCT. For a spin-out company to be successful in commercialising IP licensed from a university, it needs to raise sufficient funding. As was shown by the ACE inhibitor drugs, the availability of funding is crucial in growing the asset base of a newly created spin-out company and covering operational costs whilst the company explores avenues of extracting and maximising the potential of IP it obtained from the inventors on campus.

Interestingly, UCT decided not to use a wholly-owned subsidiary company to house its equity stakes in spin-out companies. The University are holding the shares directly and (UCT, 2016) reports that equity positions were held in only 2 companies. In total, 17 spin-out companies were started with the help in the TTO at UCT, whilst 15 of them were still in operation at the end of 2015 (UCT, 2016).

Interviewees reported during the conversations that there are no apparent managerial weaknesses they can find in the TTO, other than the limitations of human capacity already mentioned above when institutional commitment was discussed. The relationship between TTO staff, academic staff, and students and between the TTO and top management was depicted by interviewees as trustworthy and very good. The pipeline of invention disclosures at UCT is fed by the good quality and quantity of research being conducted at the institution by top class researchers. The TTO has been operating since 1999 and benefitted from having skilled and dedicated managers involved in the technology transfer process. Thus, the TTO is functioning well and received praise from interviewees, both from top management and academic staff, the only adverse comment being the fact that they seem to be understaffed and would be able to do more if more staff were allocated to the TTO. Being one of the oldest university TTOs in SA permits UCT to capitalise on efforts over an extended period of time since 1999, as is evident from their growing number of invention disclosures that lead to patents, license agreements, and spin-out companies as the main indictors of the outputs from TT activities.

7.8. Conclusion

UCT has a very strong research base. This chapter described the history and research capacity of UCT briefly. The high quality of instructional staff at the University produces solid research outputs that justify its high ranking by international standards (Mouton, 2013). Figure 7.1 shows the marked increase in the annual R&D expenditure for the university which more than doubled (130%) in the eight years from 2008 to 2015, whilst the instructional staff only increased by a mere 25.8% over the same period (Figure 7.2). Table 7.1 testifies that significant increases were achieved in terms of research outputs as measured in terms of publication outputs and postgraduate student figures.

The discussion about the institutional policies followed and its effect on TT activities employed at UCT. The IP policy and other applicable institutional policies, such as the Innovation and Research Uptake (I&RU) policy framework, are well articulated and aiding the quantity and quality of research conducted at the University, as can be seen by the very sharp increase of 130% in overall R&D expenditure at UCT over the eight years from 2008 to 2015. UCT's policies are clearly working well to create an environment for research at the University to blossom.

The institutional commitment exhibited by top management was examined next and considered to be very strong by the academic staff participating in the interviews. They also reported having easy and frequent access to staff in the TTO. A comment was made by an interviewee that the capacity constraints (lack of skilled TT staff) in the TTO shows a lack of commitment from the institution. One needs to consider this comment against the background of financial constraints experienced by universities in SA at present and their inability to appoint more staff in the TTO. A suggestion was made to allocate more proceeds from IP commercialisation directly to the TTO for it to appoint more TT staff members and thus address this issue. Top management should consider this suggestion, as it may deliver increased profits from TT activities through better mining and subsequent managing of IP assets on campus.

IP protection was considered following the discussion on institutional commitment and it indicates that the enactment of the IPR-PFRD Act in SA had less of an effect on UCT's TTO, as they were already fully engaged in TT activities prior to the implementation of the act in 2010. UCT, being one of the oldest TTOs in SA, is benefiting from a longer pipeline of invention disclosures. The legal environment for UCT's TTO has stabilised with the enactment of the IPR-PFRD act and awareness of the new Act's effect on IP created on the campus is high, as noted by interviewees. There was a feeling amongst interviewees that the IP policy of UCT and the IPR-PFRD Act may be too strict and that many pieces of IP are protected at a high cost before evaluation of commercial potential. However, this claim is not substantiated, as the total expenditure on patent registration costs has not increased dramatically since 2008 when inflation is taken into account.

Funding for R&D & commercialisation activities as the fourth dimension which is examined is considered in section 7.5. What benefitted UCT hugely was the additional staff members that the TTO could employ from funding provided by TIA. A number of funds that are available to inventors at UCT at different stages in the commercialisation process were discussed. Funding can always be improved, but the University is certainly able to attract a lot of industry funding for research, as indicated by the high increase in the value of R&D undertaken on campus. From the interviews it was apparent that the academics interviewed at UCT prefer to source their own research funding via their personal networks and they should continue to do so and extract maximum benefits from such personal contacts and networks. UCT top management also allocated funds from its available pool of investments to invest in promising new technologies. This fact underscores the strong institutional support that strengthens both the commitment and funding dimensions for TT at UCT.

The human resources discussed in section 7.6 showed that the University deploys staff members of top caliber, which ensures that UCT remains the top-rated university in SA when considering international ranking lists. Incentives for academics to engage in TT activities remain to be strong and a balance seems to be found between financial rewards and personal recognition which, as we learn from the literature, is important for academic researchers. Of interest was the observation that one faculty currently refunds about R400 000 per annum from the proceeds it receives from cost recovery on research conducted. This incentive could be tried at other faculties within UCT and at other universities in SA. The TTO seems to be doing well in promoting networks leading to collaborations, but one academic was clear in asserting that they see to their personal contacts and network themselves without the help of the university TTO.

The history of the TTO at UCT was discussed in the penultimate section of this chapter and mainly comprises an exchange of information on the commercialisation activities at UCT, licenses agreements, and spin-out companies. The fresh approach and renewed focus followed by Dr Andrew Bailey and Prof Danie Visser as the DVC Research added much needed impetus to the TT efforts and commercialisation of IP at UCT (UCT, 2007b). The new approach delivered immediate results as confidence grew in the TTO by academic staff and students of the University. As a result, new disclosures of novel inventions increased steadily and so did the value that could be extracted from it through TT processes.

The results of qualitative questions asked in interviews to key staff members at UCT are included throughout the chapter in sections where appropriate and inform the discussion with valuable inputs of how TT practices are being experienced and viewed on the UCT campus. From the interviews it is clear that the TTO requires even more staff to deal with the increased workload and if additional staff are not appointed, it may affect the functions of the TTO adversely in future.

Overall, it is clear that the enabling environment for TT is very strong at UCT. The small number of management staff of UCT that were interviewed is fully committed towards IP management and seeing it flourish on campus. Creating awareness of IP related issues on campus should be maintained at a high level, as new students and staff join annually and others leave the campus having completed their studies or retire as academics. Maintaining and broadening incentives for researchers and linking them to networks or allowing them the time and space to grow their own personal network of contacts is imperative. Such networks between researchers of different institutions are instrumental in spurring the development of innovative solutions for research questions that might lead to entrepreneurial opportunities. UCT's increased proceeds from commercialisation activities and growth in the value of equity in spin-out companies are encouraging (UCT, 2016). This figure could grow significantly in years to come and bodes well for capital growth to continue, given the growth in the value of UCT's stake in spin-out companies. The impact of regional economic growth and job creation should not be underestimated. The findings presented in this chapter unequivocally showed that UCT has performed well in the commercialisation efforts exerted by its TTO staff.

Chapter 8: University of the Western Cape (UWC) – A case study

8.1. Brief history and research capacity

Parliament enacted legislation in 1959 that led to the formation of the University College of the Western Cape. The new college was created strictly for brown people and was supervised from 1960 to 1975 by UNISA (University of the Western Cape (UWC), 2016a). The lack of alternative options for people of colour during those times caused a continuous rise in student numbers, increasing from 170 in 1960 to 481 in 1966 and to 936 by 1970 (University of the Western Cape (UWC), 2016b). The college was awarded full academic status and independence in 1970 that allowed it to develop and manage its own courses, student examinations, and degree ceremonies from then onwards. Only a few degree options were available initially, until the faculties of Theology and Dentistry in were started in 1973. Student protest against the formal dress code at the time led to students burning their ties in 1970 in a demonstration of unity. Another protest three years later led by students and black academics resulted in the appointment of the university's first black rector in 1975 (UWC, 2016b).

A new open and democratic cultural environment at UWC was promoted by Professor Richard van der Ross during his tenure from 1975 to 1986 (UWC, 2016b). It was characterised by amicable negotiations with students and staff, motivation of intellectual debate, and acknowledgement of international scholarship. The enactment of the University of the Western Cape Act of 1983 ensured that the institution obtained its autonomous status on the same requisites as were enjoyed by previously advantaged ("white") universities in SA. Professor Jakes Gerwel was appointed as rector and vice-chancellor in 1987. He hastened the process of transformation and created a space where intellectuals and lateral thinkers could deliberate ideas without negating the principles of independence, diversity, and freedom of expression. The university sided with the morals of the mass democratic movement at the time and supported academic programmes and policy research geared towards the ending apartheid and building a new democratic society in SA (UWC, 2016b).

UWC commemorated its 50th anniversary in 2010. Ten of the first 170 students that enrolled in 1960 were females and the students were initially taught in Arts, Science, and Education only (UWC, 2016b). The majority of students became nurses, social workers, librarians, and teachers and they were lectured by 17 academics and 10 support staff (UWC, 2016b). Since then, the university has expanded from three to seven faculties. The seven faculties comprise Arts, Community and Health Sciences, Dentistry, Economic and Management Sciences, Education, Law, and Natural Sciences and consist of 68 departments and 16 institutes, schools, and research centres (UWC, 2016b). Registered students have increased to 12 450, which includes roughly 215 students from foreign countries (UWC, 2016b). Postgraduate students represent 19% of the total student count and more than 1 400 people work at the university, of which 374 are permanent academic staff (UWC, 2016b).

Guided by Prof Gerwel, the university relaxed its admissions policy in favour of underprivileged students by creating a model around academic support for students entering conventional teaching degrees. This model gave gifted students a chance to acquire university degrees and unleashed study opportunities to an ever-increasing number of African students. UWC is notably the most diverse university in SA, with students representing all 11 language groups in the country. Gerwel's leadership also resulted in the founding of the Faculties of Community and Health Sciences and Economic and Management Sciences, as well as the School of Government and the Mayibuye Centre for History and Culture in SA (UWC, 2016b).

Cecil Abrahams assumed the role as UWC's rector and vice-chancellor on April 1996 (UWC, 2016b). The university's purpose gained impetus via its strategic plan aimed at the next millennium through the provision of lifelong teaching courses. In just five decades from 1963, UWC has matured with more than 30 000 students having graduated from the institution (UWC, 2016b). Many of these graduates now hold top government positions and cabinet posts or have leadership roles at businesses in commerce and industry. Since those turbulent years, UWC has emerged to be at the forefront of innovation and transformation among universities in SA (UWC, 2016b).

Research profile at UWC

The university's research output has increased significantly over the last number of years (UWC, 2009). UWC succeeded in the betterment of its postgraduate offering, which is supported by higher pass rates. Moreover, the university has created research niche areas (UWC, 2009). By 2012, UWC recorded a remarkable turnaround and was rated 6th of all SA universities when considering the proportion of fulltime academic staff with an NRF research rating, 5th in relation to academic staff with PhD degrees, 7th when considering the total income derived from research contracts and third income streams, and 5th in terms of their research impact measured by citations (University of the Western Cape (UWC), 2013). Statistics from the NRF indicated that UWC had 92 NRF-rated researchers in 2013, compared to 78 by the end of 2009 (UWC, 2013).

Mouton (2015) ascertained the extent of the increase in research output at UWC for the period 1990 to 2013, with specific focus on the last eight years from 2006 to 2013, and considering the number of journal publications and doctoral dissertations. In the study performed by CREST, Mouton (2015) used a number of bibliometric indicators to determine the research output, research demographics, research productivity, and research collaboration taking place at UWC. The scientific impact of publications can be measured by counting the number of times a particular publication was cited. CREST uses three main demographic indicators, namely gender, race, and year of birth, before connecting it to each author (Mouton, 2015).

The amendment of the research subsidy scheme by DHET in SA in 2005 caused subsidies awarded for research publications to increase significantly (Mouton, 2015). Mouton (2015) observed that the subsidy amounted to R22 000 on average between 1987 and 2003, whilst the figure for 2010 was R120 000. By using 2005 as a base year, the overall research outputs of UWC grew by 59%, which was the 3rd highest of all 11 universities measured (Mouton, 2015).

Input: Expenditure on R&D & researchers

Figure 8.1 indicates the total R&D expenditure at UWC for the years 2008 to 2015 and accentuate the fact that the university has increased its spending on research and development by 204.7% over this period, whilst growing its total complement of instructional staff by a mere 24.5%.

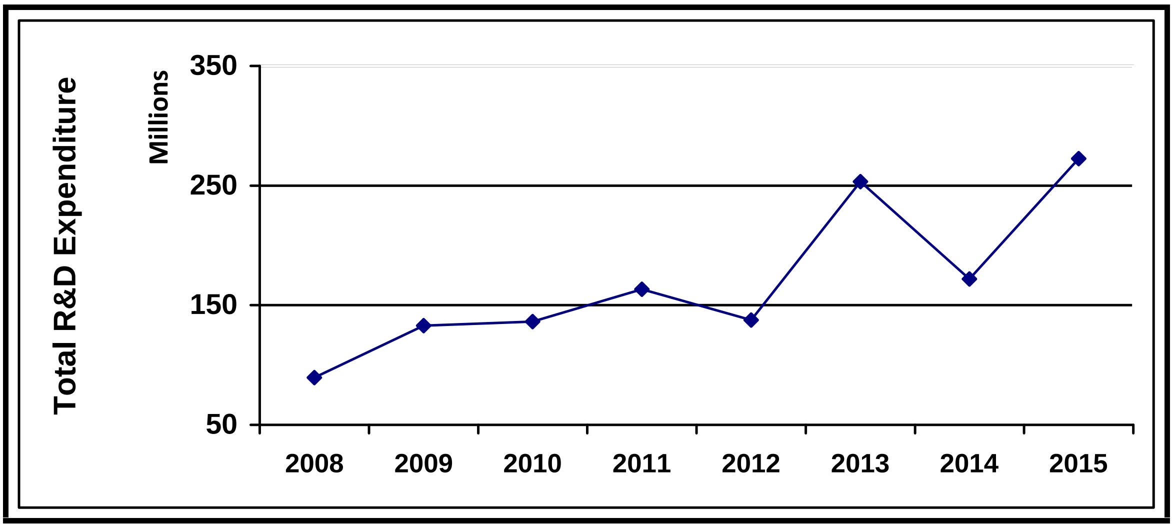


FIGURE 8.1: UWC TOTAL RESEARCH AND DEVELOPMENT EXPENDITURE
Source: Centre for Science Technology and Innovation Indicators (CeSTII) at the Human Sciences Research Council (HSRC) (2010, 2011, 2012, 2013, 2014a, 2016)

Figure 8.2 indicates the growth in the student population that have completed the requirements for a degree at UWC from 2008 to 2015. This total increased from 2 980 students in 2008 to 4 805 students by the end of 2015, whereas the instructional staff increased in total from 518 in 2008 to 645 by 2015.

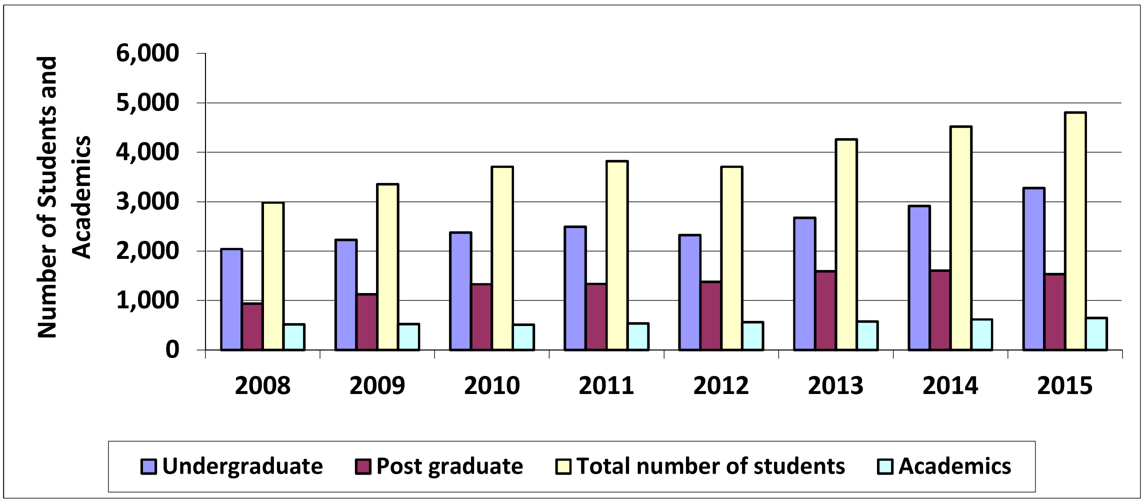


FIGURE 8.2: UWC TOTAL NUMBER OF STUDENTS AND INSTRUCTIONAL STAFF
Source: HEMIS Tables (RSA: DHET, 2015)

Currently, the student profile is comprised of 57% female and 43% male students, of which 82% are undergraduates (UWC, 2016b). An estimated 28% of the student population studies economic & management sciences, 18% arts, 15% community & health sciences, 14% science, 14% law, 8% education, and 3% studies dentistry (UWC, 2016b). UWC is not the biggest university in the Western Cape or in SA, nor is it the oldest, richest, or best equipped. Despite these attributes, the university has succeeded in drawing a high number of top-rated academic staff. Academic excellence is a significant contributor to attracting talented researchers and UWC has obtained both local and international recognition for the quality of research conducted in various disciplines (UWC, 2016b).

Research infrastructure: Centres of Excellence and Chairs

UWC had two NRF SARChI research chairs by the end of 2009, one in Bioinformatics and one in Poverty Alleviation (UWC, 2009). UWC is engaged with several national and international projects earmarked for MeerKAT, the pathfinder telescope for the Square Kilometre Array (SKA) and for the SA Large Telescope (SALT). The start of 2012 saw UWC receiving 7 additional SARChI chairs from the NRF, a record number awarded to any SA university in that round of funding applications. The main aim of the SARChI programme, in addition to sustaining a critical mass of top rated academics, is to develop scholars who will educate future generations of SA knowledge workers. By the end of 2012, UWC hosted 11 SARChI chairs and was 4th in SA, jointly with the University of KwaZulu Natal, in terms of the number of such chairs awarded to it.

It is worth noting that UWC has succeeded in assembling a significant pool of specialists in the area of Astrophysics, with three A-rated researchers in this field of study occupying three SARChI hairs. The location of UWC, which is relatively close to the South African Astronomical Observatory (SAAO) and the offices for the KAT (Karoo Array Telescope), made it a clear choice to engage in research in this field, and the Astrophysics group is thriving on utilising the SKA project to create a new group of researchers, particularly from previously historically disadvantaged groups (University of the Western Cape (UWC), 2012a).

UWC has a number of outstanding research centres too. The Centre for Humanities Research (CHR) was formed in 2006 and has developed into a central assembly point for researchers in the Humanities and Social Sciences over Southern Africa (UWC, 2012). The research activities of the centre comprise the study of the humanities in Africa, aesthetics and politics, law, violence and society, and space and politics. UWC (2012) also boasts a number of successful research centres and units such as *The Dullah Omar Institute for Constitutional Law, Governance and Human Rights, The Institute for Social Development (ISD), and The South African Institute for Advanced Materials Chemistry (SAIAMC),* to name a few (UWC, 2012).

Furthermore, UWC is home to one of the Centres of Excellence (CoEs) in SA. The Centre of Excellence in Food Security is housed by UWC and the University of Pretoria, as they were joint recipients of this CoE which commenced its activities on 15 April 2014 (University of the Western Cape (UWC), 2014a). UWC is the first former historically disadvantaged university in SA to receive this honour. The research is grouped into four themes, namely Food Creation, Food Distribution, Food Consumption and Food Governance (UWC, 2014a). Food security has been described in SA as the access by all people to sufficient quality and quantity of food for a lively and fit life. It is estimated that 54.4% of SA's population does not have frequent access to enough food (UWC, 2014a).

Output: research publications

UWC initiated a concerted effort in 2009 to increase the number of academic staff members holding doctorate degrees. A research grant was launched to assist academics who were close to completion of their doctoral dissertations. Since the inception of the programme many staff members of UWC have completed their doctoral degrees. By the end of 2012, more than 50% of UWC's permanent academic staff had PhDs. The research output continued to grow, as can be seen from Table 8.1 below. In 2014 a record number of 312 students received doctoral degrees, representing an increase of 281% over 2013 and 564% over 2009 (University of the Western Cape (UWC), 2016a).

