Masters of Management in Innovation Studies

Assessing Technology Transfer Effectiveness at South African Technology Transfer Offices (TTOs)

By

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ABSTRACT

The Intellectual Property Rights-Act IPR_Act (2008) was adopted in August 2010, with the objective to enhance utilisation of Intellectual Property (IP) generated using public funds Technology Transfer Offices (TTOs) were established at High Education Institutions (HEIs) and Public Research Organisation (PROs) to act as conduit through which R&D knowledge is explored and exchanged for the benefit of the Republic of South Africa. Additionally, state institutions such as National Intellectual Property Management Office (NIPMO) and Technology Innovation Agency (TIA) were established to create an environment that enables technology transfer (TT). Despite these intervention, innovation chasm is still persistent in SA with approximately 6.98% GDP spent on imported know how. There is a need to assess TT effectiveness at the TTOs with the objective of enhancing the utilisation of IP generated using public funds.

The TTOs based at HEIs, TIA, NIPMO and other TT stakeholders were interviewed to contextualise the core functions of the TTO, challenges experienced in executing the core functions, and the metrics used for effectiveness. The outcomes of the interviews were used as input to assess TT transfer effectiveness at the TTOs. The IPR_Act (2008) was used to provide a contextual assessment criteria for TT effectiveness at the TTOs. Additionally the contingent effectiveness model for TT was also used to assess effectiveness at the TTOs to account for the system barriers inputs that affect TT.

System barriers such as organisational structure, insufficient technology development funds, regulatory framework, capacity and capability, TTO's age, historical background and research strength of the research institutions at which the TTOs are based were found to affect TT effectiveness. These inputs are interdependent with spill over effects. TT effectiveness assessment was conducted using the IPR_Act (2008) and the contingent effectiveness model for TT. The outputs from the assessment infer that TT at most of the TTOs is *"Out of the door"*, which does not promote utilisation of IP.

To enhance the utilisation of IP, it is proposed that R&D at the HEIs to be aligned with the regional economic development roadmaps and enhance the linkages among the various stakeholders. There is also a need for a regulatory framework that promotes collaboration and coherence among the various stakeholders within the TT ecosystem. These strategies are envisioned to enhance IP utilisation thus enabling SA to transition from resource to knowledge base economy.

The short term strategy that can be adopted is for the TTOs to define their value propositions based on the system barriers that they experience to enhance TT effectiveness. Value propositions are aimed at aligning the strength of the respective TTO, identify niche markets and develop business models that will enhance TT that is aimed at IP utilisation. It also proposed that the administrative oversights of the IPR_Act (2008) be addressed to enhance TT effectiveness i.e. establishing a patent examination office that will assess the novelty of the IP generated.

DECLARATION

I, Mante H.S Kgaria declare that this research proposal is my own work conducted under the supervision of Professor Thembela Hillie. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in the field of Innovation Studies at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other University.

Signature: ……..

On this …… day of ……November……2018 ……..

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ABBREVIATIONS

AUTM -Association of University Technology Managers

CeSTII - Centre for Science Technology& Innovation Indicators

CIPC - Companies and Intellectual Property Commission

CPUT - Cape Peninsula University of Technology

DST - Department of science and technology

DHET- Department of High Education and Training

dti - Department of Trade and Industry

DUT - Durban University of Technology

FDI- Foreign Direct Investments

GDP - Gross Domestic Product

GERD - Gross Expenditure of Research and Development

HEI - Higher Education Institutions

HSRC- Human Science Research Council,

IDC -Industrial Development Cooperation

IPR - Intellectual Property Rights

IP - Intellectual Property

NACI - National Advisory Council on Innovation

NIPMO - National Intellectual Property Management Office

NWU - North West University

PRO - Public Research Organisation

R&D - Research and Development

SA - South Africa

SARIMA - South African Research & Innovation Management Association

SAVCA -South African Venture Capital Association

SPII -Support Programme for Industrial Innovation

SU - University of Stellenbosch

TIA - Technology innovation Agency

TT- Technology transfer

TTO - Technology Transfer Office

TRL - Technology Readiness Level

TUT - Tshwane University of Technology

UCT- University of Cape Town

UFS - University of Free-State

UJ - University of Johannesburg (more of a hybrid as it was merged with wits tech)

UKZN -University of Kwa-Zulu Natal

UoT - University of Technology

UP - University of Pretoria

US - United states of America

UWC - University of Western Cape

VUT - Vaal Triangle University of Technology (VUT)

VCs - Venture Capitals

WITS - University of the Witwatersrand

1. CHAPTER 1: INTRODUCTION

1.1. Purpose of the Study

The Intellectual Property Rights from Publicly Financed Research and Development Act of 2008 (IPR_Act, 2008) was officially adopted in August 2010 with the anticipation that it would enhance utilisation of publicly funded research outputs for the benefit of people of republic of South Africa (SA). The Higher Education Institutions (HEIs) were identified as key enablers to transfer, diffuse and disseminate knowledge, thus were mandated by the IPR_Act (2008) to establish Technology Transfer Offices (TTOs). The TTOs were envisioned to bridge the innovation chasm i.e. the gap between research and development (R&D) and commercialisation of publicly funded research in South Africa. The HEIs are viewed as the knowledge creators in the South African National System of Innovation (NSI), thus they were merged/restructured between the period of 2001 and 2007 to strengthen the research outputs and enhance sustainable development by generating graduates that can be absorbed in various sectors of the economy.

The Department of Science and Technology (DST) in collaboration with its agencies released a baseline report for the period of 2008 to 2014 detailing the status quo of Intellectual Property (IP) and technology transfer (TT) of publicly funded research since the adoption of the IPR_Act (2008) (CeSTII, DST, HSRC, NIPMO, & SARIMA, 2015). Inadequate specialist resources, funding (both operation and IP registration) and IP awareness among the researchers were some of the challenges that were perceived to have a moderate to high impact on TT value chain at the South African TTOs (CeSTII et al., 2015, p. 26). An assessment of TT impact post the adoption of the (IPR_Act, 2008) was not conducted.

The purpose of the study is to assess the core functions of the TTOs (established at HEIs) as outlined in the IPR_Act (2008), the challenges experienced in executing the core functions of the TTO and the metrics for TT effectiveness to quantify the impact. TT is anticipated to increase the flow of technologies from the HEIs to the industry with the anticipation that it will lead to enhanced productivity and boost economic growth. Thus the objective of the study is to provide an assessment of TT effectiveness at TTOs based at HEIs, and propose an IP management strategy that can be used to potentially enhance TT effectiveness.

1.2. Context of the Study

South Africa's Gross Expenditure on Research and Development (GERD) is approximately 0.77 % of the Gross Domestic Product (GDP) (DST_HSRC, 2014/2015). In 2015, the technology payments (i.e. the imported know how) as a percentage of the GDP was reported to be 6.98% (NACI, 2016, p. 45). The World Bank has classified SA to be positioned on medium-low technology and weakly positioned on medium to high technologies, with SA high technology export as a percentage of the world reported at 0.08%. To exploit the innovation investments, the research and development (R&D) outputs needs to be transferred to create new markets, services and improve the lives of ordinary South Africans. Wilson (2015) is of the view that countries that seek transformative/sustainable growth realise the social returns associated with innovation such as job creation and economic growth.

The IPR_Act (2008) was adopted in August 2010, with the objective to enhance utilisation of the R&D outputs for the benefit of the people of the republic. Technology Transfer Offices (TTOs) were established in SA to act as conduit through which knowledge is explored and exchanged. The TTOs were established at the High Education Institutions (HEIs) and Public Research Organisation (PROs) as they are perceived as knowledge generators in the South African NSI. Additionally, state institutions such National Intellectual Property Management Office (NIPMO) and Technology Innovation Agency (TIA) were established with the objective of creating an ecosystem that enables technology transfer (TT) in SA.