TABLE 8.1: UWC NUMBER OF RESEARCH PUBLICATIONS IN PEER-REVIEWED JOURNALS

	2008	2009	2010	2011	2012	2013	2014	2015
Articles	214.3	248.2	240.5	330.1	342.8	360.0	445.2	461.1
Books / Chapters	17.5	26.2	21.5	10.3	12.4	29.6	26.0	29.3
Conference Proceedings	8.1	3.8	4.8	6.0	11.6	16.7	10.1	6.8
Masters Graduates	116	165	221	209	254	267	256	274
Doctoral Graduates	42	47	60	80	75	111	104	288

Source: HEMIS Tables (RSA: DHET, 2015)

An analysis of the number of research publications in peer-reviewed journals revealed that the number of article publications grew by 115.2% from 2008 to 2015. Books and chapters jumped by 67.3%, conference proceedings dropped by 16.2%, master's graduates increased by 136.2% and doctoral graduates by 585.7%. The combined net overall increase for all these publications was 115.6% for UWC, whereas the number of instructional staff only rose by the said 24.5%, from 518 in 2008 to 645 in 2015. The disproportionate increase in publication outputs (115.6%) versus the increase in instructional staff (24.5%) means that the staff at UWC raised their levels of productivity considerably over this period.

UWC's increased focus on research productivity ensured its status in moving into the leading group of universities in SA (UWC, 2016a). This section highlighted the comparative performance of UWC in its research outputs. The university has made significant progress from its disadvantaged background in becoming a fully-fledged research orientated institution in SA in the new millennium.

Other outputs: technology outputs (patents/ licenses/ companies)

The outputs from TTO activites at UWC represent that of a fairly new technology transfer office. UWC is becoming a more research-intensive university and consequently invention disclosures, patent applications, and patents granted will all increase in years to come as the volume and quality of research outputs that may lead to protectable IP gradually increases. Figure 8.3 below shows the UWC invention disclosures, patent applications, and patents granted from 2008 to 2015.

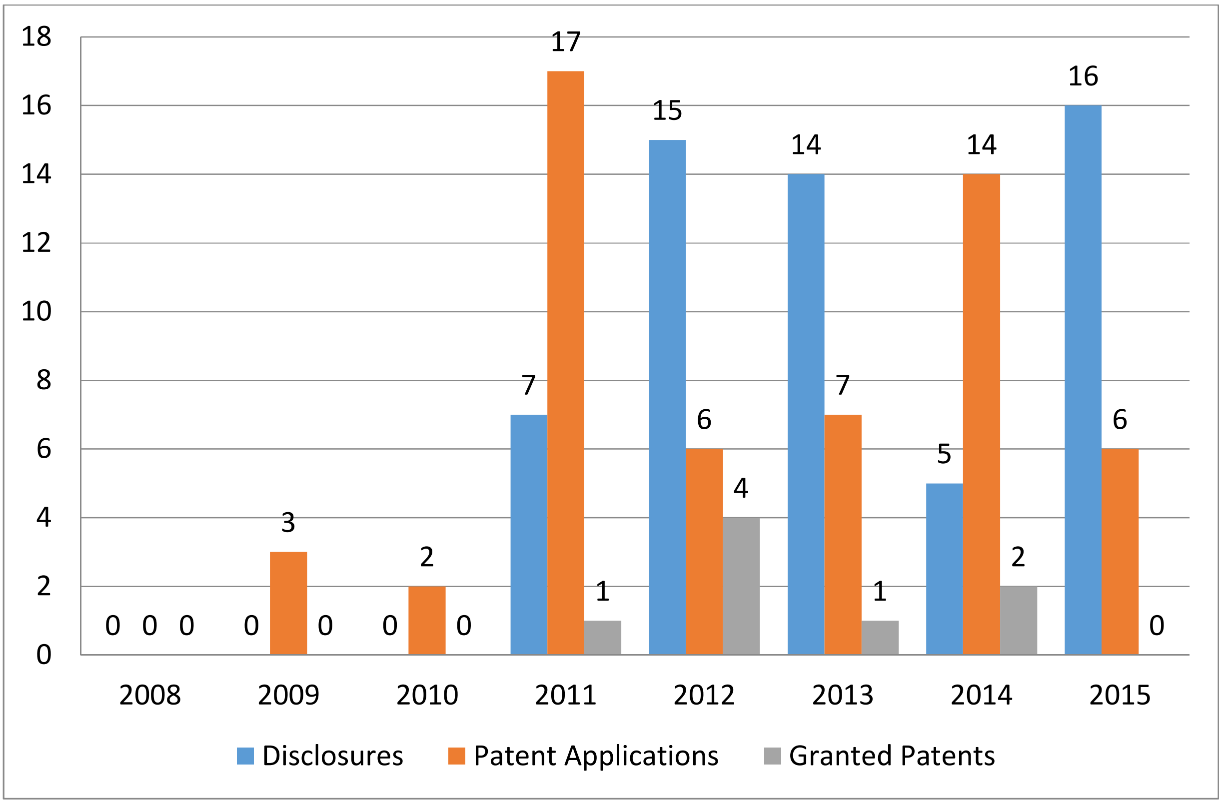


FIGURE 8.3: UWC INVENTION DISCLOSURES, PATENT APPLICATIONS & PATENTS GRANTED
Source: RSA: DST *et al*, (2017) for years up to 2014 and UWC (2018) for 2015

From the data reflected in Figure 8.3 one can see that invention disclosures started to gain momentum from 2011 onwards, after the enactment of the IPR-PFRD Act. Patent applications peaked in 2011 and resulted in 4 patents being granted in 2012. It is likely that the IPR-PFRD Act kick-started TT activities at UWC. A pipeline of constant invention disclosures that will ensure more patents and ultimately income derived from the commercialisation of the university's IP assets now needs to be established. Institutional policies are described below in the next section.

8.2. Institutional Policies

Towards the end of the 1990s, it became necessary for UWC to devise a policy or create a plan which detailed the strategic direction of the university in years to come (University of the Western Cape (UWC), 2012a). UWC's first Strategic Plan was adopted by its council in 2000. The Strategic

Plan presented a top-level framework for the allocation and monitoring of responsibilities. This was a trying time in the history of UWC, as the university experienced a leadership crisis caused by mistrust between the university council and central management. Bankruptcy was imminent and the SA government proposed a merger between UWC and another institution close to it. An important planning document followed the Strategic Plan which caused financial turnaround and stability for UWC. Stellenbosch University's School of Oral Health was absorbed within UWC's structure in 2004 and UWC then had to design an Institutional Operating Plan (IOP). UWC's first IOP (2005 – 2009) was released and brought additional funding to the institution early in 2005 (UWC, 2012a).

The IOP outlined a structure for achievements to be reached and concentrated on eight strategic goals emanating from UWC's mission and vision. The eight goals are:

i. to attract, retain and enable the development of students;
ii. to provide opportunities for an excellent teaching and learning experience;
iii. to reshape the postgraduate student profile and enhance UWC as a significant research and innovation university;
iv. to attract, retain, diversify, and develop excellent talent;
v. to develop a strong and diversified financial base;
vi. to shape the internal and external standing and profile of UWC through communication and marketing strategies;
vii. to strategically develop the campus infrastructure; and
viii. to provide effective leadership at all levels (UWC, 2010:13).

The IOP proposes that the university be engaged with all role players as best it can. Engagement in this context represents the university's awareness of itself in extracting from its history while at the same time believing in a prosperous future (UWC, 2012a). The IOP accepts that aiming to be an excellent university in challenging circumstances asks for stability in managing conflicts arising from differing demands on campus (UWC, 2012a).

The IP policy of UWC is included in its Research Policy that was approved by the university's Senate and Council in 2009 (University of the Western Cape (UWC), 2012b). The IP policy is applicable to all UWC employees and students in the course and scope of their employment or registration at UWC and any other service provider delivering services to UWC (UWC, 2012b). The decision to protect a particular piece of IP arising from publically funded R&D efforts lies with the TTO. If it decides to protect the IP, then UWC bears the cost of the patent and legal fees. If the TTO chooses not to protect the said IP, it has to report to NIPMO and provide reasons why it chose not to protect it. The creation of NIPMO within DST was a direct result of the requirements of the IPR-PFRD Act (see Section 5.4.2). If NIPMO too decides not to protect the IP, ownership thereof is offered to the inventor (UWC, 2012b).

Participants all agreed during the in-person interviews that they knew about UWC's IP Policy, although two of the respondents indicated that they have neither read it, nor were they familiar with its contents. Both participants from management claimed that the researchers at UWC do not know the contents of the policy or what it requires from them.

> So, I think the policy is good and it also gets an academic to think in a different domain. You know, academics are researchers. They do a piece of research and they think if I just publish a paper, the IP is still mine. They don't understand the law (W3).

UWC (University of the Western Cape (UWC), 2016c) reports the following key aspects of note concerning the University's IP Policy:

- The University owns all IP created mainly by its students and employees in the course and scope of their registration and/or employment on campus.
- Income derived from the commercialisation of IP at UWC will be split amongst the inventor(s)/IP creator(s) and the University in accordance with the IPR-PFRD Act.
- All R&D activities at UWC that may lead to protectable IP and which were developed by using public funds are to strictly adhere with the provisions of the said IPR-PFRD Act (UWC, 2016c).

The IP policy of UWC is important as it clearly states and removes any uncertainty about the respective rights and obligations of the university and academic staff as inventors to newly created IP. The institutional commitment expressed by top management towards TT activities on the campus of UWC is explained next.

8.3. Institutional commitment by top management at UWC towards TT activities

Technology transfer is relatively new to UWC and its top management. UWC's own challenges in changing to a more research orientated university left top management and academic staff with less time and energy to focus on issues of IP and the commercialisation of IP. However, since the promulgation of the IPR-PFRD Act, SA universities are obliged to set up TTOs and safeguard their IP assets. Yet, it will take time to build a strong pipeline of disclosures for new inventions. Instilling a culture that is supportive of the commercialisation of IP is critically important for UWC if it wants to succeed in its efforts to successfully manage and grow its young TTO.

Sanyahumbi (University of the Western Cape (UWC), 2014b) motivates why UWC should engage in TT activities by listing the following:

- the optimisation of research value in addition to publications only
- generating financial returns leading to social and economic development
- economic benefits and incentives attributing to academic staff and the university
- advancement of the research profile of academics and the university
- receiving exposure to new technologies and more research grants by academics
- connecting with people that are attracted to research at UWC
- the fact that it may lead to stimulating experiments (UWC, 2014b)

Sanyahumbi (UWC, 2014b) argues that in reality there are a number of obstacles to take into consideration about university TT. The author states that TT by and large is not a significant generator of income for universities. He argues that the main impact of TT activities does not occur in the university. The signing of a license agreement securing a 5% royalty income or the receipt of a 5% equity stake in a spin-out company implies that 95% of the economic value is created outside the university. He further asserts that patenting of novel technologies is often a long and expensive process and that commercialisation efforts can take anything from 6 months to more than 3 years to conclude. In addition, fund raising for investment in the technology may take up to 5 years. Moreover, concluding a licence agreement can take up to a year or even longer. Alternatively, the university may need to invest in a spin-out or technology without any guarantees and the time it takes to generate significant income streams may be between 5 to 10 years for a university spin-out company, or a number of years after the conclusion of a licensing transaction (UWC, 2014b).

According to Sanyahumbi (UWC, 2014b), the recipe for success in TT activities includes having applicable structures and resources in place that are assisted by academic staff performing ground-breaking research resulting in a solid pipeline of new inventions. Furthermore, he claims that a policy environment is required which is in line with legal requirements and incentives afforded to academics that increases their propensity to disclose their novel findings. He reckons that employing the right people with a positive attitude who understand the university milieu and who are service centred and client oriented is paramount.

Interviewees responded differently to the question on whether the institutional commitment at UWC is strong or weak. For example:

> I would say mixed. We are only now becoming a research-intensive university. The TTO is relatively new and it's not elevated to the level where I would say there's an earnest approach to support technology transfer (W1).

> Honestly, I don't know. So I guess we can interpret that as weak. Essentially, they set up the TTO I think because they needed to, or they had to legally now (W2).

Respondent W3 said that the executive was very committed when they established the TTO and demonstrated it by permanently appointing staff to run the TTO. Interviewee W2 responded that the staff in the TTO was brilliant but that there was no interaction whatsoever from top management within the University and it seems a lot can still be done to improve relationships and for top management to confirm their commitment toward IP commercialisation on campus. Interviewee W1 responded as follows:

> The commitment is there in terms of staff that has been appointed, but in terms of the language within the university, I'm not sure I'm seeing it (W1).

From the comments of interviewees listed above it seems as if UWC top management still needs to do a lot of work to positively influence technology transfer activities on their campus.

8.4. Intellectual property protection

The Institutional Operating Plan (IOP) of UWC, mentioned in section 8.2, also deals with innovation and the task of ensuring that new inventions are successfully commercialised for the public good. UWC is aiming to diversify its income streams with the opportunities arising from activities managed by its newly established TTO (University of the Western Cape (UWC), 2011).

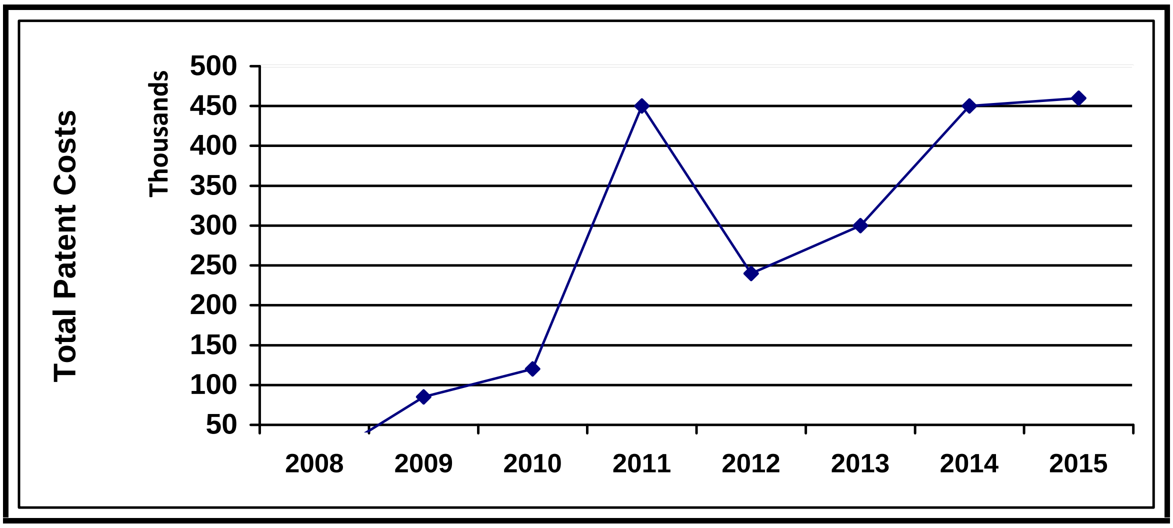


FIGURE 8.4: UWC TOTAL PATENT COSTS
Source: RSA: DST *et al*. 2017 for years up to 2014 and UWC (2018) for 2015.

The total patent costs, as depicted in Figure 8.4, rose from Nil in 2008 to R450 000 in 2011, with 2015 having been the most expensive year when R460 000 was spent on registering patents at UWC (The figure for 2015 comprises the period from 1 April 2015 to 31 March 2016 as more accurate information for the calendar year 2015 could not be obtained). In total, an amount of R2.1m was spent over the eight-year period and it is apparent from the above that the IPR-PFRD Act of 2008 may have resulted in increased patenting activities on the UWC campus since 2010.

As reported earlier in this chapter, UWC has made significant progress towards transforming itself into a research-intensive university. The shift has occurred with the knowledge that TT has become a vital form of knowledge dissemination to socio-economic markets for the public good (UWC, 2016c). While an additional income stream from TT activities is advantageous, the ultimate objective of university TT is to positively impact on society through promoting socio-economic development. The net result is an increase in the University's profile, which in turn leads to increased public and private funding for additional research opportunities (UWC, 2016c).

During 2015, a separate portfolio for Research and Innovation was started and is managed by a committed Deputy Vice Chancellor (UWC, 2016c). The TTO reports to the same structure as the Research Office. The transfer of technologies from UWC, whether products, processes, or services, to social markets and businesses in commerce and industry will add to improved competitiveness and provide socio-economic value to the region and the country as a whole (UWC, 2016c).

Participants to the in-person interviews agreed that they knew about the IPR-PFRD Act in SA which now compels universities to protect their IP and to commercialise it. The first two respondents supported it unconditionally, whilst the last one declared:

> You can gamble and risk on 50 products, but if one of them is a winner, and it becomes a global winner, you can generate enough income to cover your entire research budget with (W3).

This comment from interviewee W3 is noted with some reservation. New technologies have disparate development pathways and long lead times to production. The early stage nature of such technologies means that they are perilous and there is no guarantee of long-term success. While technology transfer is a means of generating a third income stream for universities, it is generally not a significant funds generator for most universities, even in the United States and Europe, where the technology transfer systems are well developed over many years (Mowery *et al.*, 2001).

In response to a question to describe the legal and support services received from the TTO, all interviewees praised the support provided by the TTO. In focussing on areas for improvement, Interviewee W3 noted again that the technology transfer and entrepreneurship module for final year students or postgraduate students will raise the awareness of IP issued for students and academics. Except for the first interviewee, who felt that it was too early to make a call, the remaining two claimed that they would intensely recommended the TTO's services to fellow academics and students on campus.

This section chiefly notes the measures expounded by UWC in protecting IP created on its campus by staff and students. The protection stems from responsibilities assigned to the university by the IPR-PFRD Act.

8.5. Funding for TTO commercialisation activities

UWC started a seed fund with the aid of TIA to facilitate the advancement of promising R&D projects from proof of concept phase on route to commercialisation (UWC, 2013). There is a nation-wide lack of funding in SA to drive technology development beyond basic research, and although TIA runs a Seed Fund targeted at universities, as well as a more general Technology Development Fund, this source of funding is limited (UWC, 2016c). Furthermore, other sources of dedicated funding for early stage commercialisation are few and far between (UWC, 2016c).

The South African Institute for Advanced Materials Chemistry (SAIAMC) obtained two significant research and innovation grants from DST. The first being for a lithium-ion battery and super-capacitor key programme extension for 2014/15 to the value of R12m (University of the Western Cape (UWC), 2014a). In this programme, UWC's role as the national leader in battery and energy storage technology was reiterated by the addition of an engineering and systems integration component over and above existing cell creation activities. The second grant of R3m was used to fund the development of a plasma spray-coating system at UWC, which puts the University at the forefront of this emerging manufacturing technique (UWC, 2014a). Plasma spray coating offers, amongst others, revolutionary high-volume solutions for the production of battery electrodes, gas separation systems, and photovoltaic devices.

In the area of social innovation, a number of initiatives are afoot to involve local talent in the development of mobile apps for socio-economic advances and benefits (UWC, 2014a).UWC refers technology driven projects to the Cape Innovation and Technology Initiative (CiTi), formerly known as the Cape IT Initiative, founded as a non-profit organisation in 1998 by a broad group of industry stakeholders and inspired citizens. The vision of CiTi is to develop Cape Town and the region as a global technology collection and a vibrant hub for innovation that can be a major contributor to economic growth (CiTi, 2016). CiTi is the flagship organisation for the technology sector in the region and has promoted collaboration between businesses in commerce and industry and public-sector participants. The Bandwidth Barn, a CiTi operated initiative, has been recognised as Africa's leading and most established incubator and accelerator, incubating hundreds of start-ups generating thousands of new jobs (CiTI, 2016). Numerous entrepreneurs and start-ups with their roots in Cape Town have become global success stories (CiTI, 2016).

UWC has succeeded in raising the awareness of IP protection and its commercialisation considerably, as revealed through results from in-person interviews held with top management within the University as well as academic staff and students.

In response to a question about efforts to secure funding for research, interviewee W1 observed that alliances with other HEIs and government institutions are working well for UWC. She stated:

> We forge alliances with other universities and governmental agencies performing research. We prefer consortiums as your chances of getting research projects funded is better and we also look at international grants. We are acquiring a new research and management information system to create a platform for global visibility for our research projects (W1).

Interviewee W2 confirmed that own funding generated by the spin-out company fuels further research activities, whilst they were also fortunate to obtain research grants from the Bill and Melinda Gates Foundation. Interviewee W3 denoted that UWC's share of external research income has grown meaningfully.

Interviewees were united in their reply that the university and or the TTO may assist in securing funding where possible and appropriate, but that such funding would primarily be for applied research activities to develop existing IP further. Apart from introductions to governmental funding agencies, none of the interviewees cited efforts by the TTO in promoting linkages for TT.

Two of the respondents were positive in their answer to whether TT can be a major source of income for them, their department, and the university.

> Certainly, but It takes a long time. It takes time to build a pipeline of opportunities and then investment is also needed for those opportunities (W1).Yes, I think it would be a huge income

> stream. Something that's probably not been tapped at all at the moment. I have seen lots of examples in the UK and the US in particular (W2).

Interviewee W3 again referred to funding and the protection of IP being expensive when he said that UWC is not well-resourced, being a historically disadvantaged university. To address the managerial challenges, management interviewee W1 opted for increased elevation of the status of the commercialisation of R&D on campus and support for the TTO staff. Interviewee W3 was brave in advocating, "If we had a stronger funding base, then we could take more calculated risks with IP." This response from management (W3) almost sounded like a venture capitalist when he said that UWC could take more risks by investing in technology or spin-outs if the university had more funding. He is correct; it is an economic reality in SA that we need funding support to start and build new businesses. Other universities in the same province have also identified this need and have set up seed funds to bridge that early gap in the development of new technologies with market potential.

All participants agreed that there should be a balance between the interests of academics as inventors and the public at large in an equitable sharing of the financial benefits resulting from TT activities.

8.6. Human Resources

Incentives for academic staff to engage in TT activities

In response to a question on what motivated the academic staff member or the university to engage in commercialisation activities, the first respondent said:

> Most of the research activities were in the Life Sciences and that's where the potential lies for TT. There's also a focus on research into the energy field. So there is a strong motivation to do technology transfer and a number of impactful people that are doing stuff that needs support (W1).

Another respondent was convinced by staff at the TTO in favour of commercialising his idea and his reply read:

> I went over to the TTO and I told them I wanted what we were doing to be given away for free and they laughed. Over the course of about a year they convinced me that I should commercialise the technology and that it was the only way to go (W2).

It was not surprising to see interviewee W2 wanting to give away his IP for free. It was in the early days of UWC's TTO and understandably at the time the inventor was unaware of the obligation to protect and then to commercialise his findings. It is also often part of the culture of academic researchers to not want to benefit from commercialisation but rather have the community at large reap the benefits. Researchers and students often underrate the possible uses and application of their scientific breakthroughs, or they simply do not know how to translate their research efforts into tangible products that benefit the public as a whole. The TTO can help by assisting academics to find appropriate ways to utilise their research results and to put a value on the resulting IP.

In response to a question on whether TT activities affect the academic promotion or career trajectory of academics, the first respondent was uncertain:

> I am not quite sure about that because we're not a large research-intensive university where there are many opportunities for TT. I don't think it counts a lot. I think it would be just something you mention as an output or outcome for your research and then they can give you a point probably at the same level as what a publication would count (W1).

An academic staff member that was interviewed provided an adverse answer and testified:

> Negative. Because I was involved in the commercial side of things, I consciously didn't focus on publishing papers. When I tried, I didn't get promoted as I wasn't publishing enough. I don't think I was averaging three to four papers annually and they needed more. I counted data that I have for 28 papers with me but I just haven't gotten around to writing them which definitely stood against me (W2).

Interviewee W2 was downbeat about his poor rating due to insufficient published papers in approved journals, which kept him from being promoted. One can understand that, but he needs to delegate some of his duties in the spin-out company to someone else so that he can publish and remain relevant as a renowned academic and expert in his field of study.

An interviewee from top management (W3) mentioned DHET and the fact that DHET now uses patent statistics as part the measurements of the performance of academics. When looking at other incentives (if any) used to motivate academics to engage in TT activities, the answers from the participants were similar. Apart from the usual participation in licensing income, participant W2 mentioned recognition in publications, but said it was not a strong incentive.

> The University is quite happy because what we had a very good news story. We came second in the Innovation Prize for Africa competition, so we've improved the university's reputation. I think we were mentioned in an internal publication, you know? That's not necessarily incentive for me (W2).

When asked which rewards the inventors would like to see implemented to increase their propensity to disclose their findings and seek commercialisation, the respondent from management (W1) attested:

> One of the rewards that I want to see could be for academics and students to have increased relationships with commerce and business and industry around the campus for job opportunities for students (W1).

An interviewee from academia was rather cynical in saying:

> I think if the commercialisation activities should be recognised as an academic endeavour.
> I think I'm vastly outperforming a lot of people in the university but because it's not a measurable, I'm not getting any recognition (W2).

Participant (W2) reasons that commercialisation activities should be officially recognised as an academic endeavor to enable improved recognition for his effort. As teaching and research will always be on top of the list for universities when considering performance of staff, he may have to accept that any recognition over and above that will be a bonus and will be limited to likeminded individuals that are also entrepreneurially inclined at the university.

Networks leading to collaboration

A commitment was made to harmonise UWC's leadership culture with its strategic aims (University of the Western Cape (UWC), 2011). The following achievements regarding the prevailing management culture at UWC (UWC, 2011) are worth mentioning:

- The furtherance of a strong bond with organised labour on campus
- The prioritising of a reward system in accordance with strategic objectives of the university
- The betterment of employment equity goals, in particular towards staff with disabilities
- The university's employment costs that are below the 60% national benchmark for SA universities, a significant feat for a university with such a low source of income (UWC, 2011)

UWC's convocation is actively promoting events and holding lectures on campus to lure former students back to their alma mater (UWC, 2011). The University has had an increased prominence in media coverage over the years. Apart from the usual publication for staff and students on campus and the *360 Degrees* alumni publication, the second edition of *Perspective* was published in 2011*. Perspective* concentrates on top-rated research projects and its impact and involvement within the communities served by UWC. In addition, the university holds many annual public and memorial lectures such as the Dullah Omar, Ashley Kriel, Desmond Tutu, Julius Nyerere, Jan Rabie, and Marjorie Wallace memorial lectures and others talks (UWC, 2011).

UWC is noted in both the Voortrekker Road Central Improvement District (VRCID) initiative, running from Bellville to Goodwood, and the Greater Tygerberg Partnership (GTP), created to pull public and private interested parties together for mutual benefit in the promotion of investment opportunities and the enhancement of the area (UWC, 2013). Both UWC and CPUT experience a sense of being isolated. The isolation stems from a nearby industrial container depot splitting the premises of the two universities, also separating it from the adjacent communities they must serve (UWC, 2013). However, the region also comprises medical and pharmaceutical expertise and has the possibility for innovation and stimulating economic growth (UWC, 2013).

Whereas two of the interviewees noted that they were not aware of any real efforts to promote networks, one interviewee referred to the Centre for Entrepreneurship that works closely with the TTO. The Centre recently developed a curriculum to incorporate entrepreneurship into the main curriculum and uses it to interact with businesses in commerce and industry (W3). Academic interviewee W2 was appreciative of the TTO's introduction to DST which led to international contacts that he now maintains himself.

8.7. Technology transfer office (TTO)

During 2011 the processes and implementation model for the TTO at UWC was developed and funding was received from DST to the amount of R3m for the establishment of the office (UWC, 2011). Opened on 14 February 2012, the TTO at UWC is the youngest of the four TTOs at the four universities in the Western Cape. The establishment of the office was seen as strategically important for the institution by UWC's research community, executive management, and senior management (UWC, 2012a).

UWC has a number of research projects that are in various stages of patenting and/or commercialisation. UWC (2012a) reports that the technologies developed, and research centres supported by the TTO include:

- SAIAMC, which is collaborating with businesses in commerce and industry to produce parts for HySA's fuel cells backup power systems and for hydrogen storage. This technology will allow for the substitution of diesel generators with hydrogen operated fuel cell power systems. A patent application has been filed and a prototype has been developed that is in use.
- The bioinformatics institute, SANBI, which with financial assistance from DST has enhanced drug resistance testing in HIV.
- A water treatment tool with dedicated photo catalysts that eliminates damaging microorganisms and helps decomposing and eradicating industrial organic toxins.
- A botanical product as agrochemical that repeals opposition to pesticides in plant pathogens. This natural product, when used with pesticides, has proven to lessen the dose of pesticides needed (UWC, 2012a).
- UWC neither has an abundance of license agreements from which it receives royalty income streams yet, nor does it have any spin-out companies yet (UWC, 2012b). As the TTO is fairly new, it will take time for a strong pipeline of invention disclosures to develop. Of importance for new spin-out companies from UWC's campus will be the provisions in

its IP policy that govern potential conflicts of interest of its academic staff and students. UWC (2012b) noted the following with regard to possible conflicts of interest for UWC employees:

- Each employee ought to reveal conflict/potential conflict of interest in the commercialisation of IP to the TTO and/or the legal services office at the university.
- Employees having a financial interest in the commercialisation of IP developed by them are not allowed to partake in the negotiation process.
- If an employee is involved in a spin-out company, his/her academic duties and remuneration will be lowered in view of that.
- No employee can be engaged in any company that competes with UWC.
- Any employee involved in a spin-out company in conjunction with UWC is not permitted to be engaged in a company that competes with that spin-out prior to obtaining specific authorisation from the DVC (UWC, 2012b).

As the main organiser, in conjunction with the TTOs of UCT, CPUT and SU, the UWC TTO ran the *2013 Technology Commercialisation Course: From Lab to Mar*ket and also presented the NIPMO IP Workshop in 2013, attended by TT colleagues from the other Western Cape Public Institutions (UWC, 2013).

The TTO at UWC is positioned as part of the administrative offices at the university. The director of the TTO reports to the deputy vice-chancellor (academic), who is in charge of the academic, research, and innovation portfolios. The TTO is managed by a small number of permanent staff comprising of the director, one technology transfer manager, and two technology transfer officers. The small number of staff means that each staff member is engaged in nearly all phases of the TTO's actions. The rector and vice-chancellor of UWC at the time, Prof Brian O'Connell, proclaimed the formation of the TTO as a noteworthy landmark in the University's history. Initially, the TTO team consisted of Dr Doug Sanyahumbi as the TTO director, Dr Ana Casanueva as the technology transfer officer, an intern, and an administrative assistant (NIPMO, 2015).

UWC's vision for its TTO is to be a top-rated office for the transfer of IP and technologies emanating from the institution through commercialisation. The task of the TTO is to assist in the University's attempt to achieve its vision and reach its mission UWC (2016c). Hence, the mission of the TTO is to "support, facilitate and promote the effective and efficient transfer of IP emanating from UWC to socio-economic markets in order to create value for society, IP creators, the University and SA" (UWC, 2016c:6). The TTO will achieve this by:

- identifying and evaluating university IP for its potential to create value;
- protecting relevant IP identified as protectable and attractive;
- marketing and facilitating the appropriate transfer of UWC-owned IP and related technologies to entities best positioned to take them to socio-economic markets; and
- managing the proceeds from the commercialisation of UWC-owned IP and related technologies in line with the UWC's IP Policy and the IPR-PFRD Act (UWC, 2016c:6).

The TTO will also generate an additional income stream over the next decade that may add to the university's core business of teaching and research and in doing so satisfy the 5th IOP goal of financial stability (UWC, 2016c). It is hoped that the efforts by the TTO will lead to increased compensation earned by the creators of valuable knowledge at UWC for their endeavours and that such knowledge will add to the betterment of the competitiveness of businesses in commerce and industry (UWC, 2016c).

The key indicators for the TTO will be:

- the number of ideas offered to the TTO, which gauges the awareness of the TT process;
- the number of disclosures received and evaluated, which assesses academics' inventiveness;
- the number of disclosures protected, which evaluates the quality of disclosures and market potential;
- the number of patents filed, which calculates the effectiveness of the TTO; and
- the amount of funding raised by TTO activities, which appraises the quality of research (UWC, 2016c).

Other statistical indicators are:

- the number of licenses and options successfully exercised, which quantifies the relevance and/or market value of IP created at UWC and the quality of marketing efforts of the TTO;
- the number of spin-out companies established, which rates the significance/market value of the IP and TTO ability to conclude deals with entrepreneurs/other businesses;

- total licensing income earned by UWC, which calculates the importance/market value of IP that led to signed license agreements; and
- the socio-economic impact of IP, which calculates the number of jobs created, the number of new products and services created, the endurance rate and progression of university spin-out companies, and indicators showing improvements in quality of life (UWC, 2016c).

In addition to networking with other university TTOs in the region, the TTO at UWC cooperates intimately with a number of other service units within UWC, like the Office for Research, Legal Services, Business Development, and Grants and Contracts Management. The eventual success of the TTO is reliant on the backing it receives from the university's top management and research community, which increases the propensity for disclosure of new inventions by academic staff and students (UWC, 2016c).

In November 2014, an innovative 2,5 kW hydrogen fuel cell power generator prototype unit was unveiled at UWC as one example of a successful research project. Its inauguration indicates SA's innovative capacity in hydrogen and fuel cell technologies (UWC, 2014a). The prototype was designed by HySA Systems with the help of Hot Platinum (Pty) Ltd. Hot Platinum is a local business that is active in power management and control electronics. The hydrogen fuel cell power generator unit expends hydrogen to produce electrical power with steam being the only by-product. The result is that electricity can be generated with no pollution or noise and in sparsely populated areas where access to the national electricity grid is limited (UWC, 2014a).

The Innovation Bridge Technology Showcase and Matchmaking Event, started by DST, was held in February 2015 and permitted technology focused commercialisation partners, entrepreneurs, and investors to access SA publicly-funded technology innovations (University of the Western Cape (UWC), 2015). The TTO at UWC took part in this event and exhibited four of its technologies, comprising:

- Seq2Res, an HIV drug resistance testing software;
- iBATECH, a natural pesticide and fertilizer;
- an acid mine drainage treatment technology using waste fly ash; and
- a display by HySA Systems, a centre of competence that develops novel and practical hydrogen systems and prototypes (UWC, 2015:1).

UWC's TTO was triumphant and received 2 awards at the Innovation Bridge event, one as the best exhibitor from a TTO, and the other for the best prototype produced by a TTO for its illustration of an archetype from HySA Systems of their hydrogen driven fan (UWC, 2015).

UWC succeeded in making vast improvements to the creation of innovation capacity at the university and in protection its IP developed by staff and students (UWC, 2016d). In addition to the projects already mentioned, the University started a pilot production plant for the manufacturing of lithium-ion batteries that are safer, long-lasting and portable and combined UWCs expertise in advanced battery development and manufacturing to create the new Energy Storage Innovation Lab (ESIL) in May 2015 (UWC, 2016d). ESIL represents many years of R&D and innovation at the SA Institute for Advanced Materials Chemistry at UWC (University of the Western Cape (UWC), 2016c).

This section discussed the creation of the TTO at UWC, its role and function, and noted key indicators as statistics that are typical output measurements for the work performed by TTOs. A number of promising commercialisation activities that are gaining momentum at UWC were also listed. The next section briefly explains funding for TT activities at UWC.

Commercialisation activities

When asked to express success in university TT activities, interviewee W2 was thoughtful when implying:

> And I think it's a very successful TTO if they can convince academics to do what I've done and drive the commercialisation of the IP out to industry. But then there's other academics that cares so much about their academic career that they will lose interest in pursuing commercialisation if it isn't recognised by the university. So the TTO need to convince both parties and I think that's probably their bigger battle (W2).

Academic interviewee W2 was involved with patenting, licencing, and the spin-out company he had established. He responded as follows to a question on what interviewees most like or dislike about TT practices:

:

> What I like most is that we are where we are now because of the TTO. They allowed me over to refine and develop the process and the technology and we were given the freedom to set our spin-out company alongside our academic careers and I could pursue both from within that. I wouldn't say we're trailblazers because that sounds egotistical but within UWC we're the first on this path that nobody's ever done before. So we've benefitted from that uncertainty within the university but if it was ten years down the line and they had their structures in place maybe it would be different and more constraining on us (W2).

None of the three interviewees had any specific dislike in TT activities and management interviewee W3 declared, "To be honest, I don't dislike anything. I get excited about it and want to optimise opportunities for the University."

Interviewees were pragmatic when confronted with the question of what TT successes at UWC mean to them. Interviewee W1 noted that "research at UWC improves the quality of life for all South Africans now and in the future". An academic amongst the participants illustrated:

> I am thrilled. I moved to SA from Ireland to be able to make a difference and what we're developing now is going to make a difference in the next couple of years in the lives of millions of people. That's good enough for me. I'm very proud. But it's not only me. You know, the original idea was mine but it's the whole team that did it together (W2).

The prominent top manager W3 proclaimed:

> During my seven years as Deputy Vice-Chancellor I took UWC from an institution that was doing research from an average level to become one of the top universities on the continent. I was instrumental in establishing the TTO. I watched it grow and personally I would like for it to succeed (W3).

An official from top management commented on the last question regarding support from the TTO that was most helpful and said categorically:

> The mere fact that they said "You're not alone" helps. We have a TT Officer that's going to answer your questions and we have a TTO that assists and should you come up with new IP we will guide you through the process and help you to protect it through university resources and then we'll work with you take it to the next level of commercialisation (W3).

In this section four broad themes illustrated TT activities at UWC. These were cultural, legislative, and economic components influencing university TT, together with some general questions regarding TT at the university.

License agreements

One participant saw TT as a potential activity that may lead to funding relief.

> Our University realised many years ago that state funding is going to decline and we wanted to look at alternate resources of funding to the university's core business. Income from IP became central in the institution's strategic planning (W3).

Participants provided diverse answers to the question on how the services of the TTO are advertised on campus. Interviewee W1 was critical in saying:

> There's definitely a weak link there. Because we don't have enough even awareness activities for postgraduate students. It's piecemeal information that's not enough (W1).

Respondent W2 stated that he only received e-mails that advertised the services of the TTO and an invitation to engage with the TTO if he or his research team developed protectable IP. Interviewee W3 was much more vocal and boasted:

> We started a series of engagements of running seminars within faculties to bring our staff together and to make them aware of what the opportunities are and why it is critical to protect their IP. We are very good at marketing the successes. Like the one in Bio-informatics. It was all over in the media. It was all over the university. So people say, "Hey, if they can do it, why not us?" (W3).

The first respondent was unsure about the role of the TTO on UWC's campus and stated as a managerial challenge:

> For me, the roles of the respective TT players at UWC is not clear yet. Are we promoting awareness or are we doing TT in partnership with other organisations? Are we just a registering office? You can't be everything as a university. You have to define the role of the university here and prioritise. So for me, that's where we have to start. So the TTO and its

> management plan needs to be promoted and elevated so that it becomes a language of the university. Right now, we're only talking about teaching and learning and research and not commercialisation of IP (W1).

Of course, the respondent from management (W1) was correct in summarising some of the functions of a typical TTO. Despite a limited number of staff, the TTO has numerous things to do. Academic interviewee W2 was very thankful and did not note any specific managerial challenges, stating:

> I think they definitely do have the knowledge and skills in the TTO. You know, we wouldn't be where we are if it wasn't for the TTO, particularly Doug and Anna. Yes, so they've always been very open and easy to work with and they always seemed to be well-staffed because you know, if I ring them, everything seems to happen at a drop of a hat. I think that's probably because they do not have a huge portfolio of projects that they're working on. I think it's grown over the last couple of years. But we were really one of the first ones. So we're kind of their poster child. So we get probably preferential treatment (W2).

During the interviews all participants reiterated the existence of healthy and trustworthy relationships between themselves and the TTO staff members at UWC.

8.8. Conclusion

The introductory section of this chapter points to the fact that total R&D expenditure at UWC for the years 2008 to 2015 increased remarkably by 204.7% compared to its total instructional staff that only increased by a slight 24.5%. UWC was found not to be one of the biggest, oldest, richest or best fitted university in the Western Cape, but is has drawn a high number of top-rated academic staff members to join its ranks. UWC prospered in appealing to talented researchers through its global recognition for performing solid research (UWC, 2016b).

UWC launched a strong effort in 2009 to grow the number of academic staff members having doctorate degrees. With the help of a new research grant to help academics that were close to completion of their doctoral dissertations, the number of staff members with doctoral degrees rose steeply to reach more than 50% of UWC's permanent academic staff complement by the end of 2012. This drive to increase staff having doctoral degrees may have contributed to the recently recorded increase in publications at the university. The overall net increase in research publications was 115.6% for UWC for the years from 2008 to 2015 compared to the number of instructional staff that only rose by 24.5%. This lopsided improvement in publication outputs against the increase in instructional staff denotes that the academic staff members at UWC increased their productivity significantly over this period. The result of the efforts is that UWC's is growing its status of becoming a research intensive university in SA (UWC, 2016a).

The Institutional Operating Plan (IOP) of UWC and the university's IP policy was briefly discussed in section 8.2. The release of the IOP early in 2005 ensured that much needed extra funding flowed to the university to stimulate growth at the time (UWC, 2012a). The IOP advocated interaction and connectedness between the university and all of its stakeholders and role players. Judging from the increased research profile and better qualified academic staff complement, the IOP can be seen as a successful policy intervention of note for UWC.

The institutional commitment was described next and after stating seven reasons why he believes UWC should be involved in TT activities, Sanyahumbi (UWC, 2014b) correctly advocate that there are numerous difficulties to ponder over when reflecting on university TT. The author states, as was claimed by many before him in the literature that TT is not known to be a major income earner for universities. As researcher, I agree with him that the main contribution of TT activities is not limited to the university environment alone as the bulk of the economic value established from TT efforts accrues to stakeholders outside the university.