The research study is focused on proposing a management strategy and an ecosystem that can be used to enhance TT effectiveness in South African TTOs. The proposed management strategy is envisioned to take account of the core activities of the TTOs, challenges experienced in executing these activities and the metrics used by the various TTOs to quantify effectiveness. The directors and TT managers from the various TTOs (only based at HEIs) were interviewed using structured interview to generate empirical data to be used for the study. Other stakeholder within the TT ecosystem such as TIA, NIPMO and IDC were also interviewed.

The IPR_Act (2008) was used to provide a relevant assessment criteria for analysis of the empirical data, literature and deduce the findings of the study. Additionally , the Bozeman's effectiveness contingent model for TT was used to analyse the empirical data to assess the metrics used for effectiveness (Bozeman, 2000; Bozeman, Rimes, & Youtie, 2015).

1.3. Problem Statement

Technology Transfer Offices (TTO's) were established to create an ecosystem that will enable commercialisation of R&D outputs generated using public funds (IPR_Act, 2008). A number of the TTOs were established and have been operating for approximately eight years to date since the adoption of the IPR-Act. Some TTOs, especially the ones at traditional research HEIs have been in operation before the adoption of the IPR_Act (2008).

It is reported in the 2015 IP management and TT baseline indicators report (CeSTII et al., 2015) that on average, 100 new technology(ies) were added to the portfolio from a period of 2011 to 2014; however there is no mention of progress or return on investment acquired due to the transfer of either of the technology(ies) to the market. Thus there is a need to assess the role of TTOs and barriers experienced by TTOs when executing their core functions. The aim of the study is to propose a management strategy that can be used to enhance utilisation of R&D outputs generated using public funds. The following sub-problems will be addressed;

- What are the core function of the TTOs?
- What are the barriers/challenges experienced in executing the core functions of the TTOs?
- What are the metrics used by the TTOs to quantify TT effectiveness?
- How does the ecosystem enhance TT effectiveness in SA?

1.4. Significance of the Study

Innovation is cited by various scholars as an engine for economic growth. This is evidenced by various governments playing a role in being entrepreneurial states through investing in technological innovation with the objective to enhance competitive advantage and economic catch up. TT outputs from the TTOs are envisioned to enable SA to achieve socio-economic goals and enhance the lives of South Africans. Thus the core functions of the TTOs, the barriers experienced by the TTOs when executing their core functions and metrics used to assess effectiveness need to be evaluated to ensure that SA is on the correct trajectory to achieve the anticipated TT returns. An IP management strategy, focused on enhancing the TT effectiveness is thus required to ensure the R&D investments yield the desired results.

1.5. Limitations of the Study

Technology transfer (TT) evaluated in this study is not cross-national and it is within the borders of South Africa. Only the TTOs based at the HEIs will be studied. The PROs and the HEIs have varying organisational culture and historical backgrounds, thus to avoid the distortion of the results; the research study will focus on the TTOs based at the HEIs.

Some of the major TT stakeholders are TT agent, TT recipient , TT environment and the transfer object (Bozeman, 2000; Bozeman et al., 2015). The study will be limited to the activities within the TTOs (i.e. transfer agent, transfer object, transfer media and the transfer environment) and externalities such as TT recipient will not be evaluated. For the purpose of discussing the results, the involvement of the TT recipients in the TT ecosystem will be discussed to a limited extent.

The study will exclude the R&D initiatives that are funded by international donors, 12.2 % of the South Africa's R&D funding is sponsored by the international donors (DST_HSRC, 2014/2015) and thus may have biases on conducting research that is not focused to the needs of the country (Fessehaie, Rustomjee, & Kaziboni, 2016; Muchie, Gammeltoft, & Lundvall, 2003). However where elaboration or illustration is required, the private sector will be used to contrast the discussions.

1.6. Assumptions

An ideal situation is assumed, removing external threats such as corruption where the R&D funds are not used for the intended purpose, thus affecting delivery of the research outputs.

The Global Competitive index (2010/2011) ranked South Africa the 24th place in conducting good quality research, thus it assumed that there are good research outputs that can be transferred to meet the socio-economic transformation goals. The HEIs were merged and the merger was envisioned to strengthen the R&D at the public HEIs with the objective of developing the competencies and producing graduates that can be absorbed at various sectors of the economy (Ministry_of_Education, 2002). Hence the assumption made in this study is that HEIs have the capability to conduct R&D and produce outputs that can be transferred to the market or public use.

It is also assumed that South Africa has the absorptive capability to innovate and develop new technologies for market use (Lundvall, Johnson, Andersen, & Dalum, 2002).

1.7. Definitions of Key Terms

Capability ~ is the ability to develop, use, invest, produce and implement activities in a firm supported by an enabling environment (Lundvall et al., 2002)

Capacity ~ the ability to possess the required amount of resources to be able to execute a given task.

Economic Catch –up ~ a country's growth rate per capita has risen above the global average (Lee, 2013) and can be achieved by path following, stage skipping and path creating.

Innovation ~ is the process of introducing new technologies, process, products and service to the market and creating a sustainable value (Chris Freeman, 1995; White_Paper_Science&_Technology, 1996)

Institution ~ is a set of legislative framework that provides guideline for system (Siegel, Veugelers, & Wright, 2007)

National System of Innovation ~ a complex evolving system comprising of the interaction between various stakeholders to allow for diffusion of technology and knowledge, taking into account the socio economic factors to ensure that there is a relevant capacity building and innovation (Chris Freeman, 1995; Lundvall et al., 2002; Metcalfe, 1995).

Research and development ~ systematic creative work undertaken to increase knowledge stock.

Technology ~ is a systematic application of acquired knowledge to develop process and solve realities. Technology is an object intentionally created to extend human practical possibilities. Thus TT and knowledge transfer are inseparable as the knowledge upon which the technology is built is also transferred without the base knowledge, the technology cannot be used (Sahal, 1982).

Technological catch up ~ is the process of generating technological innovations at a faster rate than the industrialised economies (Lee, 2013)

Technological Innovation ~ is a process through which firms bring into fruition the R&D results and create new markets

Technology Transfer ~ In the context of this research, TT is defined as a dynamic process that entails non-linear movement of technical knowledge/technology from one entity (with similar or different characteristics) to the other with the objective to create value from the investment made in R&D, i.e. the process of transferring knowledge for economic growth (CeSTII et al., 2015).

Battistella, De Toni, and Pillon (2016), cited that the TT is not unidirectional but involves the reciprocal response from the recipient with intense interaction until there is a significant impact formed. TT can take many forms such as (knowledge, know-how, training) and all of the actors have different properties and characteristics (Battistella et al., 2016).

Technology Transfer Office (TTO) ~ is an office that facilitates knowledge/TT using various forms like (however not limited to) IP identification, protection, licensing & management, analyse disclosures for commercialisation and refer disclosures to NIPMO (IPR_Act, 2008).

1.8. Research Questions

The following research questions will be addressed in this study;

- What are the core function of the TTOs?
- What are the barriers/challenges experienced in executing the core functions of the TTOs?
- What are the metrics used by the TTOs to quantify TT effectiveness?
- How does the ecosystem enhance TT effectiveness in SA?

1.9. Report Structure Outline

Chapter 1: Introduction

The study is aimed at contextualising the core functions of the TTOs, identifying the barriers that affect TT effectiveness and quantifying the metrics used to assess effectiveness at South African TTOs, especially the ones based at HEIs. The objective is to integrate these outputs and propose an IP management strategy that will enhance the TTOs outputs.

The sample frame comprised of TTOs based at HEIs that have R&D office and funding by government to conduct research. TTOs from University of Technology (UoTs), traditional research university (ies) and comprehensive university (ies) were used as a unit for analysis. Empirical data was collected using structured interviews. NIPMO, a statutory institution

responsible for providing support to the TTOs was also interviewed. Other stakeholder within the TT ecosystem such as TIA, IDC and the dti were also interviewed to collect data for triangulation. Government official documents available on the public domain were also used as secondary data for triangulation.