UWC's technology transfer office represent a typical university TTO in start-up mode and is experiencing many of the frustrations and challenges recorded by many authors per the literature review for this study. These challenges are not limited to the patenting of new technologies that can take long, is costly and cumbersome to commercialise. Eliciting funding for investment in a university spin-out company as start-up venture can take many years whilst opting for a licence agreement can also require a time period of more than twelve months.

Respondents to the interviews reported strong commitment from top management within UWC at the time of creating the TTO, but that little or no interaction occurred since that time which is aimed at strengthening the relationship between top management and academic staff with regards to IP commercialisation on campus. This finding is troublesome and the present management of the TTO should do their best in getting top management involved in promoting the services of the TTO on campus in order to raise the profile of the TTO as a trustworthy unit within the ranks of UWC.

Intellectual property protection is best displayed by the total patent costs incurred. This figure measured annually (Figure 8.4) increased from RNil in 2008 to R450 000 in 2011 before dropping to about R 250 000 in 2012 and ending up again at 460 000 for 2015. If total spending on patent registration cost is used as yardstick to partly determine the extent of TT activities then UWC has some way to go still to reach the levels of spending recorded by the two more research intensive universities in the Western Cape Province.

Funding for TTO commercialisation activities at UWC were boosted by the Seed Fund of TIA which assist all SA universities, as well as a more general Technology Development Fund also managed by TIA although this source of funding is limited (UWC, 2016c). UWC has succeeded in raising the awareness of IP protection and its commercialisation efforts meaningfully, as determined via the in-person interviews held with top management and academic staff and students of the university.

In response to questions about funding for research, interviewees stated that agreements with other educational institutional bodies and government institutions are working well for UWC whilst international grant funding is also pursued. The management of UWC admitted that funding for the protection of IP is expensive whilst the university is not wealthy as it stems from being a historically disadvantaged university. Management also proclaimed its willingness to take more calculated risks relating to IP commercialisation it they had more funding resources available.

A technology transfer and entrepreneurship module for postgraduate students was proposed by one of the interviewees. Although the idea in not new, it is worth exploring, as businesses requires more lateral thinkers that support an ethos of entrepreneurship in an ever changing technological environment (Idris, 2003).

From the interviews, it emerged that UWC academics may lose interest in commercialisation activities due to a focus on their academic careers. Participants also felt that commercialisation activities should be regarded as an official academic endeavor so that it may be evaluated in performance review exercises in addition to the usual teaching and research activities.

Having opened its doors on 14 February 2012, the TTO at UWC is the youngest of the TTOs at the four universities in the Western Cape (UWC, 2012a). The outputs recorded by the TTO since then is low and resembles that of a TTO in its infancy. As UWC develops towards a recognised research-intensive university, it is likely that invention disclosures, patent applications, and patents granted will allso increase in the future.

Although this is not a comparative study, it is striking how similar the TTO outputs are of both UWC and CPUT since the enactment of the new IPR-PFRD Act as both universities are starting from a low base having traditionally been historically disadvantaged universities in the Western Cape Province of SA. The next chapter comprises a case study of CPUT.

Chapter 9: Cape Peninsula University of Technology – A case study

9.1. Brief history and research capacity

CPUT was founded on 1 January 2005 when the Cape Technikon and the Peninsula Technikon merged. The merger was the result of a national transformation initiative led by DOE in SA. Being the only university of technology in the Western Cape, CPUT is the largest of the four universities in the province and has more than 32 000 students based at a number of campuses studying over 80 different academic programmes (CPUT, 2007).

CPUT has a stated objective of being within the top 10 publicly-funded universities in SA and within the top 500 universities globally (Cape Peninsula University of Technology (CPUT), 2012a). The university is one of six universities in SA which has more than 80% of its journal publications in international indices when measured by overall research publication outputs. As one of the top universities of technology in SA, the university's annual share of journal articles and books published has been consistently high (Republic of South Africa: Department of Higher Education and Training (DHET), 2014). Publications of books and conference proceedings increased significantly from 2012 to 2013 and CPUT's weighted research output per capita of its academic staff and students was amongst the top two of the six universities of technology in SA during this period (RSA: DHET, 2014). Also, considering the percentage of academics holding master's and PhD degrees, CPUT was second on the list of universities of technology and ranked 12th overall of all 23 universities in SA (RSA: DHET, 2014).

The Peninsula Technical College was founded in 1962 (Cape Peninsula University of Technology (CPUT), 2015a). Lectures were presented in Cape Town until the college moved to Bellville during 1967, where the administrative buildings of CPUT are still located (CPUT, 2015a). Through the 1970s its status was modified to a college of advanced technical education and its name changed to the Peninsula College for Advanced Technical Education. Soon thereafter, the name changed again to the Peninsula Technikon in 1979 (CPUT, 2015a). The 1990s saw degree programmes being offered for the first time and 1997 saw the reshuffling of the institution's academic programmes into the faculties of Engineering, Business, and Science (CPUT, 2015a). The then Minister of Education in SA, Prof Kader Asmal, announced the National Plan on Higher Education in March 2001 (CPUT,2015a). The plan resulted in the merger of a number of higher education institutions across South Africa and the formation of universities of technology. In 2003, the Minister approved the name Cape Peninsula University of Technology and the university formally commenced its activities in 2005 (CPUT, 2015a).

The vision of CPUT is to be at the heart of technology education and innovation in Africa and its mission statement comprises four aims, namely:

- building a university that is well-organised, sustainable, and aware of the environment;
- delivering top quality teaching and learning with a curriculum that is relevant;
- creating a lively and well-equipped living and learning space for its students; and
- promoting and extending the quality and effectiveness of its research activities and knowledge production (Cape Peninsula University of Technology (CPUT), 2015b).

By 2015, CPUT had six faculties focusing on Applied Sciences, Business, Education & Social Sciences, Informatics & Design, Engineering, and Health & Wellness Sciences. As reported earlier, these faculties boast more than 80 undergraduate and postgraduate courses in a variety of fields, in addition to career-specific short courses. The university also has 26 research centres and 3 technology stations. In addition to the two main campuses in Bellville and Cape Town, CPUT also has the Granger Bay Campus boasting a hotel school and restaurant next to the V&A Waterfront in Cape Town. Campuses are also located in Mowbray and in Wellington, as well as at two major hospitals in the area. Furthermore, CPUT has joint research agreements with a number of universities in India, Europe, USA, Russia, and China, to name a few, and of course with prominent SA universities (Cape Peninsula University of Technology (CPUT), 2018a,b).

At CPUT, the Research Directorate, mandated to manage research and innovation, performs a crucial role in assisting CPUT to promote itself as a university of technology (UoT) that pursues excellence in research. The Research Directorate delivers on its mandate by supporting researchers with grant management, finance and administration, publications management, use of the RIMS electronic management system, and research capacity development. CPUT (2018a) claims that research and innovation output will increase by the strengthening of the research capacity of researchers.

On 1 January 2015, CPUT honoured 10 years since its establishment. Over the decade since 2005, thousands of students graduated from the university (CPUT, 2015i). Although CPUT has no DST/NRF accredited Centres of Excellence, it has several research centres and units of its own that are recognised by DST/NRF. Three research centres of CPUT were incorporated into the Technology Innovation Agency's (TIA) Technology Station programme.

Research profile

The number of NRF rated scientists at CPUT has increased significantly and so have funds for conducting research activities received from businesses in commerce and industry (CPUT, 2007). Academic staff from the faculty of Engineering contributed 35% or 14.6 units of published journal articles of the university during 2007 and both the university's highest NRF rated (B-rated) scientists are employed in the engineering faculty (CPUT, 2007). Moreover, more than 60% of the academic staff of the faculty of Health & Wellness Sciences had research qualifications by 2007.

CPUT seeks to use knowledge emanating from its campuses to solve problems in a practical manner and deliver services to the community (CPUT, 2007). Research groups founded in 2009 included the Biocatalysis and Technical Biology Research Group and The Centre for Multigrade Education (Cape Peninsula University of Technology (CPUT), 2009). Prof Nhlapo noted two very important offices that were started in 2009 and which provides thorough assistance to academics and students of CPUT, namely the Technology Transfer Office and the Centre for Postgraduate Studies (CPUT, 2009).

CPUT was acknowledged by the NRF for superiority in research in the following focus areas:

- Instrumentation Research
- Computational and Applied Technologies in Manufacturing
- Environmental Toxicity and Remediation
- Material Science and Technology
- ICT in e-Business, e-Government and Community Engagement
- Real-time Distributed Systems
- Work-Integrated Learning Research (Cape Higher Education Consortium (CHEC), 2009: 1)

The centres at CPUT relating to these specific areas and other research units are listed below.

- The *Centre for Instrumentation Research* focuses on wireless networks, sensors, and high-frequency electronics and collaborates with the Universities of Cape Town and Stellenbosch.
- *Computational and Applied Technologies Manufacturing* is a specialist area that investigates the use of computational techniques for the simulation of mechanical engineering problems and combines the application of advanced technologies to unravel engineering challenges.
- *The Environmental Toxicity and Remediation Research Centre* assesses via monitoring and modelling the exposure to environmental toxicants and develops remedial technologies.
- The *Centre for Real-Time Distributed Systems* focuses on the development of new models, design methods, software, hardware, and their combined application to real-time distributed systems.
- The *Work-Integrated Learning Research Unit* has as its research aim the human, social, organisational, and work dimensions of knowledge production and its use within and over various contexts in higher education.
- The *Centre for Distributed Power and Electronic Systems* concentrate on energy efficiency, infrared application, distributed system and energy sensor technologies.
- The *Centre for Tourism Research in Africa* emphasises CPUT's role in tourism and hospitality training and research in the Western Cape and promotes research on African tourism development.
- Research at the *Crystal Engineering Unit* is interested in the composition and reaction of certain organic compounds.
- The *Energy Institute* seeks solutions to the power crisis in South Africa by advocating energy efficiency. A number of cost- and energy-saving devices have been designed, tested and patented.
- The *French South African Institute of Technology* (F'SATI) programme is the result of an agreement between SA research institutions, universities, and businesses in commerce and industry. The programme is presented in conjunction with a graduate school in electronic engineering in France.

- The *Oxidative Stress Research Centre* concentrates on the function of oxidative stress in health and disease and considers medicinal plants, bio- and inorganic materials, and analytical laboratory services.
- The *Radio Chemistry and Ion Exchange Chromatography Centre* examines radiochemical separations of radioisotopes and the labelling of organic compounds with specific radioisotopes for use in nuclear medicine and cancer therapy (CHEC, 2009).

Three specific technology stations are supported and hosted by CPUT, namely the Agrifood Technology Station, the Technology Station in Clothing and Textiles and the TIA Adaptronics Advanced Manufacturing Technology Laboratory.

Input: Expenditure on R&D & researchers

Figure 9.1 below shows the total expenditure on R&D activities at CPUT for the period from 2008 to 2015 and highlights the fact that CPUT spent 262.4% more on research and development expenditure in 2015 than in 2008, whilst its component of instructional staff only grew by 16% (Figure 9.2).

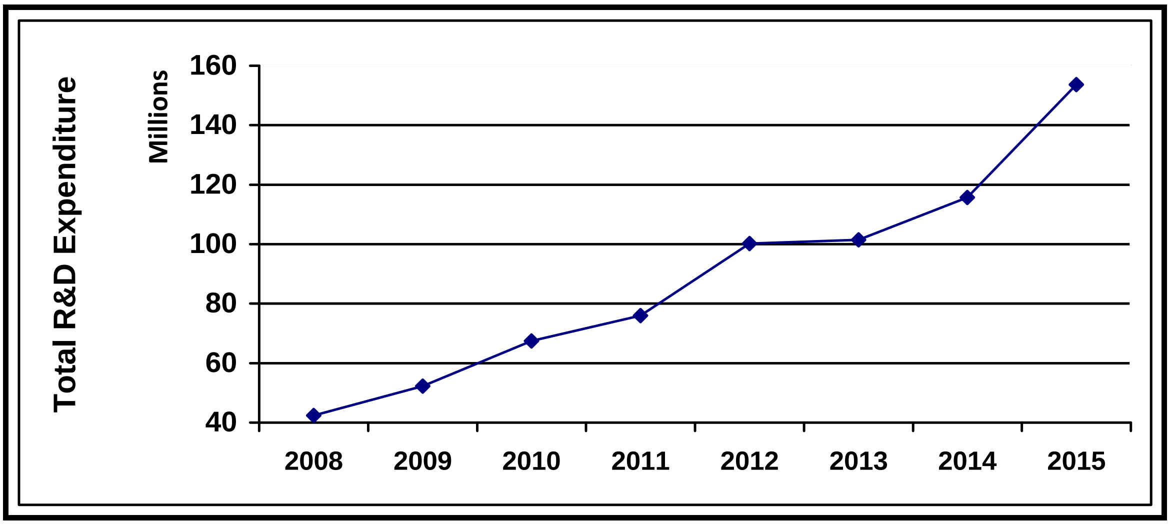


FIGURE 9.1: CPUT TOTAL RESEARCH AND DEVELOPMENT EXPENDITURE
Source: (Centre for Science Technology and Innovation Indicators (CeSTII), 2010, 2011, 2012, 2013, 2014a,b, 2016)

Figure 9.2 below indicates the growth in the student population that have fulfilled the requirements for a degree from 2008 to 2015, which increased by 19.5% from 6 977 students in 2008 to 8 342 students by the end of 2015 (RSA: DHET, 2015). The instructional staff members increased only by the said 16%, from 696 in 2008 to 807 by the end of 2015 (RSA: DHET, 2015). The number of students graduating at the end of each year is higher than at any other university in the Western Cape, as it was the only university in this province where more than 8 000 students graduated at the end of 2015.

Instructional staff contributes not only to graduate students, but also to the quality and quantity of research conducted at the university. As an emerging university of technology (UoT), CPUT has made huge progress since its incorporation towards fostering and expanding its research portfolio and research capacity (CPUT, 2014a).

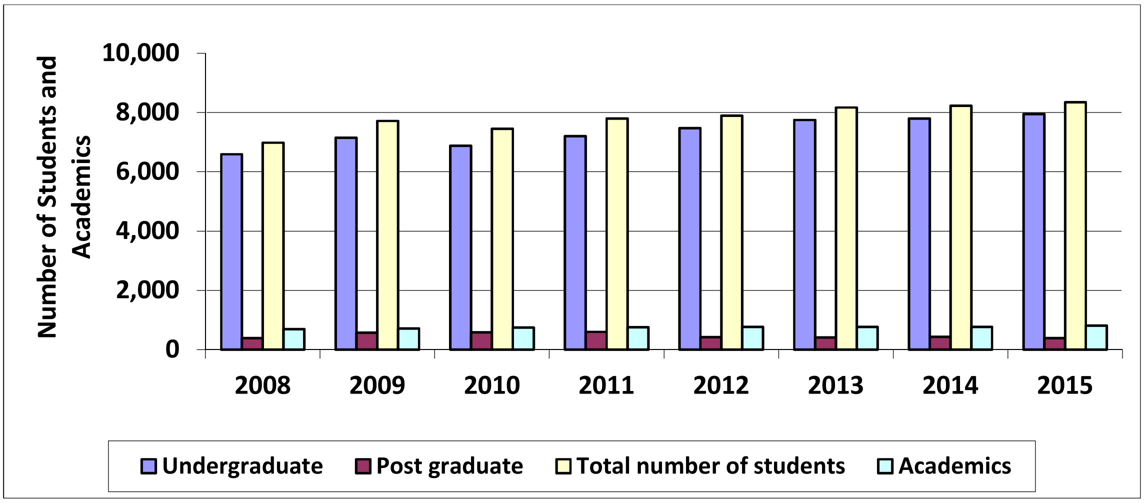


FIGURE 9.2: CPUT TOTAL NUMBER OF STUDENTS AND INSTRUCTIONAL STAFF
Source: HEMIS Tables (RSA: DHET, 2015)

Research infrastructure: Centres and SARChi Chairs

CPUT was given the first of its SA research chairs in 2011, namely the Small Satellite Research Chair in the Engineering Faculty and the Teacher Education Chair in the Faculty of Education and Social Sciences (Cape Peninsula University of Technology (CPUT), 2011). These research chairs are noteworthy, particularly in terms of their contribution to developing human resources, advancing technology innovation, and fulfilling the objectives of the National Innovation System (NSI) in SA (CPUT, 2011a).

CPUT was given permission to proceed in setting up research chairs in Teacher Education and in Innovative Small Satellite Technology and Applications for Africa in February 2012, valued at a total of R5m. By 2014, CPUT had four SARChi chairs. The chair in Wholesale & Retail Leadership, funded by the Wholesale & Retail SETA and the chair in Biomedical & Microbial Biotechnology were added to the chairs in Teacher Education and Small Satellite Technology and Applications for Africa (CPUT, 2014d). The granting of the chairs signifies a large achievement for CPUT, which has as its aims the increase of publication units, the creation of research capacity, and the expansion of the number of community-based projects (CPUT, 2014d).

Prof Christine Winberg, Director at the Fundani Centre for Higher Education Development (CHED) at CPUT, was one of 42 female professors awarded a SARChi chair recently. The award granted for the chair in Work-Integrated Learning covers her salary, expenses for master's and doctoral students, and for visiting scholars over the next 15 years. She and her fellow researchers and students will undertake many research projects. Prof Winberg's research focus includes a determination of how professional and vocational education can fulfil a more significant role in local economic development (Cape Peninsula University of Technology (CPUT), 2015c).

A number of SA research chairs awarded to CPUT researchers in recent years and chairs that are planned for the foreseeable future were highlighted above. The allocation of these research chairs to academics at CPUT acknowledges the number of very talented academic staff employed by the university and students registered at the institution and are indicative of the quality of research conducted by them.

Output: Research publications

Research outputs from DHET indicates noteworthy increases of more than 10% in publication output for CPUT for 2009 (CPUT, 2009). Since then, the university is leading all other universities of technology in SA when measuring research output, including that of its old rival, Tshwane University of Technology (TUT). Using an analysis of journal publications, conference proceedings, and book publications, DHET stated that CPUT as a university of technology expanded its research productivity by an incredible 77% from 2007 to 2009 (CPUT, 2009). The growth trajectory was 14% more than its closest competitor, Vaal University of Technology, and 31% more than TUT over the same period. The explanation for this is simply that CPUT's research mandate was underrated during the gradual change from a tuition-based vocational institution to a university of technology that includes both teaching as well as research activities (CPUT, 2009).

The year 2010 saw yet another increase of more than 50% in research outputs for CPUT, measured against its 2009 benchmark, ensuring that the university remained to be the forerunner of universities of technology in SA in terms of total annual research outputs (Cape Peninsula University of Technology (CPUT), 2010). The achievement was seen as a new standard by the university to be maintained to fulfil its role within the NSI in SA. Importantly for this study, a new culture of actively managing the IP portfolio emanating from research conducted on its various campus locations was being harnessed and by 2010 the university had filed six patents in leading research areas (CPUT, 2010).

CPUT (Cape Peninsula University of Technology (CPUT), 2014) reported strong growth in research and innovation output in its 2014 Annual Research Report. Firstly, there was an increase of 23% in research publications that qualify for subsidies submitted to DHET. In the individual categories journal articles increased by 21%, conference proceedings by 28%, and books by 14% (CPUT, 2014). Secondly, postgraduate student numbers grew by 22% and 22 students were conferred with doctoral degrees (CPUT, 2014). CPUT ranked second in a comparative ranking of the UoT's in SA and achieved average growth rates of 17.7% in research conducted for the 10 years from 2003 to 2012 and 15.9% for the 5 years from 2008 to 2012 (Mouton, 2014).

A thorough study was conducted by CREST on the performance of research production at CPUT for the period 1991 to 2012. In the study, Mouton (2014) uses a number of bibliometric indicators to determine the research output, research demographics, research productivity, and research collaboration occurring at CPUT. The scientific impact of publications is measured by counting the number of times that a publication was cited. CREST uses three main demographic variables, namely gender, race, and age and link it to each author. Mouton (2014) asserts that overall increases in the total research output of all universities in SA over the eight years leading up to 2012 emulate the total research production by the UoTs over the same period. UoTs in SA produced about 1 in every 100 academic publications in the early 1990s, whilst two decades later they produce nearly 1 in every 20 papers (Mouton, 2014). The significant growth in their publication output is indicative of CPUT's ability to break from their disadvantaged history in becoming a fully-fledged research oriented academic institution (Mouton, 2014).

Mouton (2014) argues that the average weighted research output of a university is the strongest indicator of performance measurement for research activity currently in use for SA universities. Research output used as part of this measurement includes articles, books, book chapters, and conference proceedings, as well as the output of graduate students (Mouton, 2014). The total of these outputs is divided by the total number of full-time academic and instructional staff employed by the university. For the period 2008 to 2012, CPUT was ranked 2nd behind TUT and 18th on the list of all SA universities (Mouton, 2014). The average weight per capita output for CPUT increased from 0.25 in 2005 to 0.46 in 2012 (Mouton, 2014).