Thematic analysis was used to analyse the empirical data. The IPR_Act (2008) was used when analysing the themes emerging from the data collected to provide a contextual and relevant assessment criteria for analysis. The contingent effectiveness model for TT developed by Bozeman et al. (2015) was used to assess effectiveness, taking into account the barriers experienced by various TTOs when executing their core functions.

Chapter 2: Literature Review Overview

Literature review was conducted to build a scholarly base to assess the innovation and TT value chain at TTOs. The TT landscape was studied, mainly focusing on TT of publicly funded R&D outputs, the barriers affecting TT effectiveness, metrics to quantify effectiveness and various TT modes used in developed countries. The TT modes used in developed countries were reviewed because TT is fairly new on the African continent and it is approximately less than ten years.

Chapter 3: Research Methodology

The chapter details the research methodology followed by the researcher to generate empirical data, analytical methods used to review the empirical data and literature, process followed to make conclusions and recommendations for the study. The strategy used to select representative sample frame, data collection method used together with the techniques used enhance the reliability and validity of the empirical data collected are discussed in this chapter. The ethical considerations followed by the researcher and guidance from the qualitative research method literature is also discussed in this chapter.

Qualitative research method was used to contextualise the core functions of the TTOs, challenges experienced when executing the core functions and the metrics used by the various TTOs to quantify effectiveness. The HEIs webpages and official government reports were used as secondary data.

Chapter 4: Presentation of Results

The data generated from the interviews was transcribed, coded and themed according to the various concepts emerging from the literature study. The data was presented using descriptive method to provide outcomes from empirical data thematic analysis.

The sample frame comprised of more than ten TTOs thus percentage will be used to present some data, however in situations where the evaluated phenomenon is experienced by less than 60% of the sample frame, percentage will not be used to avoid distortion of the results.

Chapter 5: Discussion of the Results

The findings from the research are discussed in this chapter of the report. The data was analysed using thematic analysis. The themes that emerged during data analysis and were not covered in the literature review were used to make recommendations for further study. The following information was used for the results discussions;

- The literature findings reported in Chapter 2.
- Empirical data collected from the interviews with the various TTOs, Innovation Funding and Pre-Commercialisation and Support unit of TIA, New Industries Business Unit of the IDC, NIPMO and the Directorate of Innovation and Technology Policy of The dti.
- Secondary data from the websites of the HEIs that participated in the study (including the IP policy documents) and Department of Science and Technology (DST) reports i.e. CeSTII et al. (2015). , DST_HSRC (2014/2015),NACI (2016)
- The IPR-Act (2008) and the Bozeman's effectiveness contingent model for TT (Bozeman et al., 2015) were used to provide contextual analysis for assessing effectiveness at the TTOs based at HEIs.

Chapter 6: Conclusions and Recommendations

Contribution to knowledge is discussed and the recommendations for further study are made where the results were inconclusive or there was insufficient data to conclude on the findings.

2. CHAPTER 2: LITERATURE REVIEW

2.1. Innovation and Economic Growth

Various innovation scholars cite that innovation is the engine that enhances welfare, economic growth and create jobs (Fagerberg, Martin, & Andersen, 2013; Chris Freeman, 1995). Technological innovation has the potential to enhance economic growth, with Mazzucato (2013) advocating for the state to fund technological innovation to create competitive new markets. Mazzucato (2013) empathised that the role of the state is to support the firms, provide an enabling environment for growth; especially to firms focused on technological innovation.

Chris Freeman (1995) and Salter and Martin (2001) identified R&D as the source of technological innovation. The technological innovation value chain entails ideation phase, concept phase (research and proof of concept), development and commercialisation. Soumonni (2016) cited Stinchcombe (1990) that the process of turning an invention into innovation requires a social system that natures the technical ideas, makes risky investments, and create incentive structures to motivate knowledge generators. Thus to exploit the technological innovation value chain outputs, it is important to systematically understand innovation (Fagerberg et al., 2013).

Chris Freeman (1995), introduced the National System of Innovation (NSI) framework, defined as a "network of institutions that interact to initiate, import, modify and diffuse new technology (ies)" thus enhancing the adoption of R&D outputs by new markets. The NSI provides a framework for governments to introduce new policies and stakeholders that will create an enabling environment for technological innovation to occur (Metcalfe, 1995). The R&D outputs can be exploited by systematically transferring technology to end users thus creating new markets. TT can be instrumental in meeting the country's economic growth strategy and thus an efficient TT process is required to meet these objectives.

Schumpeter (2000) in defining the concept of economic destruction is of the view that a company can renew itself through adopting new technologies and gain a competitive advantage to enter new markets. Technological catch up focused on shorter technology cycle has the potential to enhance economic growth as observed in Korean industries (Lee, 2013; Lee & Lim, 2001) and help countries break from the middle income trap. Efficient and effective TT in countries that have matured innovation systems is an enablement for economic growth.

2.1.1. Innovation System in South Africa

The White Paper on Science and Technology (1996), adopted the National System of Innovation (NSI) framework with the drive to create opportunities that support inventions and help translate the inventions into innovation (White_Paper_Science&_Technology, 1996, p. 18). The adoption of the framework was intended to form an ecosystem that creates, acquire and diffuse new knowledge with the objective of promoting socio-economic transformation agenda in South Africa.

The Department of Science and Technology initiated a Ministerial Review to assess the science, technology and innovation landscape since the adoption of the NSI (Minesterial_Review_Committee_DST, 2012). The objective of the review was to assess the readiness of the country to meet some of its strategic plans e.g. the ten year innovation plan and the 2030 National Development Plan (NDP). Some of the findings outlined in the Ministerial Review report are summarised below;

- South African NSI is fragmented and recommendation was made to integrate businesses, especially the growth of Small, Medium & Micro Enterprises (SMMEs) into the NSI. This was also reported in the 2006/2007 review conducted by the Organisation for Economic Cooperation and Development (OECD).
- More attention needs to be focused on science push and not assume that the market will pull the R&D outputs, thus proactive marketing of the R&D outputs is required.
- There is an inadequate resource inflows in the system for R&D venture capital (VC) for start-ups and innovative enterprises.

An integration of the SMMEs in the South African NSI may potentially bridge the fragmentation by ensuring that there is absorptive market for new technologies. Acquiring technology (ies) has the potential to provide various business with the competitive advantage for economic growth (Mazzucato, 2013), thus this will ensure potential growth of the SMMEs and attract VC's to invest in innovation based enterprises. The investment criteria used by most VCs is potential growth (SAVCA, 2013) and thus an enhanced growth of the SMMEs will attract investment.

Most African countries are characterised to have an immature innovation system (Kruss & Gastrow, 2012) and thus are at a risk of being re-colonised if they are unable to self-sustain and grow their economies by leveraging innovation benefits (Soumonni, 2016). In the 2017

Ministerial Review report it is stated that the science, technology and innovation institutional landscape of the country need to keep pace with the expanding global frontier (Ministerial_Review_Panel, 2017). South Africa is positioned on medium-low technology and weakly positioned on medium high to high technologies and there is a lack of policies for knowledge exchange between the research and business sub-systems (The_World_Bank, 2017)

Despite the efforts and interventions since the adoption of White Paper (1996), the rate technology diffusion in SA has been relatively constant at 0.1% since 1996 (NACI, 2016). Hence there is need to enhance the diffusion of the technology developed using public funds to boost economic growth.

2.1.2. Technology Transfer Landscape in South Africa

The adoption of the IPR_Act (2008) mandated the HEIs to establish TTOs with the objective of enhancing commercialising R&D outputs. The capabilities required in South African TTOs to execute the core functions are outlined in the IPR_Act (2008) and they entail; interdisciplinary knowledge, qualification and expertise in the identification of intellectual property, management and commercialisation of intellectual property and intellectual property transactions (IPR_Act, 2008). Alessandrini, Klose, and Pepper (2013) conducted an empirical study to understand IP management and TT practices at South African TTOs, the study evaluated organisational structure, TT barriers and measure of TT success used by the various TTOs (some established since 1999). Alessandrini et al. (2013) indicated that the innovation ecosystem need to be strengthened to enhance TT efficiency at the TTOs. The same findings were outlined in the 2017 Science and Technology Ministerial review report (Ministerial_Review_Panel, 2017).

Alessandrini et al. (2013) stated that the major activities in South African TTOs are IP protection, research management and limited assistance with business plans. IP commercialisation remains untapped, with South African TTOs focused more on the search of the new IP but not capitalising and generating revenue from the existing IPs (Alessandrini et al., 2013). In the 2016 South African Science, Technology and Innovation Indicators report, it is stated that there is an increased number of registered patents locally and at international IP offices since the adoption of the White Paper (1996) (NACI, 2016). Some of the R&D outputs outlined in the report are registered patents, trademarks, publications and copyrights (NACI, 2016). South Africa has a number of afore mentioned outputs, especially patents with a substantial number registered at top global patent offices (NACI, 2016). The Science,

Technology and Innovation Indicators report does not account nor measure the impact of these outputs. It is also cited that there in increased scientific publication and patenting activity in developing countries in the Frascati Manual released in 2012 (OECD, 2012) however there is no assessment to quantify the impact of publication on TT.

Some of the South African patents are with multinational companies (NACI, 2016). The patents with multinational are anticipated to enhance the innovative capability through knowledge/ TT and generate the required skill set for innovation. This is based on the science, engineering and technology landscape in the less developed, with the skill set to advance innovation non-existent. Viotti (2002) proposed the national learning systems for developing countries, and that the developing countries need to reverse engineer to enhance the absorptive capability to innovate. Most scholars have cited that innovation is a cumulative process (Chris Freeman, 1995; Lundvall et al., 2002) and thus the relations with multinational companies, patents lodged at reputable countries, and increased publishing, it may be assumed that SA has the capability to innovate. However the impacts of these inferred innovation capability are not quantified in the various government documents aimed at reviewing the innovation status qou.

The strength and the weakness of the TT landscape need to be contextualised with reference to the objectives of the various policies introduced to enhance TT effectiveness. There is need to quantify the TT effectiveness in SA to be able to integrate and develop strategies that can be used to enhance TT effectiveness. This has the potential to create new markets and forester economic growth.

2.1.3. Technology Transfer Value Chain

Technological innovation has long lead times, at least estimated seven years (Mansfield, 1991) and hence Mazzucato (2013) proposed for the state to fund technological innovation as it requires patient capital. Teece (1996) characterised technology innovation to be uncertain, path dependent, cumulative, irreversible, tacit, improbable and interrelated. Thus, some of the technologies may fail during the development value chain.

To translate the inventions into innovations, technology/ knowledge has to be continuously transferred from inception until commercialised or transferred for market use (DST_HSRC, 2014/2015). Absorptive capability is required to exploit technological innovation with the intention to create new markets to meet the socio-economic transformation goals.

Technological innovation value chain comprises of idea generation, selection, development, TT and commercialisation aimed at ultimate benefit for the people of the republic (CeSTII et al., 2015). The initial stage comprises of knowledge creation and Mazzucato (2013) promoted the concept of an entrepreneurial state and recommended for the state to provide patient capital for funding R&D activities. The SA's state spent approximately 0.77% of the GDP (i.e. R 29 billion) on the Gross Domestic Expenditure on Research and Development (GERD) (DST_HSRC, 2014/2015). Approximately 55% of the GERD budget is used for basic research at HEIs (DST_HSRC, 2014/2015, p. 16) and has increased from 51% in 2013/2014. The portion of the expenditure on basic research at HEIs is almost half of the GERD budget and this may be attributed to the mandate of the HEIs (Etzkowitz, Webster, Gebhardt, & Terra, 2000). In South Africa, the HEIs strategic role is to increase the human capacity, efficiency and global competitiveness (Ministry_of_Education, 2002). Enhanced human capacity and efficiency is envisioned to generate the required skills that can absorbed in the industry to advance technological innovation. Technology based innovation require both codified and tacit knowledge (Cohen & Levinthal, 1990) and are cumulative in nature.

The process of the TT entails the following steps as outlined in the IPR_Act (2008) and the The South African National Survey of Intellectual Property and TT at Publicly Funded Research report (CeSTII et al., 2015).

- *Disclosures.* The discoveries made during knowledge creation step need to be documented, developed, managed and protected to ensure that R&D outputs are packaged in such a manner that can be used to generate commercial revenue (CeSTII et al., 2015). The TTOs and NIPMO were established post the adoption of IPR_Act (2008) to carry out the above mentioned functions. The function of the TTO is also to determine the novelty of the disclosures and assess if they have the potential to be commercialised (IPR_Act, 2008). The TTO is responsible to identify the suitable mode of TT that will increase the probability of generating an impact out of R&D outputs.
- *IP protection.* The novelty of the IP is protected to manage the risk of the IP being used by other entities without public benefit. The IP can be protected either by patenting or generating trade secret. The protection mode selected should be selected such that it will promote the commercialisation of the R&D outputs at a later stage. The modes of protection frequently used are patents, copyrights, trade secrets and industrials designs.

- *Fund raising and technology development.* Some of the IP is protected at infancy stage due to the potential for commercialisation at a later stage. Thus seed funding is required to develop the technology to a point where the technology is ready to be transferred to the market for societal/public benefit.
- *Marketing.* The technology (ies) developed needs to be marketed to create an awareness to the end users and thus promote the market push as cited in the 2012 Ministerial Review report (Minesterial_Review_Committee_DST, 2012). The process entails identifying market opportunities and partners that can utilise technology (ies).
- *IP transaction.* This step entails the transfer of the IP ownership to commercial partners that will exploit the created R&D products or services. The IP transaction can be made with an existing company or a start-up (CeSTII et al., 2015)
- *Product development.* The process entails collaboration between knowledge creators and TTO assist with the transfer of technology to external stakeholders. Techno-preneurs are instrumental at this stage to enhance the success probability of IP translating into products for commercial use (Etzkowitz et al., 2000)

The steps outlined above may infer that TT is a linear process, which is not especially for transfer of technology from non-traditional fields such as high technology sectors, where feedback loops and re-engineering determines the success of the process. TT is an interdependent process and Bradley, Hayter, and Link (2013) advised that more accurate TT models need to adopted by TTOs based at HEIs to achieve their entrepreneurial mandate. A linear TT focuses on a "tick-box paradigms" relative to ensuring that the strategic objectives are met.

The desired impact for TT in developing countries are poverty elevation and improved standards of living (Upstill & Symington, 2002). The impacts can translate into job creation, enhanced science and technology skill set, revenue for the TTO and tax revenue resulting with GDP growth (CeSTII et al., 2015). There is a need to evaluate the impact of TT and develop a management strategy to enhance TT effectiveness in SA. Alessandrini et al. (2013) is of the view that effectiveness is measured in SA using IP disclosures and registered patents. If such metrics are adopted for effectiveness, the TT models and methods used in South African TTOs need structured such there is an enabling environment for these outputs to be achieved. Thus need to be critically assess models and methods of TT used in South African TTOs to ensure the effectiveness (Bradley et al., 2013).