Table 9.1 below shows the number of CPUT research publications in peer-reviewed journals from 2008 to 2015.

TABLE 9.1: CPUT NUMBER OF RESEARCH PUBLICATIONS IN PEER-REVIEWED JOURNALS

	2008	2009	2010	2011	2012	2013	2014	2015
Articles	61.7	101.8	129.8	115.5	147.1	103.0	122.8	173.1
Books / Chapters	0.6	1.3	1.0	1.0	0.1	2.5	2.5	6.0
Conference Proceedings	17.9	23.8	24.5	25.3	20.3	41.8	46.5	33.4
Masters Graduates	55	87	84	101	117	100	110	127
Doctoral Graduates	13	12	11	13	24	28	51	57

Source: HEMIS Tables (RSA: DHET, 2015)

By adding three more years (2013 to 2015) to the data for CPUT (Table 9.1), the number of research publications in peer-reviewed journals revealed that the number of article publications grew by 180.7% from 2008 to 2015. Similarly, books and chapters grew from 0.6 units to 6 units, be it from a very small base, conference proceedings by 87%, master's graduates by 131%, and doctoral graduates by 338%. Over the eight-year period the combined net overall increase for all these publications was 167,7% for CPUT, whilst the number of instructional staff (Figure 9.2) only rose by a small 16%, from 696 in 2008 to 807 by the end of 2015 (RSA: DHET, 2015). These statistics depict that academic staff at CPUT increased their research outputs exponentially over the said eight-year period.

Mouton (2014) highlights that UoTs like CPUT became eligible to receive research subsidies in 1991. The author depicts steep increases in the volume of research outputs at all UoTs in SA from 2005 to 2012. For CPUT, the strong growth over the years since 2004 matches the implementation of the new funding framework introduced in 2005 in SA by DHET. The upsurge in total research output at CPUT over this period can be attributed to the effect of the research subsidy grants in SA on the increase in the number of publications (Mouton, 2014).

Other outputs: technology transfer outputs

The statistics below from CPUT confirm that the TTO at CPUT has only recently started and has yet to build a longer pipeline of new inventions that may lead to protectable IP.

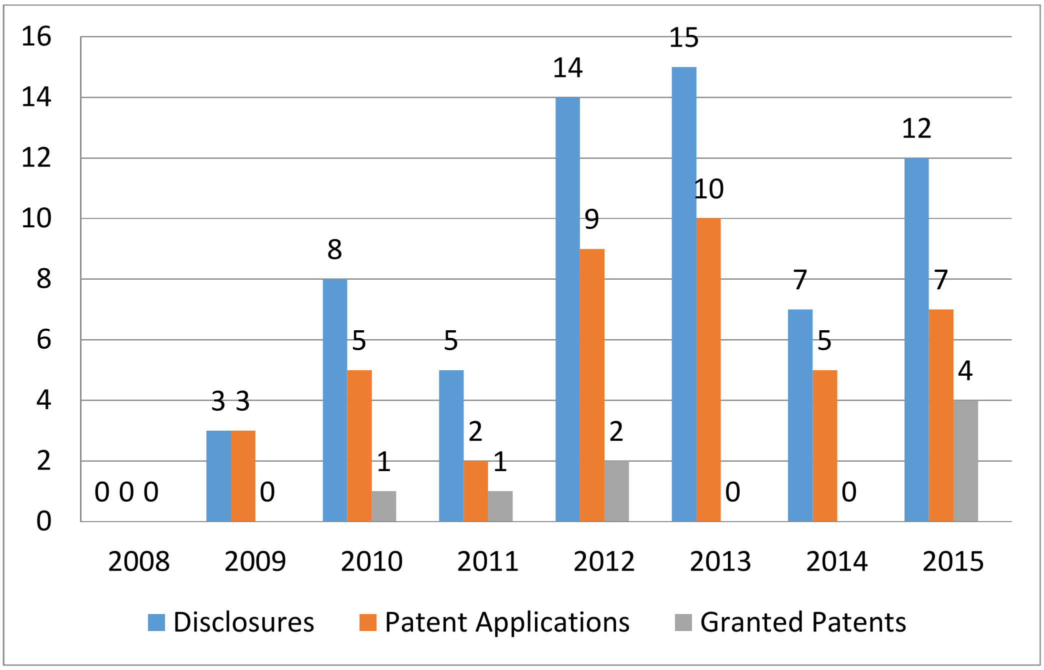


FIGURE 9.3: CPUT TECHNOLOGY TRANSFER OUTPUTS (EXCLUDING SPIN-OUTS)
Source: (RSA: DST *et al*. 2017) for years up to 2014 and CPUT (2018d) for 2015

From the data reflected in Figure 9.3 above we notice more specifically that invention disclosures originating from CPUT have been growing steadily, except for 2014 when it dropped from 15 the previous year to 7 before increasing to 12 again for 2015. Patent applications followed a similar trend. Patents granted are still very low and is a function of good quality disclosures and consequent patent application derived from it.

The next section denotes institutional policies employed by CPUT to stimulate and enabling environment for TT activities on the CPUT campus.

9.2. Institutional Policies

During 2010, CPUT approved a 10-year plan called the Research & Technology Innovation (RTI) blueprint to further increase research and innovation capacity at the institution. The vision of RTI also comprises the overall Vision 2020 for CPUT, which is "*to be at the heart of technology education and innovation in Africa*" (CPUT, 2012:10). In essence, the RTI wants to "*unlock the potential of staff, students and partners to excel in research, technology and innovation that offer solutions to the needs of society*" (CPUT, 2012:10). The RTI blueprint is the main policy document with which CPUT wants to stimulate research on its campus in the fields of technology and innovation. The policy indicated the many strengths and benefits of CPUT, namely:

(i) Strong relationships with the world of work and industry - CPUT concentrates on the employability of its graduate students, making the university more conscious of the day-to-day realities and practical problems facing employers in the country than most other higher education institutions in SA.

(ii) An applied approach to research, technology and innovation - The very nature of many of the faculties, research centres, and technology stations at CPUT is that a favour exists to commercialise research results that create tangible products and services as output.

(iii) Pockets of excellence that are nationally or internationally recognised - CPUT has various recognised areas of specialisation which can be further developed, such as oxidative stress and rooibos, unmanned Aerial Vehicles (UAVs), space initiatives, food technology, work-integrated learning methods, teaching methods, and community water supply and sanitation, to name a few (CPUT, 2012).

(iv) Existing partnerships and robust regional, national, and international collaborations - The university has built and maintained partnerships and collaborations with individual researchers, public research institutions, the SA government, other universities, and businesses in commerce and industry (CPUT, 2012).

(v) A large and diverse student base - CPUT has a vast student base in excess of 32 000 in the Western Cape and reflects a student profile comprising a microcosm of society in SA, including many South Africans from both advantaged and disadvantaged backgrounds (CPUT, 2012).

(vi) Values of social inclusion and engagement with the community - Historically, the university was founded on strong values of social inclusion and community engagement.

(vii) Demonstrated success in building research capacity and increasing research output - In the five years leading up to 2012, CPUT has proven that it can expand and improve significantly on research and innovation performance.

(viii) Central structures to champion research, technology and innovation - The core leadership team and structures are in place for managing the institution well in support of its vision for research.

(ix) A base of research, technology, and funding available - CPUT has internal and external financial resources that are sufficient to fulfil its mission and reach its stated objectives (CPUT, 2012).

Six important aspects guide the RTI blueprint. These aspects are excellence, strategic partnerships, releasing the potential of staff and students, service, and research uptake. The blueprint focuses on seven specific research areas in which CPUT has gained particular strengths, being biotechnology, space science, energy, climate change, human and social dynamics, economic growth, and design for sustainability. Important for CPUT is that the dissemination of knowledge must be for the public good and that the strong growth in research outputs in the 5 years preceding 2012 serves as a solid base that may lead to a pipeline of invention disclosures from which to foster TT activities (CPUT, 2012).

The overriding policies (CPUT, 2012) determine that the university should portray the principles and values that support RTI at CPUT, which are (1) to strengthen the DVC’s office tasked with RTI and partnerships to facilitate change and exert strong leadership and management within the

RTI environment, and (2) to establish methods and change policies to initiate a rearrangement of the systems and processes at CPUT that will ensure that its RTI aims are reached (CPUT, 2012).

The following criteria were set by CPUT in order the gauge its successes in service and research uptake:

- "Citations and impact factor
- Number of conversions into popular media articles
- Number of design registrations and patents
- Percentage of projects designed from the outset with service and research uptake in mind
- Percentage of RTI projects communicated to internal audiences and external audiences
- Research income per academic staff member, in terms of the following categories:
  - Income from industry
  - Income from public research institutions
  - Income from international donors and NGOs
- Number and growth rate of spin-out companies established and sustained over 5 years
- Number of start-up companies supported
- Number of technology transfer agreements
- Value of royalties generated
- Number of public and non-profit policies, strategies, plans. or initiatives influenced by evidence from CPUT research" (CPUT, 2012:36)

When considering the IP policy of CPUT, a worrying factor for management at the university is that not all of the academic staff interviewed were aware of the university's IP policy. An updated version of the IP Policy is found on the website of CPUT. The policy states that the advancement of research at CPUT has been cited as one of the tactical focus areas for the university. In particular, the protection, management, and commercialisation of IP originating from R&D are seen to be part of this focus area (Cape Peninsula University of Technology (CPUT), 2016). The policy refers to the IPR-PFRD Act that requires the formation of technology transfer offices at publicly funded universities as obligatory.

Specific objectives of the said policy include:

- the creation of an enabling environment within which good quality research, entrepreneurship, the building of partnerships with businesses in commerce and industry and TT can occur;
- the provision for the efficient production, documentation, safeguarding, use, administration and commercialisation of IP originating from the academic staff and students of CPUT;
- the building of an atmosphere that promotes the diffusion of inventions, novel findings, and new knowledge created by researchers;
- the ensurance that income derived from IP and accruing to CPUT is accurately and fairly allocated to inventors, the university, and all other role-players;
- confirmation that IP is distributed and accessible to the public through effective TT practices;
- advancement and stimulation of scientific inquiry and R&D;
- the guarantee that conflict of interest (if any) noticed during the commercialisation of IP is dealt with amicably; and finally
- adherence by the university to the IPR-PFRD Act of 2008 where research is to a degree or wholly publicly financed (CPUT, 2016).

The IP policy continues by stating that the commercialisation strategy for new created IP will be project specific and that "CPUT may elect to make, sell, copy, adapt, apply, publish, develop, use, assign, license, sub-license, franchise, establish a start-up company or otherwise utilise the intellectual property for the purpose of generating financial or other commercial gains" (CPUT, 2016:18).

This section highlights the RTI Blueprint and the IP policy of CPUT as two policy instruments that specifically deals with issues relating to the stimulation of R&D on its campus and the protection and resultant commercialisation of IP originating from such R&D efforts by researchers. The next section debates the institutional commitment as the for CPUT to be considered in this case study. Answers to open ended qualitative questions put to CPUT interviewees about the institution's commitment towards TT activities are included where applicable.

9.3. Institutional commitment by top management at CPUT towards TT

From the literature reviews in Chapters 4 and 5 and from the results of the interviews conducted at the other universities in the Western Cape as case studies, we learn that a strong institutional commitment and positive inclination to TT is important for it to flourish on university campuses. The RTI blueprint indicated a number of unique obstacles needed to be overcome by CPUT for it to reach its research, technology & innovation (RTI) goals (Cape Peninsula University of Technology (CPUT), 2012a). These barriers are:

- Perceptions and culture: The current perception is that CPUT is mainly involved in delivering students with diplomas that are ready for the workplace instead of concentrating on quality research and innovation performed by postgraduate students and academic staff.
- Staff and student profile: The current composition of students reflects too many inexperienced undergraduates, smaller numbers of postgraduate students, a diminutive number of staff with PhD qualifications, and only a few NRF-rated researchers.
- Facilities: Some of the university's technology and facilities are substandard when measured against businesses in commerce and industry.
- Specialist RTI support structures: There remains to be a shortage of specialist support for research and innovation before CPUT can become an exceptional RTI university.
- Institution-wide RTI structures: The history of CPUT reflects that its historical organisational structures are rigid and not fully supportive of RTI activities (CPUT, 2012).

To address these barriers requires a change in perceptions and for that to happen necessitates strong leadership by top management within the university. A number of questions were posed to staff members of CPUT as part of interviews conducted, aimed at getting responses from top management and researchers at the university.

In response to a question on how participants would describe the institutional commitment from the central university top management towards TT activities, interviewee P1, an academic staff member, responded:

> I think I would consider it to be weak and was it not for the TTO office it would have been very difficult to achieve anything. So at the moment from the top structure of the university I don't think the people understand what innovation means and they're too much orientated

> towards publications. There is little or no understanding or appreciation or what we do and Top management is stagnant about growing our TTO and lifting its profile amongst staff and students (P1).

Another academic (P2) further added that "management is only concerned in how much money we can make and how soon it can be received by the university".

Contrary to the perceptions and concerns raised by the academics, a participant from top management communicated the following:

> I think the institution is really committed to technology transfer. As a consequence, we have actually yearly set aside some funding to support good ideas coming from the institution and it's actually in line with our mission of being at the heart of technology innovation in Africa (P3).

The same interviewee cautioned against risk in saying, "There's a subcommittee of council that is actually advising council against potential risk. Because you know, the innovation space is highly risky."

Responding to a question on what motivated the academics/CPUT to commercialise their research results, the interviewees stated:

> I think we realised our research over many years needed to get to the population at large. I read all the latest literature on the subject and it clearly indicates that there's a worldwide need for a product like ours (P1). We did a lot of market research on the quality of available products on the SA market and we found that many of it was exceptionally poor. We then went ahead with this product not only looking at the nutrients and the nutritional contents but also at the quality aspects because that was lacking on the SA market and still is (P2).

Interviewee P3 from management replied by referring to examples from abroad.

> We visited Florida in the United States and visited Caltech University of Technology and from there we visited Uppsala University in Sweden. They were very strong in the commercialisation of research. This actually fed into our mission to say, we're the only University of Technology in the Western Cape and we see our role not to compete with SU, UCT or UWC but to ensure that our research is actually commercialised for the people of the Western Cape.

In response to a question regarding the managerial challenges to TT at the university, management representative P3 asserted that there are certainly challenges.

> We are trying to solve them. Over the past year and a half now, the council has actually taken this up consider a corporate structure to approve some of the start-up companies and mitigate against the potential risk.

The same senior manager admitted a lack of entrepreneurial attitude:

> The whole architecture of the university is not geared towards businesses yet, we're a bureaucracy. If you come with a proposal or a contract, it would go through a number of checkpoints and you'll find that at the end it's not approved because of either lack of knowledge or the risk (P3).

On a number of other questions, the accounts given were similar than the above. Frustration was clearly felt, as indicated by the academic interviewees using descriptions such as:

> Top management needs to buy into TT and believe in its potential. They have to staff the TTO properly so that it can maintain solid service levels. We have invited top management many times to visit our lab and see what we have been doing, but they are not making the time available" (Academic P2) and "Our problem is not with the TTO but with the lack of appreciation from top management for what we are doing (P1).

Academic P2 observed, "Our application for the spin-out company's establishment has been with the Council for almost 3 years and they have not approved it yet and we get no feedback." The accusation voiced by the academics interviewed was that top management is paying lip service and doing little to encourage them to engage in more commercialisation activities on campus.

This section highlighted the institutional commitment or lack thereof by senior management within CPUT towards TT activities. It does seem to be a major stumbling block for some of the academics interviewed, as the lack of commitment they experience is a deterrent for them and other academic staff and students wanting to engage in TT activities. The apparent lack of commitment and belief in TT by top management is also contrary to the Research & Technology Innovation (RTI) blueprint mentioned in the previous section and which is more fully described in section 10.5 below. The next section briefly describes intellectual property protection offered for inventions emanating from research laboratories at CPUT.

9.4. Intellectual property protection

CPUT seeks to increase the number of knowledge workers able to participate in a competitive economic environment through commercialising the results of the research of their staff and students. The number of patents filed and licenses signed by CPUT are increasing (CPUT, 2009) and is testimony to the university's drive to commercialise the fruits of the brains of its academics. During 2009, the Advanced Manufacturing Technology Laboratory within the faculty of Engineering confirmed its first patent for an Unmanned Aerial Vehicle (UAV). It is imperative for academics to become inventors and for such academics to progress from teaching and research to innovation and the commercial world. During 2010, 6 patents were filed, of which 3 were completed, 2 were provisional patents, and 1 was a Patent Cooperation Treaty (PCT) application (CPUT, 2010). A total of 13 technology transfer contracts were concluded. By the end of 2010 the TTO at CPUT experienced solid growth and was expected to increase its service offering to academic staff and students in the years to come (CPUT, 2010).

CPUT was successful in 11 bids during 2014 when Cape Town served as the World Design Capital (WDC). The university was keenly active in all aspects of WDC 2014, from getting Cape Town nominated, to judging the thousands of proposals submitted for consideration. WDC is a showcase of festivities that envisages features of design that may assist cities to function better in future. The WDC award is conferred in alternate years and Cape Town won the title for 2014. Some of the successful submissions from CPUT were:

- Driving Dreams – cost-saving adaptive vehicle technology for disabled people in Africa
- mTriage– a method of gauging medical statistics of patients whilst in crisis
- Design Garage – a platform where students, alumni and emerging designers at CPUT can manufacture their products and exhibit them to the public
- The Product Lifecycle Management Competency Centre – trains stakeholder designers in the art of product development and merchandise lifecycle management (Cape Peninsula University of Technology (CPUT), 2013b)

The Department of Science and Technology (DST) provided funding for an incubator and enterprise centre at CPUT's Bellville campus. On 1 September 2014, six groups of students with promising business ideas were taken into the incubator to help with prototype design, manufacturing, pricing tactics, and marketing. The TTO registered a number of patents for inventions originating from the incubator (Cape Peninsula University of Technology (CPUT), 2014).

Figure 9.4 below depicts the total CPUT patent costs from 2008 to 2015.

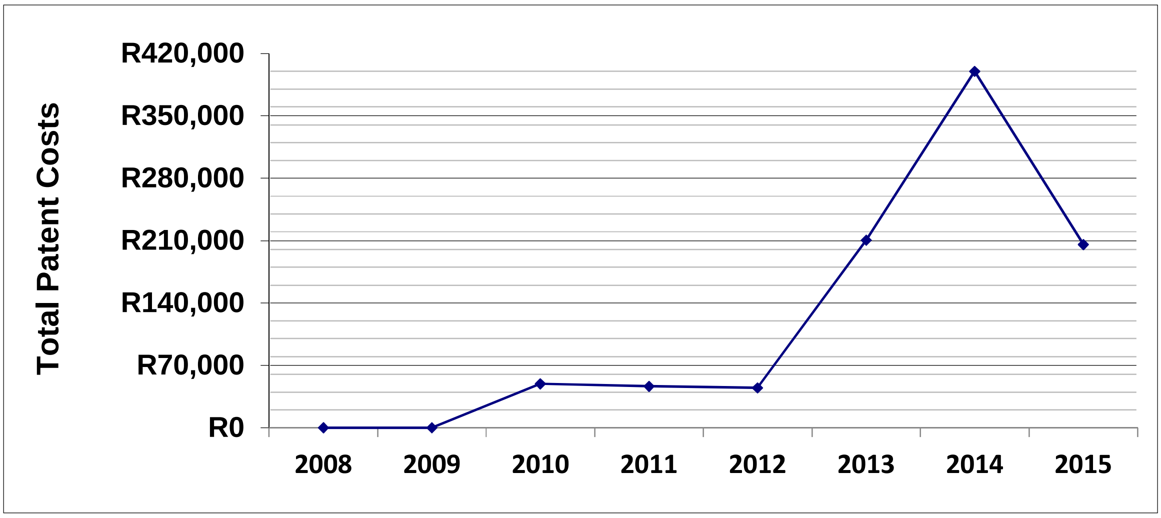


FIGURE 9.4: CPUT TOTAL PATENT COSTS

Figure 9.4 CPUT Total patent costs
Source: CeSTII (2016) for the years to 2014 and CPUT (2018b) for 2015

The enactment of the IPR-PFRD Act in 2010 may have had an effect on the patenting costs incurred by CPUT as it increased sharply from only R49 349 in 2010 to R 400 000 in 2014 before dropping again to R 205,817 in 2015 (Figure 9.4 above). In total, an amount of R 816 356 was spent over the last three years, compared to only R141 000 in the three years prior to that. These numbers come from a very low base and is still very low compared to some of the other universities in this study.

From the literature we learn that IP protection along with commercialisation activities are important goals of any successful university TTO. The TTO at CPUT was started after the enactment of the IPR-PFRD Act in 2010 (CPUT, 2009); hence, the university has only recently started building on a pipeline for newly created inventions. The patent costs incurred by the university is still small and will grow as new invention disclosures increase in number.

In response to whether interviewees were aware of the IPR-PFRD Act 51 of 2008 in SA that now compels universities to protect newly created IP and commercialise it and their opinion about it, there was consensus amongst participants that they knew about the legislation and that they were positive about it. A respondent from top management asserted:

> I think it's a good piece of act and it's forward looking and I think the DST did a very good job. We have lost so many of our technologies that could have been safeguarded. So, I'm happy about the act.

IP protection at CPUT is in its infancy, as can be seen by the data obtained as part of this study. Funding for R&D and commercialisation efforts are paramount in aiding an environment that is conducive to TT activities, and is the topic of the next section.

9.5. Funding for TTO commercialisation activities

CPUT took part in a DST-NRF funded internship programme for 12 months where science and technology graduates were allowed to hone their skills while working next to a number of SA's top researchers. The thinking behind the internship was to create an opportunity for graduates to have employment and gain valuable experience that can be used in academia or in further studies. More than 40% of the first interns were offered full-time jobs after completion of their internship programme (CPUT, 2014). Such younger up and coming academics are crucial for building a culture at CPUT that is loyal to seeking answers for research questions.

Adding to an institutional commitment of innovation that leads to entrepreneurship, is the CPUT Idea-Create Student Innovation Competition that is gaining in stature. During 2014, several bright ideas were turned into products, such as the beer tub recycled into a barbecue, a snack dryer, and a solar wonder. The winners and finalists of the competition applied for funding from TIA and succeeded in getting funding up to R3 175 495 to create prototype models, manufacture samples, and commercialise their finished product (CPUT, 2014). CPUT also sets aside funds from its University Research Fund (URF) to be used as grants in university research projects. The NRF though its Institutional Research Development Programme (IRDP), Thuthuka, and THRIP also supported a number of these university research projects (CPUT, 2007).

The TTO at CPUT received a grant of R3.46m from TIA to assist the university in aiding researchers to commercialise their research findings. TIA and CPUT have set up the TIA Seed Funding Board that can convene at short notice to consider funding applications based on short decision-making processes. The board has had many applications and funding has been awarded to numerous projects. Funding is limited to R50 000 and ought to be used for early stage design of prototypes. Academic staff and students of CPUT may apply for funding on an individual basis, or jointly as partners on research projects. If the prototype model is favoured by TIA, they are keen to fund the following stage in the development cycle. Prof Atkinson-Hope was very thankful of TIA and described it as an impressive programme that will promote new inventions at the university (Cape Peninsula University of Technology (CPUT), 2015a).

Besides the TIA Seed Fund, CPUT established its own Innovation Fund in 2009 with the objective to invest in later or final stages of research projects where knowledge gained from the research projects can be turned into brand new or advanced products, processes, or services. Original research ideas with the biggest likelihood for success and technological discoveries that deliver meaningful national benefits will almost certainly be funded by the seed fund. The CPUT Innovation Fund helps to convert research ideas into commercially viable products by financing items of equipment, manpower for research and development, managers, legal fees relating to intellectual property rights (IPR), and the building of initial models. Over the last three years, (2009-2011) a few innovation projects were successfully funded by the CPUT Innovation Fund (Cape Peninsula University of Technology (CPUT), 2012b).

Funding for new inventions emanating from universities is part of the funding environment affecting universities. When asked, some of the academic staff members expressed frustration with the seemingly lack of funding they receive from university management. The reply from one academic stated:

> I think that there are some people on Council that are very knowledgeable about research and innovation, but the VC itself does not realise what it cost and how much time and trouble goes into the commercialisation effort. They just want to see the money rolling in and they don't really understand that it's a business and it needs to be build and over a long period of time (P2).

In answering to a question on the source of funding for new research projects and whether the TTO assists in funding efforts, respondents replied as follows:

> We received some international funding from the Malaysian government as some of the components for our product is sourced from Malaysia. The TTO helped us to secure funding for research leading to innovation and commercialisation. (P1).

> We've applied to TIA, via CPUT and received some money there. We have to be careful though as we could be accused of being biased towards funders. The University Research Development unit should help with funding for research but they are useless (P2).

> We received funding from both local, national and international funders. We obtained funding from the DST in SA, bilateral countries in Europe, in Japan, China and almost all over and we assist our academic staff in their applications for funding (P3).

Interviewee P2 was critical in saying that their research team is not getting much help from the TTO and university management in the sourcing of research funding. Funding is increasingly difficult to obtain in circumstances where there is an economic downturn in the country. Global funders are key to the funding of research projects at African universities like CPUT.

Replying to a question on how the university TTO stimulates interaction with entrepreneurs, venture capitalists, angel investors, and governmental funding agencies, interviewees were mostly negative. Both participants P1 and P2 have had no contact with other entrepreneurs. An interviewee from management noted:

> We are starting innovation evenings now. We want people to come after work. We used to do it only in Innovation Week, but we are saying come after work for a very nice finger lunch, and then people come, have coffee, and we tell them what it is that CPUT is doing around innovation on campus (P3).

Respondent P2 returned, "Some venture capitalists were present at some of the courses that I attended and they were invited by the TTO staff but we prefer to source the companies ourselves." The same interviewee said that connecting them to TIA as governmental funding agency by the TTO was very fruitful.

Funding for TTO commercialisation activities will always be critically important for a university and the TTO alike, as it leads to new inventions of the TTO to be commercialised for the public good in addition to the initial inventors. Very useful and valuable IP may be developed on university campuses across SA, but without funding at various stages of development, the IP will stay on the shelves in laboratories and will not be commercialised for the benefit of the economy. Human resources and its impact on TT efforts at CPUT is stated hereafter.

9.6. The technology transfer office (TTO)

The TTO at CPUT was started as a result of the enactment of the IPR-PFRD Act, which acknowledges the vital part universities can play in spurring research and innovation activities that lead to local economic growth (CPUT, 2009). The TTO at CPUT, initially called the Technology Transfer and Industrial Linkages Office, was established during 2010 in accordance with the provisions and requirements the IPR-PFRD Act of 2008. Prof Gary Atkinson-Hope, who has several years of academic, research, and IP experience, was appointed as the first director of this office on 1 June 2010 (CPUT, 2010). The TTO falls under the supervision of the Deputy Vice-Chancellor: Research, Technology Innovation and Partnerships, Dr Chris Nhlapo. The TTO operates in union with the legal office and senior managers of the financial administration department. The objective of the TTO at CPUT is to assist, safeguard, and promote the transmission of IP from CPUT to the businesses in commerce and industry for the betterment of civil society, simultaneously earning valuable income streams for the university and the inventors (CPUT, 2010).

The TTO promotes research relationships with businesses in commerce and industry, where license agreements or spin-out companies are the probable results from IP developed at the university. Staff at the TTO also encourage academics to think afresh and to progress past publication towards commercialisation of their discoveries by using technology innovation (CPUT, 2010). The technology transfer office at CPUT aims to foster links with DST, TIA, the SPII programme of DTI, the Research Institute for Innovation and Sustainability (RIIS), and venture capitalists to promote research projects within CPUT. During 2011, 52 technology transfer contracts were examined and concluded (CPUT, 2011).

In September 2012, Prof Atkinson-Hope was chosen by the then Minister of Science and Technology, Ms Naledi Pandor, to serve on the advisory board of NIPMO. The advisory board was formed to comply with provisions of the IPR-PFRD Act 51 of 2008 and advises NIMPO on its role and responsibilities in terms of the said Act (CPUT, 2012a).

An important objective of the TTO is to enlighten academic staff and students within CPUT about the management of IP and the financial benefits that commercialisation of their research results can bring. Similarly, the detection of valuable IP and its safeguarding before publication is a crucial duty of TTO staff. TTO staff members also conduct one-on-one interviews and present workshops for research units, faculties, academic staff, and students on issues relating to TT. Academic staff and students of CPUT are actively persuaded to engage the TTO and to seek help on technology transfer issues affecting their research projects (Cape Peninsula University of Technology (CPUT), 2018c).

During the in-person interviews, participants were asked how the TTO's services are advertised on campus. The responses received were:

> I am on the TIA committee for CPUT and TIA launched student competitions and the TTO has been very active over the past years since 2012 to promote TT on campus (P2)
>
> I'm satisfied that it is advertised well and I believe that our Technology Transfer Office is providing an excellent service (P3).

When probed for any managerial challenges relating to the TTO, participants said:

> The TTO manager is leaving and we are concerned about succession planning (P1).
>
> We have heard that someone from UCT's TTO will be joining us and that is good. The TTO is understaffed and I am worried they will cut staff due to budget constraints (P2).

Respondents replied as follows when queried about the relationship between them and TTO staff of the university:

> Very good - Our problem is not with the TTO (P1)
>
> No complaints about the TTO (P2)
>
> There's actually a very good trusting relationship and if there are issues, they are ironed out. If it is issues related to compensation for bright ideas, we normally stick to the IPR Act as the spirit of the Act is about changing the lives of South Africans and also safeguarding good ideas to remain in the country. Our first prize is really the Western Cape and it is about contributing to the economic development of the province (P3).

The legal and TTO support services were described as mainly positive by interviewees, and all confirmed that they would definitely recommend the TTO's services to fellow academics and students.

> They helped with the patent and was very supportive. The University also paid for the patent costs. They safeguarded the IP which was their main task and they always have a willing ear to listen (P1).

> Very good. Gary-Atkinson Hope was a lawyer himself and that helped too. They're working well as a team. We have not had bad service from them and they have sound knowledge about the IP environment (P2).
>
> Good, the TTO is working mostly on contract research. So, normally the whole legal cluster work together in terms of who takes what. I'm happy that I have a very strong team who look at IP issues from all angles. I believe our TTO is in line with what the developed countries are actually doing (P3).

Commercialisation Activities

Several successful inventions have been developed at CPUT, such as SA's first nanosatellite, ZACUBE-1 ("TshepisoSAT"), which was built and launched into space on 21 November 2013 (CPUT, 2013). The satellite orbits the earth and tracks the propagation of radio waves through the ionosphere (CPUT, 2013). Following the success of its space programme, the university's new research capacity development programme was launched during 2013. The programme seeks to transfer and improve the skills of researchers, including research writing, publishing in accredited journals, and writing funding proposals (CPUT, 2013).

The TTO at CPUT follows a well-known innovation success model. Called *Innovation Chain,* the model emphasises the stages usually followed in the commercialisation of innovative products. In each stage there are obstacles to overcome for university academics as inventors. Some researchers choose to focus on publications, whilst others endeavour to work in the innovation space. Referring to the founders of Omega Caro-E as "New academics", Atkinson-Hope (2013: 4) claims that these researchers are "true innovators" who have through perseverance overcome challenges to cross "the innovation chasm and entered the manufacturing stage reaching a commercial product called Omega Caro-E". The product is a unique patented food additive and is backed by the Cancer association of SA (CANSA). The endorsement by CANSA was the first for any scientifically developed food supplement in SA. Atkinson-Hope (2013) asserts that the success of this product can be ascribed to the fact that the developers knew the market need and could demonstrate the advantages of the new product to potential customers.

CPUT's first spin-out company, UAV Sys Co (Pty) Ltd, was formed and unmanned aerial vehicles (UAVs) were built and displayed. The Nicky Drive vehicle was developed by Professors Mugendi M'Rithaa and Oscar Philander, who worked with CPUT's Disability Unit and Nicky's Drive, a non-profit organisation (NPO) that creates adaptations for people with disabilities. CPUT students worked with Nicky Abdinor who established the NPO to create the complicated technology she uses to drive her vehicle. Her physical limitations permit her to drive a car by using a joystick hydraulic steering system with her right shoulder. More spin-outs followed, including the Omega Caro-E capsules, distinctive supplements that are backed by the Cancer Association of South Africa (CANSA). FlowViz, a collaborative project between CPUT and the Swedish Institute for Food and Biotechnology, is an in-line fluid characterisation system for non-Newtonian industrial fluids. Another spin-out of CPUT is a content managing system called MyConference (Cape Active Web) that supports the websites of clients (Cape Peninsula University of Technology (CPUT), 2012c).

Students and academic staff members of universities are key to commercialisation activities on university campuses. The number of students and staff at a university will no doubt have an impact on the number of invention disclosures its TTO receives. From 2008 to 2009, CPUT reported no income generated from the commercialisation of its IP. The figure for 2013 was R905 818, which increased sharply by 70.1% to R1 541 388 for 2014 (RSA: DST *et al*. 2017). It is likely that the trend will increase in future, as we learn from the literature that a long lead time is necessary for a pipeline of new inventions to turn into income streams.

CPUT lists several novel findings that are being commercialised with help from the university's TTO in a printed publication called *Innovation Showcase 2015*. Current proven technologies are recorded in an online version and vary from early stage technologies to protected IP, ready for licensing to businesses in commerce and industry.

The responses to a question on whether participants believed that TT could be a major source of income for them, their department, and the university were:

> Yes I believe so. Certainly, but It takes a long time. It takes time to build a pipeline of new inventions (P1)
>
> Yes, although in our case we have not benefitted as inventors yet. I think society should benefit most but at least some benefit should go to the inventor too (P2).
>
> Yes, I do. What I normally say that source constraints shouldn't be viewed as a liability but as an opportunity. It's an opportunity to look at our processes in terms of efficiencies (P3).

The interviewees that were academic researchers were asked to define success in university technology transfer activities and to indicate what they liked or disliked most about it. They responded as follows:

> I would say it is gratifying as in our case where we have developed a product that people believe to get some very positive feedback. We do have about 1 500 to 2 000 clients buying the product regularly. I like being in control of our own successful business. I dislike being hampered and being put under pressure from other people who doesn't know what's going on (P1).
>
> Being profitable and being able to produce something that the market requires. I dislike the procurement processes of the University. I takes very long to get purchase orders approved which affects our ability to manufacture the product negatively. I dislike the lack of support that we get from top management. (P2).

Licenses

In addition to a number of patents, CPUT also recorded its first movie, called *Intonga.* The copyright protection for this film was secured in August 2011 (Cape Peninsula University of Technology (CPUT), 2011). By the end of 2012, the TTO was three years old and had successfully filed ten patents, two trademarks, and a registered design. The TTO currently also manages industrial linkages and oversees research contracts (CPUT, 2012a).

The most successful license agreement for CPUT earning royalty income is the Omega Caro-E supplement. The additive, developed by the university's Functional Food Research Unit, is a cost-effective option for the public to reduce the risk of contracting chronic diseases such as cardiovascular illness, arthritis, cancer, and strokes (CPUT, 2015c). Created by Prof Spinney Benade and Dr Maretha Opperman, Omega Caro-E offers an exceptional combination of natural molecules, compared to all other Omega-3 fatty acid additives that are commercially available. Omega Caro-E is presented in a capsule (see Figure 9.5) and consists of a combination of fish oil and a palm oil reduction which contains as much as 11 different carotenes and 5 different kinds of vitamin E.

FIGURE 9.5: OMEGA CARO-E SUPPLEMENT

Development of Omega Caro-E was supported by funding of R3.2m from the CPUT Research and Innovation Fund that was allocated to the Functional Foods Research Unit. The fund supports promising research findings that can eventually be fully commercialised. According to DRUSSA (2013), clinical trials were held over three years to develop and test the effect of the additives on degenerative diseases. A partnership with the palm oil industry followed, which ensured the realisation of this product that is unique in the world. The Cancer Association of South Africa (Cansa), who completed its own comprehensive research on 63 fish oil supplements available on the market, supports the product. Cansa's research found that the combination of Omega-3 fatty acids, docosahexaenoic acid, eicosapentaenoic acid, carotenes from plants, tocopherol, and tocotrienols in just two capsules of Omega Caro-E decreases inflammation and may help in diminishing the risk for cancer. Omega Caro-E capsules also contain a unique kind of vitamin E with super anti-oxidant qualities. The product was approved for sale in Canada in 2014 (DRUSSA, 2013; CPUT, 2014).

Income generated from the sale of Omega Caro-E is utilised to fund future research projects that comprise essential fatty acid-, micronutrient-, cancer-, HIV- and cardiovascular related illness research. The results of this research effort satisfy the aims of the Millennium Development Goals which is also an important part of CPUT's Research and Innovation Strategy (DRUSSA, 2013). The eight Millennium Development Goals were derived from the Millennium Summit of the United Nations held in 2000, when all members undertook to assist in reaching the following objectives by 2015:

- eradicating extreme poverty and hunger

- attaining universal primary education
- advancing gender equality and empowering women
- decreasing child mortality
- enhancing maternal health
- fighting HIV/AIDS, malaria, and other diseases
- making sure of environmental sustainability
- creating a global partnership for development (United Nations (UN), 2016)

As reported earlier, CPUT was well represented at the World Design Capital 2014 competition held in Cape Town. Of particular interest was the Industrial, Surface, and Fashion design exhibitions. The CPUT BTech Industrial DesignR5k projects drew attention and showcased talented student designs which aimed at achieving R5 000 or more worth of sales. Some products designed by students recorded sales in excess of R140 000, even for long after the student had graduated. Products developed by students during 2014 reflected South African motives, such as an ingenious food dehydrator (HeyPresto), a braai tool and a portable barbecue made out of recycled beer tubs (Kegs on Legs) (CPUT, 2014b).

Ismail Fareed, a mechanical engineering lecturer, joined CPUT's elite list of innovators when his patent in Small Scale Modular Solar Powered Aquaponics System was registered (CPUT, 2014c). The novel finding by Farred provides for communities to do small scale farming in remote areas where there is little or no infrastructure and a lack of expertise. The invention advances entrepreneurship, creates awareness of green energy, and supplies sustainable livelihoods throughout. The system comprises an aquaculture unit to breed and grow fish, plus a hydroponics water filtration unit that facilitates the growth of vegetables and fruits. CPUT (2014c) maintains that this invention will reduce the burden on the erosion of natural resources in oceans, dams, and rivers and will reduce the carbon footprint by providing a sustainable energy efficient means to provide food.

RSA: DST *et al*. (2017) reveals that, although CPUT had earned R905 818 from IP, no licenses had been issued by the end of 2013. One spin-out company, UAV-SYSCO (Pty) Ltd, was created in 2011. Universities often join IP which it is considered less useful when separate. Once joined, the combined IP represents a new basis from where value may be extracted in commercialisation efforts. One such strategy may involve the setting up a new spin-out company. Frequently, unique and valuable pieces of IP held by the university TTO are licensed to the new spin-out company.

Spin-out companies

Shares kept in the issued share capital of a spin-out company correspond to a proportionate share in the total rand value of that company. Through having shares in a spin-out company, the academic staff member, as inventor and creator of IP, is tempted to get further involved in the development and commercialisation effort of the particular piece of IP or technology. Bray and Lee (Bray & Lee, 2000) note that shareholding in a university spin-out company may significantly improve relationships between the TTO as licensor and the spin-out company as licensee, even if the university holds a very small stake. Hopkins (2004), on the other hand, found that spin-out companies, particular in booming sectors, may fail and leave universities with shares that have no value attached to it.

At CPUT, the unmanned aerial vehicle (UAV) project resulted in the first spin-out company from the university. It is called UAV-SYSCO (Pty) Ltd and develops UAV products (Figure 9.6) (CPUT), 2011). The company designs and produces mini and micro unmanned aerial vehicle systems that are used for surveillance in various businesses in commerce and industry. The company was founded by Prof Oscar Philander, who began experimenting with unmanned aerial vehicles several years ago. UAV-SYSCO is completely operational and manufactures two types of unmanned aerial vehicle systems that can be used for aerial surveillance for various purposes, like observing forest fires, anti-poaching supervision, and border scrutiny (CPUT, 2014).

FIGURE 9.6: UNMANNED AERIAL VEHICLE (UAV)
Source: CPUT (2014:7)

Every one of the unmanned aerial vehicles manufactured by UAV-SYSCO is equipped with cameras suited for ground surveillance and can function optimally at a height of 1000m (1km) (CPUT, 2014). UAVs weigh between 2.5kg and 13kg and can attain speeds from 60km/h to 130km/h (CPUT, 2014).

The technologies developed at CPUT testifies of a research methodology that is aimed at finding practical solutions to societal needs. The university has succeeded in producing a few very important and useful inventions and is well-placed to increase its rate of disclosures of new inventions in the future.

9.7. Human Resources

CPUT possesses a number of top rated and knowledgeable scientists, technologists, and technical aides. Where expertise is lacking, the university uses individuals from academic circles at other public research institutions and networks of people in commerce and industry to help in the research effort.