2.2. The Role of Technology Transfer Offices (TTOs)

TTOs are a conduit through which knowledge is explored and exchanged (Siegel, Waldman, & Link, 2003). The Association of University Technology Managers (AUTM) outlined the TT process to entail various facets such as patents, proof of concept, industry partners, business plans, innovation/entrepreneurship initiatives, venture capital and patenting costs. All of these factors contribute towards the success of TT process. Bozeman et al. (2015) listed various TT modes when defining the contingent effectiveness model for TT and they are; patent, license, personnel exchanges to enhance the skill set, spin-outs, publications and trademarks. The mode of TT is dependent on various factors such as the capability of the transfer agent to identify the appropriate mode for TT, availability of resources, funding, organisation structure, the character traits of the technology recipient and the complexity of the technology being transferred (Bozeman et al., 2015; Upstill & Symington, 2002). Upstill and Symington (2002) stated that the TT process can be non-commercial transfer, commercial transfer and new company generation depending on the mode of the TT chosen. Thus various modes will have different outputs and impact.

2.2.1. Metrics for Technology Transfer Effectiveness

The metrics used to quantify the effectiveness of TT process need to be identified/ defined to be able to assess the performance at the TTOs. Bozeman et al. (2015) developed the contingent effectiveness model for TT to assess the effect of the various contextual dimensions on TT effectiveness. The effectiveness metrics used by (Bozeman, 2000) and (Bozeman et al., 2015) entailed public value, economic development, market impact, opportunity cost, political and scientific human capital. Bozeman et al. (2015), argued that not all the TT processes have an economic impact, and some of the TT outputs may address the social needs. Upstill and Symington (2002) is of the view that some TT outputs have non-commercial gain and referred to them as non-commercial TT modes. (Friedman & Silberman, 2003; Phan & Siegel, 2006; Upstill & Symington, 2002) used number licensing agreements between the HEIs and the firms, revenue generated through royalties and the number of start-ups to measure the effectiveness of TT. In the Annexure to the Frascati Manual, it is argued that the number of patents and revenue generated through licensing of IP does not contribute towards socio-economic transformation (OECD, 2012), thus metrics such as job creation, poverty reduction and financial benefit for the country need to be accounted for when reviewing the effectiveness of TT, especially for developing countries.

The metrics used by (Friedman & Silberman, 2003; Phan & Siegel, 2006; Upstill & Symington, 2002) are used in developed countries such as the US and they have a developed NSI. Viotti (2002) proposes the notion of National Learning Systems (NLS) as opposed to NSI for developing countries, and advocates for the developing country to be learning while advancing technological knowledge. Based on the NLS proposed by Viotti (2002) for developing countries and the NSI in most developing countries being immature and fragmented (Ministerial_Review_Panel, 2017; OECD, 2012), using metrics linked to economic impact to measure effectiveness of TT may be premature and misleading. Revenues generated from TT are not instant and have minimum lead times of seven years (Friedman & Silberman, 2003). Thus for a country like South Africa, using the number of spin outs as a measure of effectiveness maybe be inadequate due to the newness of this discipline. Thus the use of conceptual frameworks such as the (Bozeman et al., 2015) effectiveness contingent model for TT to assess effectiveness maybe adequate.

2.3. Factors Affecting Technology Transfer efficiency at TTOs

The factors that affect innovation differ based on the type of innovation (Ross & Anton, 2006; Teece, 1996) .The mode used for TT also differ based on the complexity of the technology being transferred (Upstill & Symington, 2002), hence it is imperative to understand the activities and the barriers the TTOs experience in executing their core functions to be able to select the most suitable mode of TT.

Mazurkiewicz and Poteralska (2017) classified the TT barriers experienced by the Poland TTOs into three categories, namely; technical, organisation-economic and system barriers. The classification is based on Mazurkiewicz and Poteralska (2017) experience in research projects, collaborations with the industry and in depth analysis of literature. Mazurkiewicz and Poteralska (2017) mentioned lack of market knowledge by the transfer agents, insufficient technology piloting and validation, disjuncture between the technology providers, absence of implementation and technology developmental plan at macro level being the major organisational-economic barriers affecting the development of innovative entrepreneurship.

The impact of these barriers vary depending on the socio-political and the economic situation of specific countries. Mazurkiewicz and Poteralska (2017) characterised system barriers to be due to lack of a focused national technology development plan that promotes coherence amongst the various TT stakeholders. A focused national technology development plan can be used to provide a guideline for TT and also be used to mitigate unanticipated TT failures. The

technical barriers are dependent on the complexity of the technology being transferred, the technical competence of the transfer agents and the end users.

Bozeman (2000) and Bozeman et al. (2015) stated that TT effectiveness is dependent on the contextual dimensions, which entail the role of the inventor, TT agent, interaction with the industry through marketing, transfer recipient, technology mode, transfer environment and transfer media. Bozeman et al. (2015) views are supported by (Bozeman et al., 2015; Etzkowitz et al., 2000; Siegel et al., 2007; Upstill & Symington, 2002). These dimensions have various character traits and are interdependent thus affecting the effectiveness of TT to varying extent (Bozeman et al., 2015; Etzkowitz et al., 2000; Siegel et al., 2007; Upstill & Symington, 2002).

Other factors that contribute towards TT effectiveness are entrepreneurship, incentive structure, IP policy and individual and institutional characteristic traits (Bekkers & Freitas, 2008; Siegel, Waldman, Atwater, & Link, 2004). Alessandrini et al. (2013) mentioned lack of technically inclined personnel at the TTOs and lack of seed funding as the major barriers to TT in South Africa. Friedman and Silberman (2003) conducted a qualitative study using data from AUTM to evaluate the effect of size of the TTOs, incentives, faculty quality and age, number of disclosures, geographic location and the support by the university mission on TT effectiveness and found a strong correlation.

The various factors affecting TT are discussed below.

2.3.1. Policy Framework

Bozeman (2000) suggested paradigms shaping policy pertaining to TT to be market failure, mission and cooperative technology. Market failure paradigm account for a situation where there is no appealing/absorptive market environment for technology innovations. The mission paradigm account for TT with the intent to meet the country's strategic goals and the cooperative paradigm contests that neither the mission nor the market paradigm can generate economic growth (Bozeman, 2000). The cooperative paradigm advocates for industrial policy and emphasis the need to integrate the private sector in TT process.

Alessandrini et al. (2013) stated policy as an enabler for TT. The South African Government has instituted new "regulatory" bodies to support the diffusion of technologies into the public domain to sustain micro enterprises and small business. Wolson (2007) outlined the policies that enhance TT in South Africa, mainly focusing on the biotechnology sector and these policies have advanced post the Wolson (2007) study, with the IPR_Act (2008) and

("Technology Innovation Agency Act," 2008)adopted post her study. The IPR_Act (2008) was established to identify, protect, utilise and commercialise public funded research outputs for the benefit of the South African citizens. The adoption of the IPR Act required the HEIs to establish TT Offices (TTOs) and allocate human resource responsible for undertaking TT. The IPR_Act (2008) also mandated NIPMO to provide financial assistance, training and development of the required skills for TT. Thus the adoption of the IPR_Act (2008) made provision for the primary strategic role of the TTOs, which can be summarised to be to promote economic development and entrepreneurial capability.

"Technology Innovation Agency Act" 2008) mandated the establishment of Technology Innovation Agency (TIA), which was also established with the objective to provide seed fund to bridge the "innovation chasm" i.e. the gap between R&D and commercialisation. Some of the interventions instituted to create an environment that enables TT include the Innovation fund, Support Programme for Industrial Innovation (SPII) and tax incentives for new business. These initiatives were envisioned to accelerate diffusion of technologies into the industry, especially among the Small Medium Enterprise (SME).

The Department of Trade and Industry (the dti) has developed a framework for technology commercialisation in South Africa, providing guideline for key activities targeted at enhancing commercialisation of R&D outputs. The framework for technology commercialisation in South Africa is part of the intervention strategy to enhance commercialisation of R&D outputs. The framework is shown in Figure 1.

These interventions as depicted in Figure 1 are anticipated to create a conducive environment for technology commercialisation. Bercovitz and Feldman (2006) mentioned that the IP policies are focused on the narrow perspective of TT, as they mainly promote spin-outs and technology licensing. TT is in its infancy stage in developing countries thus "appropriate" modes and metrics are required to quantity TT effectiveness.

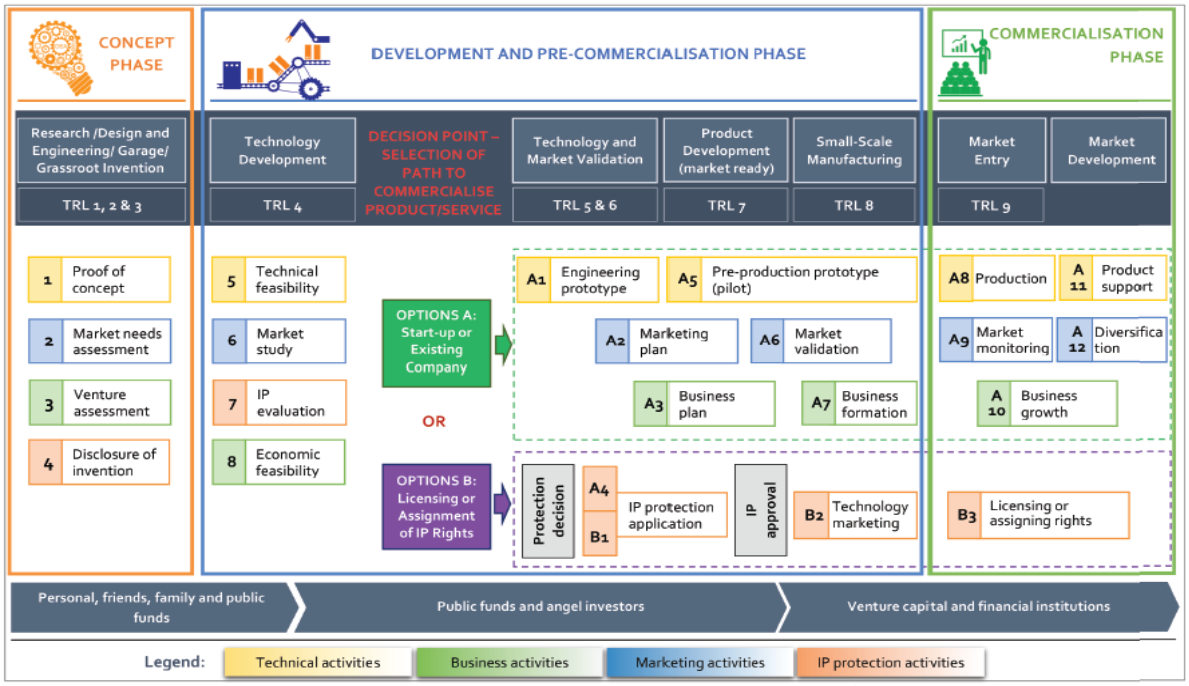

Figure 1: The department of trade and industry commercialisation framework (The_dti, 2016)

2.3.1.1. IPR-Act context

The IPR-Act of 2008 has the same premise as the United States (US) Bayh-Dole Act of 1980 and United Kingdom (UK) Patent Law of 1978 (NACI, 2016, p. 15). The Bayh-Dole Act was envisioned to enhance commercialisation of the technologies by providing the HEIs the flexibility to negotiate IP licenses and management the IP developed using public funds (Siegel, Waldman, & Link, 2003). Mowery and Sampat (2004) cautions that embracing the Bayh-Dole Act of 1980 in developing countries without taking into account the context of the US may not trigger the significant anticipated outputs.

Mowery and Sampat (2004) conducted a study to evaluate the viability other governments adopting the Bayh-Dole Act of 1980 to improve TT and industrial linkages. In their study (Mowery & Sampat, 2004), provide historical background of R&D landscape in the US prior 1970s and post the adoption of the act in the 1980s. The Bayh-Dole Act of 1980 was established post an era where the US government research efforts was focused on public welfare (Mowery & Sampat, 2004). It can be inferred that there was a market pull, and thus the HEIs were able to build the industrial linkages for TT. The strong industrial linkages were boosted by the US HEI landscape, where most of the institutions are not funded by federal government and thus had to generate revenue to be sustainable (Mowery & Sampat, 2004). Thus it can be inferred that the concept of the entrepreneurial university defined by Etzkowitz et al. (2000) has been

existing in the US prior the adoption of the Bayh-Dole Act of 1980. Mowery and Sampat (2004) acknowledges that there may be an improved TT outputs post the Bayh-Dole Act of 1980, however the contextual history is critical when copying the act.

2.3.2. Organisational Structure

Organisational structure enables managers to meet their strategic mandate through assigning various roles to human resources with the objective of enhancing operational efficiency. The mandate of the managers at various TTOs vary from creating value, linkages with various stakeholders, making profit and devising business models for various activities along the TT value chain given section 2.1.3 (Landry, Amara, Cloutier, & Halilem, 2013).

Alessandrini et al. (2013) evaluated the organisational structures in 13 TTOs, of which nine where based at the HEIs in SA. Alessandrini et al. (2013) found that most of the TTOs have average staff personnel of three, with roles in IP protection, contract research management and limited business planning for services for knowledge creators. Due to the limited human resources, most of the TTOs are resource strained to execute their functions. Wolson (2007) mentioned that most of the TTOs in South Africa are focused on IP identification and they are not capacitated to exploit the IP. Landry et al. (2013) argue that the TTOs perform various functions along the TT values chain (see section 2.1.3), thus the structure at the different stages ought to be different to enhance TT effectiveness. Different types of TTOs have different types of business models to offer complementary service to their clients and the value proposition needs to be re-structured for different clients (Landry et al., 2013). This requires frequent re-structuring of the TTO to ensure the strategic functions are met.

The TTOs in South Africa were established as per the guideline outlined in the IPR_Act (2008) and offer a one size fits all value proposition. The HEIs that were unable to establish TTO were mandated to establish a regional offices (IPR_Act, 2008). Some of the TTOs are fairly new and do not have “independent offices”, but rather housed at research faculty divisions. Though this structure may improve the linkages between the IP creators and the TT agent, the structure may negatively affect TT success due to different organisation culture and missions (Phan & Siegel, 2006). The management and leadership of the HEI will more likely impact the TTO (Friedman & Silberman, 2003) and ultimately affect the organisational structure of the TTO. Siegel, Waldman, Atwater, and Link (2003) conducted a study to assess and understand the TT process in the United States (US), they found that bureaucratic inflexibility and ineffective management affects the TT outcomes.

2.3.3. Incentive Structure and Funding

Section 2 of the IPR_Act (2008) states that the knowledge creators must be rewarded and acknowledged. The adoption of the IPR Act of 2008 has led to various HEIs establishing institutional strategy for research and commercialisation (i.e. IP policy document). The IP policy document details the incentive structures for knowledge creators and the mission of the TTO (UCT, 2011). The IP policy document is anticipated to encourage the knowledge creators to disclose their inventions at the TTO thus increasing the TTO IP pipeline. Friedman and Silberman (2003) conducted a study to evaluate the effect of incentives (independent variable) on TT process and found that TT success of advanced technologies requires input from the knowledge creators during the development and the marketing phase. Friedman and Silberman (2003) hypothesised that the HEIs with great incentive structures are more likely to generate increased revenue through licencing/royalty income. The hypothesis was not strongly supported by the outcomes of the study; Friedman and Silberman (2003) found that the incentivising the knowledge creators has a negative impact on the cash flow of the TTOs thus ultimately affecting the execution of the TTO mandate. Some of the TTO revenue is allocated to salary payments (CeSTII et al., 2015), thus low budgets may have an impact on recruiting highly skilled human resource for TTOs due to constrains in incentivising them accordingly.