Incentives for academic staff to engage in TT activities

The Khula Programme at CPUT was renewed in 2009 after its establishment in 2007 to lure and equip promising students to become academics in an attempt to diversify CPUT's academic staff profile through equity and transformation (CPUT, 2014c). Initial funding was provided by the DOE in SA, supplemented by R2m provided by CPUT itself (Cape Peninsula University of Technology (CPUT), 2015d,e). Khula means "to grow or develop" in Nguni languages. The programme is CPUT's endeavour to solve the skills shortage that universities face due to retiring academics. Two candidates were placed on a three-year work/study contract in each of CPUT's six faculties. On fulfilment of their master's or MTech degrees, candidates are eligible for placement in their respective departments (CPUT, 2015e).

To attract and retain competent staff that perform groundbreaking research is important for CPUT to become a world-class research orientated tertiary institution. Interviewees were asked how their TT activities have affected their academic promotion or career trajectory at the university (if any). The responses were as follows:

> Not for me as I was appointed to come as Extraordinary Professor out of retirement to set up a research unit at CPUT (P1).
>
> I was taken out the academic environment because I wanted to go into research. There's an enhancement of my reputation on campus but with no financial benefit (P2).

Respondent P3 from management at CPUT replied in the affirmative and said:

> We will have a look at the patents and whether it is locally funded with patent families and if it is a PCT or EU patent. For Trademarks or Copyright and we actually give points accordingly and the widespread scoring and can resulted in promotion if the researcher have achieved a certain minimum scoring. I am on the DHET committee that considers measurement criteria for the promotion of academics. We are now including issues such as patents and IP into the evaluation criteria.

Academic researchers interviewed further indicated that there were no other incentives to motivate them to engage in TT activities, apart from personal satisfaction and "*achieving your own goal of being successful with a product that you have developed" (P1).*

Yet, the interviewee from top management stated:

> Apart from funding provided by TIA we also have our own competition for staff and students to stimulate new ideas and innovation. We have an innovation board that sit and adjudicate over these wonderful ideas and see how we can actually take it to market. The staff then get recognition and exposure for their ideas. We use SATN (The South African Technology Network). It's a body governing the six universities of technology, who have a platform where they exhibit work of inventors and there is a national competition (P3).

Participants to the survey were asked which rewards they would like to see implemented to increase their willingness to disclose new findings and seek commercialisation thereof. The reactions were:

> I think financial rewards will be very good. From the proceeds of commercialisation we could employ two people and buy equipment but personally I have not received any money (P1).
>
> We have actively developing this product. There have been cumulative sales to the value of R4m to R5m but we have not seen any of it in spite of the IPR-PFRD act stating that inventors should also share in the financial rewards (P2).

A respondent from top management said:

> We have other rewards in the pipeline but we have to be fair to all faculties at the University. Usually when you talk about innovation it exclude education and exclude business sciences. So we're working with entrepreneurship lecturers that are actually assisting us to

> ensure that fairness is achieved across all the academics. We also want to look at social innovation and bring that to the table (P3).

Interviewees were queried on what the successes that they have achieved in TT mean to them. Two replied from the perspective of academics, while one returned from the point of view of top management.

> Personal satisfaction. I think, that's all I can say. You feel happy. We have had people with Eczema and some with Psoriasis and they were healed completely. We have built an impressive lab from where we can launch more products (P1).
>
> We've sold about 40 000 units of the product and we have not had one single comeback which is very satisfying. Personal satisfaction from seeing what influence it has on pre-school children's lives and how much it will actually benefit them in terms of brain development and school performance (P2).
>
> Success in TT activities at a university should be demonstrated by income earned either from royalties, etc. or in terms of properly exploiting the IP of the institution. So, success is really getting along with people within the small community of innovators at CPUT and learning from the sister directors of TTOs at SU, UCT and UWC. We share success stories to grow more successes and share failures and learn to avoid the pitfalls. If we can make the regional system of innovation functional by showing that issues related to service delivery can be addressed for example solid waste management then that is what I call success (P3).

It is clear that staff performing research activities want to be acknowledged and rewarded accordingly. Often the rewards required equate to financial returns, but for some the rewards they are seeking most are the personal recognition of peers in their industry, combined with personal satisfaction for the contribution they are making to the body of knowledge and society.

Networks leading to collaboration

CPUT, in conjunction with DST, the Department of Economic Development and Tourism, business in commerce and industry, and a number of universities in the Western Cape commenced the Western Cape Regional Innovation Forum on 18 December 2009. The slogan of the forum was "Innovation through Cooperation" and its aim was to kick-start the Regional Innovation System (RIS) by promoting broad interactions between Western Cape businesses in commerce and industry, research institutions, and local government, also known as Triple Helix participants. The forum offers a chance for networking and exchanging research ideas in aiding regional and national innovation. Such networking events are vital for universities to establish strong relationships with businesses in commerce and industry (Cape Peninsula University of Technology (CPUT), 2010).

Participants to the personal interviews were asked how the university TTO stimulates their interaction with other academics and students, governmental scientists and laboratories, and businesses in commerce and industry, to which they replied:

> No it is our own personal connections that we harness to stimulate interaction (P1).
>
> We have our own database of contacts build up over many years. It is mostly our own initiative not a TTO initiative. The TTO does sometimes have events where you can come and learn to fill in application forms for fundraising. Then there are opportunities like the Lab to Market course, which I attended (P2).
>
> We have a Café on campus next to the TTO where we promote interaction between academics and students as entrepreneurs. We have an incubator that we call the Design Garage. The Incubator showcases designs from students that you can actually buy and it's a platform where people are engaging over a cup of coffee and discuss innovation issues. We also have what is called innovation week, where we actually exhibit inventions for an entire week where people from all over can see the ideas, and the ideas are pitched to them (P3).

Networks are very important for academics and students as would-be entrepreneurs of their new inventions. There seems to be disparity between the perceptions of academic staff at CPUT and top management with regard to the role of the TTO and the university in promoting networks leading to collaboration for researchers. The TTO, as facilitator of TT on campus, should take the lead in promoting such networks and to eliminate differences in perceptions of researchers and top management at the university.

9.8. Conclusion

This chapter starts with the history of CPUT which was established as a result of the consolidation of the Cape Technikon and the Peninsula Technikon at the start of 2005. Universities of technology (UoTs) increased their contribution to the overall research production at SA universities from 1.1% at the beginning of 1991 to 4.7% by 2012 (Mouton, 2014) whilst CPUT increased its own growth in research production by 15.9% during the five years from 2008 to 2012, due mainly to the revised research subsidy scheme which came into effect during 2005 (Mouton, 2014). CPUT was found not to have any DST/NRF accredited Centres of Excellences, but it does have a number of very good research centres and units as well as SARChI research chairs that were awarded to CPUT by DST.

The increase in research activities at CPUT bodes well for technology transfer opportunities for its newly created TTO that was started in 2009. The ten-year Research & Technology Innovation (RTI) blueprint that was approved as policy document by the university in 2010 has set the institution on course to becoming a world-class research orientated university. An analysis of the statistics (Figure 9.2) depicting the total expenditure on R&D activities at CPUT for the period from 2008 to 2015 found that CPUT spent significantly more (262.4%) on research and development expenditure in 2015 than in 2008, whilst its component of instructional staff only grew modestly (16%) over the same period. Over the eight-year period the combined net overall increase (Figure 9.1) for all research publications in peer-reviewed publications for CPUT was much higher (167,7%), whilst the number of instructional staff rose the slight 16% testifying to the fact that academic staff at CPUT increased their research outputs exponentially over the eight-year period. Despite these statistics pointing to much higher R&D workloads for academics, the number of students graduating at the end of each year at CPUT was higher than at any other university in the Western Cape at over 8 000 students graduating at the end of 2015

Notwithstanding the statistics indicating a higher spending on R&D activities at CPUT, a longer pipeline of promising new inventions that may lead to protectable IP has not yet materialised. The average number of new invention disclosures were only 9 per annum since 2009 when the TTO started its operations to the end of 2015 and only about 6 patent applications per annum were completed of which only 1.14 patents on average were granted each year.

When considering the IP protection efforts and policy of CPUT, a worrying factor emanating from the interviews for management at the university is that not all of the academic staff interviewed were aware of the university's IP policy. This shortcoming should be addressed immediately by university administrators and the TTO management so that all staff and students should be aware of the content describing the rules and regulations of the IP policy of the university.

A reflection on the institutional commitment that was a topic under evaluation during the in-person interviews revealed that participants described it to be weak and lacking. One interviewee went so far in stating that very little TT if anything would have occurred had it not been for the efforts of the TTO. The same respondent claims that there has been too much focus on publications and less on the potential of TT in relation to the research being conducted on the CPUT campus.

The absence of a strong entrepreneurial culture on campus emerged from the interviews and it was confirmed by an admission from a top management official that a bureaucracy exists with a notion of being risk averse. This fact is problematic and could be detrimental to a fledgling TTO trying to find its feet in meeting the demands from a growing body of academic staff and students representing an emerging technology transfer industry in SA. The disclosed lack of institutional commitment experienced by academic staff, students and TTO personnel is a major obstacle for people wanting to engage in TT activities. The professed lack of commitment and belief in TT by top management is also contrary to the Research & Technology Innovation (RTI) blueprint policy stance that was adopted by CPUT in 2010.

Researchers interviewed were mostly critical of the efforts of top management in supporting the TT drive at CPUT. The top management official interviewed was seemingly unaware of the disparity between his views and the claims of the academic researchers that was interviewed as part of the case study conducted by the researcher for this study. Top management needs address this issue as soon as possible if TT activities are to blossom on the CPUT campus.

IP protection at CPUT was found to be in its infancy, as can be seen by the quantitative data collected as part of this study which indicates that patent registration costs reached a high of about R400,000 in 2014 before dipping to R205,817 in 2015. CPUT traditionally was seen to be less research intensive along with UWC when reference was made to research outputs in the past. As CPUT is moving increasingly to becoming a research intensive university, it is likely that more invention disclosures emanating from research activities will be forthcoming and which in turn will lead to increased expenditure on patent registration costs.

CPUT received a grant funding for TTO commercialisation activities of R3.46m from TIA to support the university in assisting researchers to commercialise their research findings. Together, TIA and CPUT set up the TIA Seed Funding Board that evaluates funding applications based on short decision-making processes. The board has had to consider many applications of which funding has been awarded to many. The upper limited for initial funding was set at R50 000 to be used for early stage design of prototypes. CPUT also established its own Innovation Fund in 2009 with the aim of investing in later stages of research projects that are close to the launching of new products.

The discussion about CPUT then turned to human resources as enabler identified in the conceptual analysis for the study. Academic staff interviewed testified that there were no other incentives to motivate them to become involved in TT activities. As with a number of other universities surveyed in the Western Cape province, personal satisfaction was mentioned and rated high as a reason why academic entrepreneurs starts on the journey of commercialisation of their research results. In the one case, patients with Eczema and some with Psoriasis were totally healed from a product developed at CPUT.

The personal connections and databases of contacts built up over time was provided as evidence for creating and maintaining networks leading to collaboration for academic entrepreneurs. Respondents replied in the affirmative that there was a solid and trusting relationship between them and TTO staff of the university. Similarly, the legal and TTO support services were described as mainly positive by interviewees, and all confirmed that they would definitely recommend the TTO's services to fellow academics and students.

The most successful license agreement for CPUT that is making significant royalty income was found to be the Omega Caro-E additive as health supplement. The inventors, when interviewed said that it reduces the risk of contracting chronic illnesses such as cardiovascular disease, arthritis, cancer, and strokes. Being very proud of their achievements, the academic staff members as entrepreneurs stated that they have sold 40 000 units of the product without any comebacks whilst positively influencing the brain development of pre-school children.

CPUT as one of the previously disadvantaged universities in the Western Cape has progressed meaningfully in the last few years on a new path of research intensiveness. Against this background it is expected that the TTO activities at this university will grow in similar prominence as new invention disclosures increases to match the recorded increase in research and development expenditures. The next chapter concludes the study.

Chapter 10: Conclusion

10.1. Introduction

Many authors confirm that university TT activities have blossomed since the enactment of the Bayh-Dole Act of 1980 in the USA (Bozeman, 2000; Colyvas, Crow, Geljins, Mazzoleni, Nelson, Rosenberg & Sampat, 2002; Mowery, Nelson, Sampat & Ziedonis, 2001). This study set out to gain a better understanding of the effective commercialisation of IP at SA universities.

One objective of this study was the development of a conceptual framework that was used in the case studies of four universities in the Western Cape. The conceptual framework consists of five key dimensions, namely: the policy environment, institutional commitment, the legal milieu, the funding arena, and human resources. TTO commercialisation efforts at four SA universities were analysed by using multiple, embedded case studies and a mixture of qualitative and quantitative research approaches. The four universities reflect different environments with regard to research intensity, which produced interesting insights when the results from the research instruments were evaluated.

The study sought to determine how effective the four SA universities in the Western Cape have been in commercialising their IP assets through TT practices. Empirical evidence (Sibanda, 2009; Wolson, 2007) indicated the low number of patents and the small number of spin-out companies emanating from SA universities annually to support the problem statement. This study evaluates that assertion and addresses the main research question of how effective have SU, UCT, UWC and CPUT been in commercialising their IP assets from 2008 to 2015. The determination is guided by the use of enabling factors as dimensions for university TT.

10.2. Summary of findings

10.2.1 R&D expenditure, research intensity and patent activity

Heher (2005) asserts that the most important factor influencing the performance of a university TTO is its R&D expenditure as it has a direct impact on the success from TTO commercialisation activities as reflected through patenting rates, licensing agreements, and spin-out company formation. Reichelt (2007) also refers to R&D at country level and notes that a successful innovation system is directly linked to the level of funding for research activities by a country. Korean universities improved their research capabilities significantly due to the Korean economy being one of the world's fastest growing economies that spent 4.29% of its GDP on R&D during 2014 (Zastrow, 2016). For the year 2013, SA has spent only 0.726% of its GDP on R&D compared to 2.364% for OECD member countries (OECD, 2017). This inevitably has a major limiting effect on R&D spending at SA universities and the consequent volume of research being conducted.

We found that research intensity at SU and UCT was significantly more than at UWC and CPUT over the 8 year period covered as part of the case studies. Annual R&D expenses for the year 2015 reached R 1 000m at SU and R1 300m at UCT compared to only R250m for UWC and R160m for CPUT. Understandably, both UWC and CPUT being less research-intensive universities than SU and UCT are lagging behind as they first needs to grow their R&D capacity before reaping the benefits of increased invention disclosures leading to more patents being awarded. The resultant impact on the TTO commercialisation performance for the more research intensive universities are clearly evident from the statistics documented in the case studies. The patent activity at SU and UCT was much more than at the less research intensive universities covered in the case studies with the resultant impact on the TTO commercialisation performance of each university.

Heher (2006) asserts that the low levels of funding for R&D by SA causes less TT success stories forthcoming from SA universities. This fact should not detract from the fact that university TT should accentuate other benefits, such as job creation, as envisaged by NIPMO and TIA. Universities of Technology (UoTs) have increased their contribution to the overall research production at SA universities considerably from 1.1% at the start of 1991 to 4.7% by 2012 (Mouton, 2014). CPUT increased its own research production efforts by 15.9% from 2008 to 2012 (Mouton, 2014).

Griliches (1990) claims that *patent activity* is the main determinant to measure technical change and innovative performance. Patent activity was examined and SU was confirmed as having the most PCT patents issued to it from 2009 to 2015 (SU, 2016) compared to all other SA universities and businesses in commerce and industry. This achievement testifies the entrepreneurial activity prevalent on the SU campus. A strongly funded R&D system and supportive institutional culture towards technology transfer are needed to sustain a sufficient rate of new invention disclosures at tertiary institutions.

10.2.2 Policies and Institutional commitment

Bourne (2000) asserts that governments in developing countries should spur R&D in their countries through specific subsidies and incentive schemes as an integral part of innovation policies to stimulate economic growth. Bansi (2016) attest to the fact that inventive behaviour by academic researchers depend to a large degree on the country's national pioneering capacity, its ability to engage, and national government's policies which include R&D policies. Bansi (2016) also advocated for a strong top-down vision, strategy and institutional leadership to drive academic entrepreneurship by creating a culture of commitment by university top management towards TT initiatives.

Institutional policies of SA universities stem from the SA national policy environment and set the scene for universities within which IP protection and IP commercialisation activities are governed. Having a clear legal framework adds considerably to the success of university TT activities. Since the enactment of the new IPR-PFRD Act, universities in SA are compelled to have IP policies and protect inventions emanating from their campuses. Both UWC and CPUT adopted IP policies and started their TTO's in 2009 some 10 years after SU and UCT first opened the doors of their respective TTOs. The advantage of the 10 year head start by these two universities are clearly evident in the cumulative invention disclosures and TTO commercialisation activities recorded by SU and UCT compared to both UWC and UCT over the eight year period that was covered in the case studies.

At CPUT, not all of the academic staff that were interviewed were aware of the university's IP policy. The TTO should take note of this comment and engage with CPUT staff and students regularly to ensure that they all know of the policy and its contents. At UCT, there was a view amongst respondents that the IP policy of the university and the IPR-PFRD Act may be too strict and that many pieces of IP are protected at a high cost before evaluation of its commercial was established. This claim could not substantiated, as the total expenditure on patent registration costs for UCT has not increased dramatically since 2008 when taking inflation into account.

Davis (2005) contends that the attitude of university vice-chancellors towards entrepreneurship is the key to successful TT at academic institutions. What matters the author asserts are whether or not they truly believe in entrepreneurship and are willing to commit time, effort and the resources of the institution to it. Much of the success of any university TT programme can be attributed to the institutional commitment demonstrated by senior management. Many previous studies confirm the effect that university top management has on TT efforts. Studies by Tornatzky *et al.* (2002) and Henton *et al.* (2002) contend that the University of California at San Diego (UCSD) has had dynamic and imaginative leaders during its history, who contributed to growth and achievement. Both sets of authors found that the institutional commitment at San Diego is well established and mutually reinforcing, which attracted academic staff to join the university that are positively orientated towards entrepreneurship. Henton et al. (2002) argue that it is the commitment displayed by top management of universities that makes the difference between achieving success and others that have not been as successful.

The institutional commitment was found to be high and conducive to fostering an enabling environment for TT at three of the four universities. The institutional commitment at CPUT was described as weak and lacking by the academic members staff interviewed. One interviewee went so far in stating that very little TT if anything would have occurred had it not been for the efforts by the TTO. The same respondent claims that there has been too much emphasis on publications and less on the potential of TT in relation to the research being conducted on the CPUT campus. Specific complaints were levelled against a top management official of CPUT that was hindering innovation and entrepreneurship on campus. This was contrary to what that person testified to the researcher during an in-person interview. The interviewed senior official did admit to a preference by CPUT for being risk averse when considering spin-out company formation on campus.

It emerged from the literature that effective commercialisation and TT practices require strong leadership and institutional commitment displayed by university top management. Evidence obtained from the interviewees in this study echoed that fact and interviewees suggested that:

- their university has a strong “institutional entrepreneur” at top management level to drive TT initiatives from the top down; and that

- their university TTO improves communication of success stories of commercialisation efforts on their campuses in order to raise the awareness and profile of TT activities.

At SU, the institutional commitment exerted by SU top management was found to be very high, and it manifests according to interviewees through strong institutional support for Innovus. An academic interviewee was cynical in stating that the message advocating TT at SU is less supported by the Dean of their faculty. This comment seems to be isolated as none of the other participants reported similar issues. Capacity to deal with the approval of research contracts was seen as a problem by some interviewees. Although research contracts falls under a different unit within the university this impediment was indicated as noteworthy and cumbersome by respondents partaking in the in-person interviews.

10.2.3 Academic staff and the TT process

Jensen and Thursby (2001) discussed some drawbacks of university TT, claiming that efforts spent on the commercialisation of IP causes academic staff to spent less time on teaching. From the interviews conducted at the four Western Cape universities, it emerged that the proposition by Debackere and Veugelers (2005) holds true for these universities in that the affected academic staff were able to better manage the balancing roles of teaching and research than before they started commercialising their IP. Siegel *et al.* (2004) also discovered that participation in TT activities may promote the quantity and quality of R&D and TT activities of academic staff at universities. Not everyone is as successful in doing both. One of the academics interviewed that is very active in TT commercialisation activities was disheartened about his poor NRF-rating as researcher due to inadequate number of published journals articles, which prevented him from being promoted. His unease illustrates the tension between pursuing financial gain through TT commercialisation activities from applied R&D and the demands of teaching and basic R&D which is mostly done for the public good.

A key measure of success for university technology transfer is the level of participation by academics in the technology transfer activities, which is reflected by the number of invention disclosures received by a university's TTO. Thursby and Thursby (2011) attest that such invention disclosures are the best way to effectively measure the participation of academic staff in university TT. To keep academic staff involved in TT activities requires an incentive of some sort. For many is might simply be personal satisfaction. Academic staff members of all four universities noted personal satisfaction as the reason why they embark on the journey of commercialising of their research findings. In the one case at CPUT, patients with Eczema and some with Psoriasis were totally healed from a product developed at CPUT.