In SA, the HEI researchers are incentivised through publication and are individually rated by the National Research Foundation (NRF) as leading researchers with the objective of building a globally competitive capability system. Thus if the publication benefits outweighs disclosing inventions to the TTOs, researchers are more likely to default to opting for publications (Etzkowitz et al., 2000). Researchers are thus mostly likely to be incentivised for publication relative to the patents or registration of an industry partner.

2.3.4. Age and Faculty Quality

Technology transfer (TT) is a fairly new field in SA (approximately seven years old post the adoption of the IPR Act in 2010). The data published in (CeSTII et al., 2015) was only for bench marking and was the first report released in SA to assess TT landscape post the adoption of the act.

Friedman and Silberman (2003) suggested that seven years lead times have to be allowed before an IP disclosure or a patents can start generating revenue from the licensing of the technology. Friedman and Silberman (2003) supports Mansfield (1991) that technological

innovation have long lead times. Thus newly established TTOs are mostly likely to lack in earnings generated through licensing due to long lead times for technology development.

Friedman and Silberman (2003), hypothesised that older TTOs are more likely to have higher number of licenses relative to the new ones and this hypothesis was found to be strong based on the outcomes of their study. In assessing TT effectiveness, (Phan & Siegel, 2006) mentioned new universities to have a negative impact on TT effectiveness as they have weaker academic research and are not entrepreneurial inclined. The faculty quality was correlated with the IP disclosure which majorly affect the TT process (Friedman & Silberman, 2003). From the literature conducted, it can be inferred that high quality faculty offices generate IP that can be successfully commercialised.

2.3.5. Competency and Capability

TTOs in South Africa are mandated to receive and assess disclosures for commercial viability, protect and secure funds for technology development, IP transactions and IP marketing. The TTO human resource conduct interdisciplinary work and need to have a mixture of the skills to be able execute their functions. The skills required in South African TTOs are outlined IPR_Act (2008), and they are interdisciplinary knowledge, qualification and expertise in the identification, protection, management and transaction of intellectual property. Alessandrini et al. (2013) and Wolson (2007) mentioned marketing and negotiation as critical skills to increase the likelihood of technologies to be transferred. In the 2015 report published on assessing the IP management and TT status quo in South Africa (CeSTII et al., 2015); legal, marketing, scientific/technology and commercialisation/business skills were mentioned by the various TTOs to be important for effective TT.

Landry et al. (2013) suggests that various strengths in with the various TTOs can be leveraged through dismantling the TT value chain in South Africa, and distributing the various function based on the strengths of the respective TTOs. This anticipated to offer tailor made value proposition for various clients and thus enhance TT effectiveness. The process is dependent on the capability and the capacity of the TTOs.

Siegel et al. (2004) found staff placement a limiting factor when establishing TT units as the placement needs to be strategic to ensure that staff has the required knowledge and competencies to execute their functions. Salter and Martin (2001) are of the view that face to face interaction enhances innovation propensity, thus virtual teams can be established among

the various TTOs to address skill shortage and complement the service offered by the TTO along the TT value chain

Technological innovations requires absorptive capability (Lundvall et al., 2002). Innovation is an incremental process requiring tacit and codified knowledge to further advance knowledge (Christopher Freeman & Soete, 1997; Viotti, 2002). Phan and Siegel (2006) conducted literature study on TT effectiveness and recommended that to enhance TT effectiveness, the skill deficiency and training of the TT personnel need to be addressed. The professional accreditation for TT personnel in SA are CLP (Certified Licensing Professional) and RTTP (Registered TT Professional). To be registered as a RTTP, a minimum 5 years working experience is required and approximately 62% of the TT personnel in SA are RTTP (CeSTII et al., 2015, pp. 21, 22). The RTTP is adjudicated by the Association of TT Professionals (ATTP) to address the capability required in the TTOs. The IPR_Act (2008) outlines that NIPMO mandate is to provide support to the TTOs by capacitating them and help them secure IP rights.

2.3.6. Entrepreneurship

The mission of the HEIs is to teach and generate professionals to be adopted in the various industries. However, due to the cut in the GERD, universities in the US and UK had to identify other revenue streams, and this lead to the concept of entrepreneurial university (Etzkowitz et al., 2000; Hindle & Yencken, 2004; Phan & Siegel, 2006). The ethics and social responsibilities of the university need to be addressed prior the TTOs embarking on an entrepreneurial paradigm (Phan & Siegel, 2006)

Mthanti and Ojah (2017) cited Schumpeter (1942) that "entrepreneurship serves a conduit for knowledge filter, linking new knowledge to economic development". Hindle and Yencken (2004) advocated entrepreneurship as the engine for innovation and being essential in the commercialisation of knowledge to create new technology based firms. Entrepreneurship affects the TT process and the extent of the impact is dependent on the mode of TT used. When the mode of TT is creation of Spin-outs, entrepreneurship plays a vital role (Hindle & Yencken, 2004). For Spin-Outs creation, there is a need to identify the market opportunity, business concepts and business model. Most of the technological innovation are new, thus the TT agents require the ability to price technologies accordingly and identify new markets (i.e. market push).

Phan and Siegel (2006) conducted an exploratory study to evaluate the barriers, role and efficiency of the TTOs in the US and they interviewed knowledge creators, the TT personnel and technology recipient. The outcomes of the study inferred that there is a misalignment between the various stakeholders. The TTOs mentioned that the industry is not understanding the environment they are working in and knowledge creators the being unrealistic about the worth of their inventions thus making the negotiation for licensing unrealistic (Phan & Siegel, 2006). The misalignment hinders TT effectiveness.

Alessandrini et al. (2013) and Wolson (2007) mentioned that the South African TTOs do not exploit their IP portfolio for commercial revenue and they are only good in "filling" IP. To advance technological innovations, lateral thinking and prior technical knowledge are required. Hindle and Yencken (2004) stated competencies such as technology management, strategy, risk assessment and financial management required for TT. This makes the need for techno-preneurs vital to enhance TT effectiveness (Hindle & Yencken, 2004)

2.3.7. Effect of Industry Government HEIs Interactions on Technology Transfers

The lack of mature ecosystem in Africa is evidenced by the study conducted by Kraus et al, (2012), where the University Industry Linkages (UIL"s) have an impact in meeting the socio-economic goals. Kruss and Gastrow (2012) suggested connecting people looking for technology inventions, providing feedback loops and helping faculties to further develop technologies in the pipeline can help boost fledging start-up companies. Proactive linkages with the inventors departments can increase TT outputs (Phan & Siegel, 2006). Bercovitz and Feldman (2006) cited the output of the TT process can be enhanced by strengthening the relationship within the helix, with collaborative links between business, innovation protection and knowledge on technology aspects of TT. The interlinkages are anticipated to address the skill shortage and create an environment where there is interdisciplinary skill, thus synergy of the various departments will help achieve this objective.

TT is a bilateral process, in Friedman and Silberman (2003) study, the interactions with the inventor led to increased TT output i.e. licensing of patents and revenue generated. Thus interaction or linkages with the inventors is more likely to increase the efficiency of TT process.

2.3.8. HEIs Historical Background

The HEIs in SA were established based on a colonial system, where education was only for the privileged members of the society(Ministry_of_Education, 2002). The HEIs were funded by

various external sources and research was conducted for the sake of research i.e. with no intension for commercialisation. This might have contributed to the prevailing culture of fundamental research conducted with no intention of commercialisations. The publication culture among the researchers is promoted by the educational mandate and the incentives by the NRF. Wolson (2007) is also of the view that TT is not a priority to the researchers due to teaching mandate.