Colyvas *et al.* (2002) found that the most common reason for the continued involvement of academic staff in the further development of licensed technology is the fact that the technology is often in its early stages. The LaunchLab incubator facility used by SU provides the ideal opportunity for academic staff and students to be involved in the further development of their inventions should they wish to do so. Theoretical analysis by Jensen and Thursby (2001) showed that further development of new inventions would not occur unless the remuneration (return) earned by the inventor is coupled to the output of the licensee when the invention is successfully commercialised. The new IPR-PFRD Act allows for adequate sharing by academic inventors to the income that their inventions generate. Participants to the in-person interviews when asked were all satisfied by the income sharing provisions of the IPR-PFRD Act.

A comment of an academic staff member at SU was striking when the person suggested that publication units should be awarded to inventors for patents registered, rather than the publication of academic articles. This suggestion seems doable and may well lead to improved levels of disclosure at SA universities if implemented. Also worth mentioning was the comment from one interviewee that TT activities should be included in the annual performance review assessments of academic staff. The suggestion hold promise as TTO commercialisation activities often earn extra income for a university and its reputation as an innovative organisation is promoted.

10.2.4 TTO services, incubator support and networking

Alessandrini *et al.* (2013) noted the lack of the availability of trained technology transfer professionals in SA. Participants to the in-person interviews were mostly very appreciative of the TTO support services they receive from TTO staff employed at the respective universities. However, from the case studies, it emerged that the speed at which new research contracts are approved prior to implementation was a problem for a few interviewees of SU and UCT. At SU, the responsibility falls under a different unit within the university whilst the TTO of UCT also manages the concluding of research contracts. This impediment is noteworthy and needs to be addressed by the respective universities as the delay causes a ripple effect throughout the R&D and TTO commercialisation value chain at these universities. Both UWC and CPUT can learn from this challenge by allowing for sufficient human resources capability in their legal departments as the volume of research contracts increases.

This finding should be considered against increasing workloads for TTO staff members at both universities due for a more TTO commercialisation activities undertaken are required due to ever increasing R&D spending at these universities. Also, constraints on the operating budgets of SA universities have caused fewer permanent staff members being employed. An interviewee from UCT suggested that more proceeds from TTO commercialisation activities should be allocated directly to the TTO for it to increase its human resource capacity in the office. Top management of all four universities might consider this suggestion, as it could deliver increased profits from TTO commercialisation activities through better mining and subsequent managing of IP assets on these campuses.

These universities were fortunate that TIA paid for the salaries for additional staff members to work in the respective TTOs for a period of time after the enactment of the IPR-PFRD. The new Act made it compulsory for all SA public universities to have TTOs and these units must have skilled staff to manage those TTOs. Respondents replied in the affirmative that there was a solid and trusting relationship between them and TTO staff of the university. Similarly, the legal and TTO support services were described as mainly positive by interviewees, and all respondents of all four universities confirmed that they would definitely recommend the TTO’s services to fellow academics and students.

At SU, the LaunchLab incubator facility was highlighted by the respondents as a significant contributor that stimulates entrepreneurship on campus through its TT awareness programmes and innovative ideas competitions. The LaunchLab was also credited with providing interaction and networking opportunities for academic staff and students as entrepreneurs, venture capitalists, angel investors, and other governmental agencies. Similarly, CPUT also has an incubator, initially funded by DST on its Bellville campus where the university held its Idea-Create Student Innovation competition to good effect. These incubators located on the main campuses at the two universities were seen by interviewees as key to developing relationships with all stakeholders involved in TTO commercialisation activities.

The personal connections and contacts built up over a long time was used by academics staff extensively in maintaining networks leading to collaboration. Melville and Walesh (2002), Winston (1998), Lundvall and Borrás (1997) and Salter *et al.* (2000) all assert that innovation is an interactive process that does not occur in a straight line but through interactive processes that involves people. The view is supported by Henton *et al.*, (2002) who claimed that innovation comprises of the inputs of many people in a dynamic process which involves multiple teams having face-to-face interaction. Incubators or common meeting places of interest where scientists and students can interact with each other and representatives from businesses in commerce and industry allows academic staff and students to grow their network and influence exponentially.

Bozeman (2000:629) defines TT as “the movement of know-how, technological knowledge or technology from one organisational setting to another”. It makes sense then that such meeting places should be central to the strategy of any TTO wanting to expedite its commercialisation efforts. An example of the use of networks that originated from the interviews was that academics of both SU and UCT prefer to source their own research funding via their personal networks and they should continue to do so and extract maximum benefits from such personal contacts and networks.

Interviewees representing top management from the four universities selected in the case studies suggested a number of steps that the TTO can do to promote the participation of faculty members in TT activities and to increase the disclosure rate of novel inventions. To obtain the buy-in from faculty members, these participants proposed that TTO staff members:

- show academic staff how commercialisation of inventions can add value to teaching and learning activities;
- ensure appropriate recognition and that reward schemes are implemented for new inventions; and
- promote collaboration and sharing of information relating to the TT processes among university staff members and students within different faculties and among regional tertiary educational institutions.

It was evident from the literature review and from the in-person interviews that social dynamics of TT commercialisation activities and thus the ability to connect with all stakeholders in a strong regional, national and also international network is a crucial element of effective TT efforts.

10.2.5 Spin-out company formation leading to economic growth

With cumulative licensing income of more than R20m over the eight year term under discussion in this study SU leads the four universities with UCT being next at over R12m for the same period. Both CPUT and UWC still have to build a sizable portfolio of IP that can be licensed to businesses in commerce and industry. An interviewee from the top management of UWC asserts that one winner out of 50 inventions may become a significant global success, earning huge amounts of money for the university. While TT might create new income streams for SA universities, it is likely not to be substantial and is true for most of the universities in the United States and Europe where TT systems have matured over many years (Mowery *et al.*, 2001).

Garduño (2004b) reasons that gross licensing income generated by universities is mainly used in developed counties as an important determinant of success for TT activities. However, he asserts that universities in developing countries should rather concentrate on creating spin-out companies to commercialise new technologies, and that the number of spin-out companies should be the measure of success for universities in these countries.

Bray and Lee (2000) argue that holding equity in a spin-out can dramatically improve relationships between the university TTO as licensor and the particular spin-out company as licensee, even if the university holds as little as 5%. The authors conclude that taking equity allows licensing managers at universities the freedom to do more deals, but also produces money faster than a typical licence agreement. However, Bray and Lee (2000) also claims that taking equity may not be advisable if the business skill of the academic or entrepreneur is suspect, or if the particular technology is not appropriate for a spin-out company. The lack of available entrepreneurs in SA (Alessandrini *et al.*, 2013) negatively affects this proposition and hence the spin-out route may not be advisable to SA universities.

Statistics studied by Bray and Lee (2000) in the United States indicated that the highest returns achieved on equity held in university spin-outs are more likely to occur in countries that have an excellent supply of venture capital. Again, this might be a problem for TTOs at SA universities, as venture capital for early-stage seed funding is very limited in SA (Koekemoer & Kachieng'a, 2002).

Nelson (2001) believes that universities can and should contribute to economic growth in their local economies as well as the global knowledge-based economy through TT activities. Heher (2006) indicates additional benefits from university TT that are not recorded at the level of the institution, but by the local economy, such as job creation. Public SA universities are expected to contribute to economic development in addition to earning income from contract R&D activities. Barnett (SARIMA, 2012), when referring to SA, claims that the yardstick of the economic impact of TT should not be limited to disclosures, patents, and income generated, but should extend to meeting the needs of marginalised people and local economies. Secundo *et al.* (2016) too, observe that concentrating on financial returns only is not an appropriate way to gauge the effectiveness of TTOs.

An interviewee from SU representing top management described a model used at MIT that incorporates postdoctoral fellows to create new spin-out companies rather than publishing a research paper as the required output for a postdoc. This person also alleges that 300 new jobs might be created if 10% of 30 000 students of SU were to have a good idea of which another 10% of that might be very good (300 ideas) so that a further 10% (30 ideas) can be used to form a new university spin-out company that creates 10 new jobs on average. If 20 of the current SA universities can create ideas 30 spin-out companies employing 10 people each than at least 6 000 new jobs can be created claims this person. Form a socio economic perspective, the scenario explained by this SA representative is attractive. The problem for SA is that we may not have enough entrepreneurial managers to run these new businesses.

SU via the LaunchLab and its network of mentors and resident entrepreneurs has managed to establish more than 20 spin-out companies employing almost 200 staff members. None of the other three universities included in the case studies comes close to those numbers due mainly to the factors mentioned above as well as the perceived reputational risk associated with failing businesses.

From the results of the case studies, it stems that the ability to spin out companies by using IP and technology, universities in the Western Cape are hampered by the lack of skilled entrepreneurs. The shortage of entrepreneurs is likely to be the same for other SA universities, in particular those universities located in sparsely populated provinces. Faculty members who wish to benefit fully from the commercialisation of their new inventions often have to leave the employ of their university to do so and take the responsibility as the entrepreneur. This is especially true when know-how is involved in addition to the technology which may or may not be patented.

10.2.6 General recommendations

The findings of this study enabled the researcher to make a few general recommendations and comments to be considered by academic staff and students as well as management within SA universities in their pursuit to effectively commercialise IP emanating from their institutions:

- SA needs to optimise scarce resources that are available and active in the higher education sector. Researchers must be encouraged through increased incentives to disclose their findings early and be active in capitalising on the enabling environment that has been created through legislation and which led to the creation of NIPMO and TIA.
- The biggest challenge to the management at SA universities is to gain the trust of academic inventors and to convince them that they should share information and their know-how to better commercialise their research findings.
- Higher education institutions in SA should use performance criteria that are conducive to promoting increased disclosure of new inventions and innovative ideas. Such criteria could include similar recognition and the same benefits as currently afforded to researchers who publish on research conducted by them.
- Businesses in commerce and industry, and government bodies in particular, should focus on creating and then growing the enabling environment necessary for effective technology transfer from SA universities. This should include, but is not limited to, tax holidays for companies engaging in technology transfer activities, coordinating angel investors, promoting strong scientific and entrepreneurial networks, and sharing of resources across the country.

- Many more non-profit incubating facilities similar to the LaunchLab ought to be established at SA universities in order to leverage new technologies quicker and easier into the marketplace and to foster economic growth and prosperity.
- A particular focus for SA universities should be the building of partnerships, noted as second generation technology transfer by Barnett (2004). In partnerships, an increase in research activity is generated through the use of IP as a tool, rather than first generation methods such as licensing and obtaining shares in spin-out companies.
- Partnerships are promoted by Barnett (2004), who asserts that the traditional model of restricting rights with licenses and patents is probably inappropriate for higher education. The author claims that companies should continue to pay for the rights to use university inventions, but that the licenses should be inexpensive, non-exclusive, and easy to execute. Building such partnerships to enhance research activity might produce more money for a typical university in the form of research grants, student bursaries, and joint ventures, than from license agreements or equity shares held in spin-out companies. The researcher advocates that such partnerships can work very well in the context of SA as developing country.
- The success rate of TT activities at SA universities should take into account the unique social background of SA, the high level of unemployment in this country, and the economic reality of a slow growing economy.
- Funding for new research projects and early stage technologies should continue through established units like TIA and other efforts by the Department of Science and Technology.
- Entrepreneurship, as the engine of innovation, can and should be taught to people at all levels of society and with different backgrounds and skills. Universities and lower levels of tertiary institutions should take the lead in this regard.
- Equity shares in new spin-out companies ought to be accepted in lieu of royalties with caution due to the lack of experienced entrepreneurs and an immature venture capital sector in SA.
- SA universities should accept that the success of TT activities for the institution would firstly mean regional economic development and job creation rather than a blockbuster patent delivering millions of rands in licensing income.
- Academics are often not good business people and should be limited to assuming a non-executive position on the scientific advisory board, rather than being part of the

management teams of a new spin-out company (if a spin-out company is the chosen route to commercialisation). This view is also proposed by Angelos (2004). Yet, academics employed at SA universities do have very valuable social contacts within networks and are ideally placed to assist in marketing new technologies to buyers or licensees.

- Top university management should notify their academic staff and students that scientific output and scholarly achievements are complementary to commercialisation efforts and need not be opposites in the pursuit of academic excellence and financial independence.
- The University of Austin in Texas, USA was branded and marketed across the world as an emerging high-tech area. Similarly, SA universities should decide in which technologies they have specific expertise and then market it to regional businesses to promote research activities that may lead to new inventions.
- Often, becoming an entrepreneurial university has nothing to do with reality but everything with perception. Once the research community acknowledges success in technology transfer activities and embraces innovation and entrepreneurship, it becomes easier to sustain and increase such activities.
- Cash-strapped SA universities should remember that they cannot fulfil the role of venture capitalists and should join forces with other universities and businesses in commerce and industry.
- University TTOs in SA should not aim at creating a blockbuster patent out of every new invention; rather, their goal should be to minimise paperwork and maximise deal flow. Universities should realise that the optimal deal is often not achievable and it is best to negotiate the best deal they can and continue to the next. SA universities should also realise when negotiating with industry on behalf of researchers that often they will not get the deal they deserve, but rather what they can negotiate. It is therefore critical for TTOs to employ TT managers with excellent negotiation skills and when negotiating a deal, these TTO managers should know that trust takes years to build and only seconds to destroy.
- As researcher, I agree with Iscoe (2004) and propose that SA universities be made aware of the fact that their technologies have intellectual, but no social value, and thus no apparent value until such time that a product has been developed and markets have been identified.

- Iscoe (2004) further maintains that corporate structuring in a new entrepreneurial venture too early is fundamentally flawed. He proposes a move along the embryonic incubator phase and doing corporate structuring much later. The researcher fully agree with him and recommend from his own experience that this approach should be followed in commercialising early stage technologies when the search for strategic partners has not yet been completed.
- The Lambert Review (2003) in the United Kingdom suggested a move away from small offices at universities and suggested that teams work together as that makes it easier to raise capital from government and private investors. Such regional TTOs can work very well in the SA context, as the current low level of deal flow of promising inventions emanating from SA universities does not warrant an investment into a full scale TTO at each of them.

Although entrepreneurial thinking needs to be developed on many levels and in various areas, the academic arena is one of the most important. This is where innovative technologies with the potential to form the basis of internationally competitive businesses and ventures are being developed. Through developing new technologies, academics can create their own work opportunities and employment for many others. The challenge for every higher education institution is to help propel many of the inventions developed at the university into the marketplace through exposing innovators to opportunities and providing them with some commercialisation concepts.

Technology transfer occurs in a world where connectivity is constantly improving and social media interaction is growing at an alarming rate. SA universities that are able to join the discussion and debates around TT commercialisation efforts will reap the benefits in years to come. Technology transfer incorporates many disciplines and needs multiple partners to effectively commercialise new inventions. Wiggens (2004) claims that universities should create technologies and not commercialise them. When considering SA universities and after reflecting on the outcome of the four case studies undertaken as part of this study, the researcher disagree with Wiggens and contend that the more research intensive universities have made good progress in TT commercialisation since the enabling environment of TT efforts at these universities has changed for the better. The key is for these universities not to work in isolation but to join their efforts to collectively seek and find partners in commerce and industry and other stakeholders in the commercialisation process.

The scope and depth of university TT activities across developed and developing countries were considered in this study. It became evident that a magnitude of research activities take place in countries spending 2.5% or more of their annual GDP on R&D, whereas countries spending less failed to keep pace. The researcher uncovered that most of the vast number of TTOs at universities across the world are not breaking even financially, while only a very small percentage of less than 10% are generating significant income streams for their respective universities.

Although this is not a comparative study, the researcher discovered that the less research-intensive universities have a much shorter pipeline of new invention disclosures for novel technologies as they have very limited funding to direct to basic or applied research activities. It is likely that the research-intensive universities in the Western Cape will yield meaningful income sooner than the universities that are less research intensive, as the number of invention disclosures resulting from a longer pipeline of new inventions is directly related to the volume of research being conducted.

The facts were obvious that very few new invention disclosures, leading to weaker deal flow, and thus lower income streams, were generated by the TTOs of the less research-intensive universities. However, the limited number of new invention disclosures needs to be considered against SA's context of a developing country within which the Western Cape resides. The researcher agree with Heher (2004) that no TTO can perform well, no matter how professional the role players are, if there are no new invention disclosures leading to increased deal flow. It must be noted, though, that both CPUT and UWC, as previously disadvantaged universities, are shifting from a historical low base of R&D performed towards becoming much more research intensive in the future.

The facts around the quality and quantity of research results having an influence on the quantity and quality of new invention disclosures of university technologies are so strong that it can be interpreted as a clear concept and a belief which cannot be ignored. The number of A-rated NRF researchers at a particular university, for instance, has a direct bearing on the funding for R&D a university might receive, which in turn has a direct influence on the quality and quantum of research performed and research results achieved. The facts also suggest that the age of a university TTO has a significant impact on the number of current new invention disclosures to the TTO. Both UCT and SU, having started their TTOs in 1999, have the benefit of many more years of cultivating an entrepreneurial culture on their respective campuses, which is conducive to academic staff and students disclosing their novel findings.

All things considered, this study showed that success in university TT activities is not easily obtained, and the endeavor is certainly not for the faint hearted. It is an intriguing and multi-faceted environment that requires dedicated staff with a unique combination of skills and management capabilities. In this study the five key dimensions covered seems instrumental in the success of any university TTO effort. The use of enabling institutional policies, upkeep of a conducive institutional commitment, soliciting of research funding, setting up of spin-out companies, recruitment of skilled TT staff, and managing a TTO optimally is a daunting task to complete to say the least.

10.3. Contribution of the study

The limitation of this study lies in the fact that it focuses on four SA universities in one province only. However, no prior study on technology transfer activities at SA universities has reached the extent of the probing qualitative questions as put by the researcher to interviewees of the four selected universities. Thus, these questions and the answers obtained allow the researcher to contribute to the current body of knowledge. The quality of the new knowledge obtained is substantiated through, and can be defended by, the rigour of the research approach and methodology followed in this study.

On the positive side, the development of a conceptual framework and the resultant findings from answers to the qualitative questions in the case studies add to the body of knowledge. No similar study has been conducted to the same extent at the specific participating universities.

In their study Siegel *et al*.(2004) found that participation in TT activities may actually increase the quantity and quality of R&D activities performed by academic staff at universities. The researcher found it to be true amongst those academics interviewed at the four participating universities in the Western Cape and it confirms the feedback loop existing between TT efforts and research results of the university academic staff as innovators and creators of novel technologies in SA.

The main research question of this study asked how effective the four Western Cape universities have been in commercialising their IP assets through the use of TT practices. Results from the study indicate that the particular universities through their respective TTOs are trying their best to commercialise the IP forthcoming from their campuses, albeit with limited financial and human resource capabilities. The two less research-intensive universities were found to be less effective, mainly due to lower levels of basic and applied research being conducted by them. As their research intensity grows, increases in protectable IP having commercial potential will follow. The two universities having higher research activity also have the benefit of TTOs that are at least a decade older than the two that are less research intensive. It is therefore understandable that their pipeline of new inventions and their conversion ratio of moving new invention disclosures to successfully concluded license agreements or spin-out companies will be better than the less research-intensive universities in the province.

From the study, it is also apparent that the single biggest factor affecting the rate of new invention disclosures, and ultimately the success rate of TT commercialisation activities, is the total R&D spending which occurs at SA universities. It is critical, therefore, that the SA government significantly increases its spending on R&D in the country as a percentage of its GDP, without which a robust and growing university technology transfer industry would not be possible.

10.4. Recommendation for future research

The awakening entrepreneurial spirit evident at the four SA universities bodes well for the Western Cape and for SA as a whole. Without doubt, university TT is a ‘contact sport’ and the social interaction and dynamics within the TT environment are as important as the new invention itself. The role of staff at university TTOs is critical and will remain so in the years to come. Future research might explore the impact of communication strategies used by the various stakeholders involved in university TT and the effect of these strategies on the successful dissemination of research results. Also recommended for future research is the mixture of staff and their qualifications required to manage a typical SA university TTO as a multi-cultural and interdisciplinary team is required having exceptional technical, negotiation and social skills to maximise deal flow.

It is hoped that the results of this study will lead to increased disclosures of new inventions from SA universities due to a better understanding by TTO staff members and academic staff and students once they engage with this study. It is also wished that this study will result in top management at SA universities considering their actions towards TT activities, as they have immense influence over the academics within the scientific community that they serve. Lastly, it is yearned that academic staff, students, top management, as well as TTO staff from SA universities within geographical regions will work much closer together to jointly commercialise research findings for the benefit of the country as a whole.

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