The mandate of the HEIs in SA is to teach according to the High Education Institution Act of 1997 and HEIs are knowledge creators (White_Paper_Science&_Technology, 1996). There is an expectation that the knowledge generated from the HEIs should be utilised to improve the lives of ordinary South African by enhancing economic growth and where possible eradicate poverty. For the HEIs in SA to embark on an entrepreneurial paradigm, the ethical considerations have to be accounted for (Phan & Siegel, 2006) to ensure that the educational mandate is not distorted (Etzkowitz et al., 2000).

The HEIs were merged between the period of 2001 and 2007 from 36 resulting with 23 public HEIs funded by government (DST_HSRC, 2014/2015) and regulated by the DHET. The merger of the HEIs was envisioned to strengthen the R&D at the public HEIs with the objective of developing the competencies and producing graduates that will enable SA to achieve the social- economic development goals (Ministry_of_Education, 2002).

2.4. Private Sector IP Management Strategy

A concern raised in the DST_HSRC (2014/2015, p. 26) report is that though the SA publication data is impressive, it does not translate into scientific innovations and faster innovation growth. The lack of scientific innovation and economic growth was attributed to be due to the following; (DST_HSRC, 2014/2015, p. 26)

- Research not aligned with the economic progress
- Lack of transfer of R&D outputs into the market place

There is a need to enhance the TT effectiveness in South Africa, especially in strategic areas identified in the ten year innovation plan which are water, farmer to pharma, space science, energy, global change and human and social science (DST_Innovation_Plan, 2008). TT focused in these strategic areas may enhance economic growth as there is market pull phenomenon. Uctu & Essop (2013) cited the biotechnology industry as one of the industries with potential to increase the economic growth, market drive and levels of innovation.

Barnard and Bromfield (2009) conducted a research study aimed at understating the management and development of IP strategy used by Sasol to create competitive advantage and for Sasol to establish itself as a Multi-National Cooperation (MNC). They stated that patenting strategy combined with active use of publication enhanced the technological credibility of Sasol. Publication and patenting can be used as a proxy for technical competence, with strong IP having the potential to attract cutting edge competitors for collaboration. Collaboration with cutting edge competitors has the potential to enhance competencies required for technology development. This strategy can used to enter into foreign markets, and enhance technical competence through open source innovation Sasol used this strategy and thus promoting Viotti (2002) view that developing country(ies) should adopt National Learning Systems to build technical competence.

2.5. Theoretical Framework for Assessment

The Bozeman et al. (2015) contingent effectiveness model (CEM) for TT has been used as a conceptual framework for assessing TT effectiveness in a variety of sectors (Borge & Bröring, 2017; Fulga et al., 2016; Smart & Benaroya, 2016). The Bozeman et al. (2015) model was developed based on the outcomes of TT literature study of federal research in the US. The model was developed to provide TT evaluation criteria that takes into account determinants/dimensions that affect TT effectiveness (Bozeman, 2000; Bozeman et al., 2015; Smart & Benaroya, 2016). The determinants/dimensions that affect TT transfer are categorised into who, how, what, where and who the technology is transferred to. The dimensions are, namely; transfer agent, transfer recipient, transfer media, transfer object and demand environment and transfer recipient (Bozeman, 2000; Bozeman et al., 2015). Incorporating all of these dimensions to evaluate TT effectiveness provides a realistic assessment and thus a multiple effectiveness criteria is required.

The Bozeman et al. (2015) model has seven criteria used to evaluate TT effectiveness and they are ,namely; out of the door, market impact, economic development, political advantage, development of scientific human capital, opportunity cost and public value. A pictorial view of the contingent effectiveness contingent model for TT, showing the interaction between the various dimensions and the possible effectiveness criteria is shown in **Error! Reference source not found.**. The arrows indicates the interdependence of the determinants/dimensions.

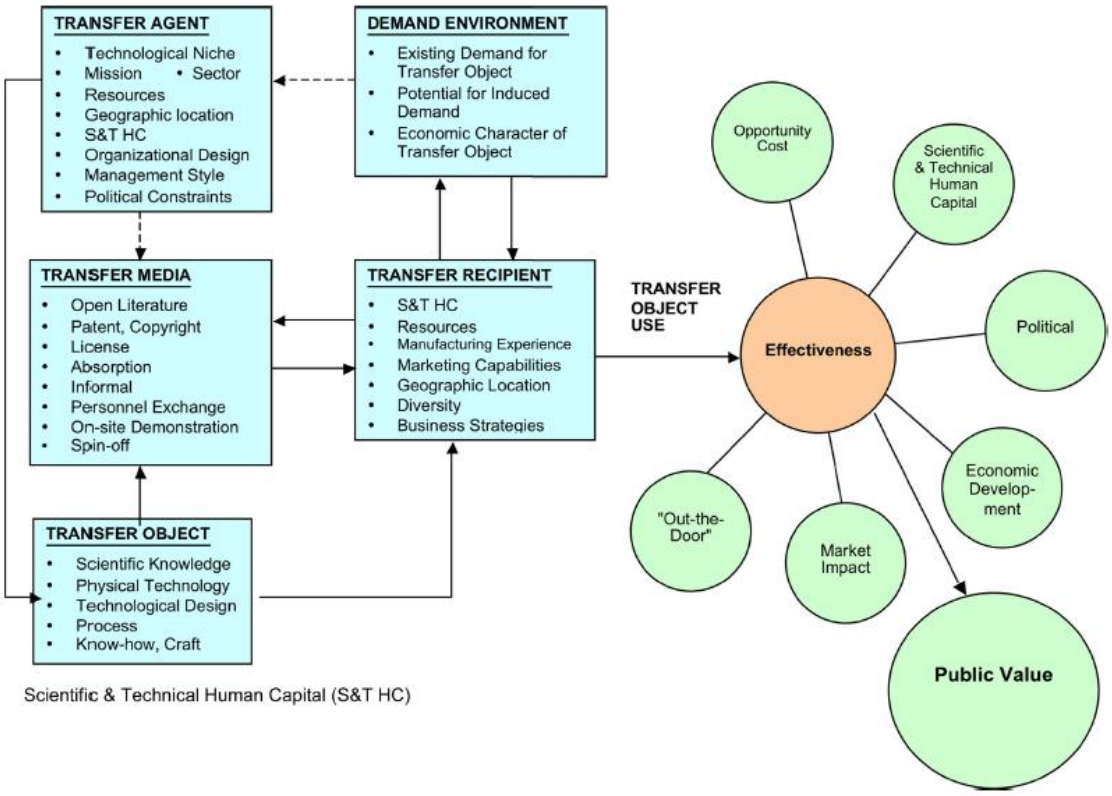

Figure 2: Revised contingent effectiveness model for TT sourced from Bozeman et al. (2015)

The multiple effectiveness criteria by Bozeman et al. (2015) is perceived to be adequate to evaluate TT effectiveness as various stakeholders within the TT ecosystem have various expectations of what TT effectiveness should entail. The effectiveness criteria used by Bozeman et al. (2015) is elaborated below;

- *Out-the door* effectiveness criteria that evaluates if there has been any form of transfer from the TTO. The disadvantage about this criteria is that it places a major emphasis on activity i.e. "tick- box syndrome"(Bozeman et al., 2015). The out of the door criteria is sub-categorised into three sub groups i.e. *pure out of the door, out of the door with transfer agent impact* and *out of the door with transfer partner impact*.
- *Market impact* ~ effectiveness criteria is developed from the microeconomics theory and is used to assess if the transferred technology has an impact on profitability (Bozeman et al., 2015). This effectiveness criteria ignores the non-commercial aspects of technology transfer stated by Upstill and Symington (2002)
- *Economic development* ~ effectiveness criteria to assess if the TT outputs lead to regional economic development (Bozeman et al., 2015). This effectiveness criteria is

suitable to use when assessing return on investment of R&D conducted using public funds. The economic development effectiveness criteria has correlation to GDP growth.

- *Political advantage* ~ effectiveness criteria used to assess if there is any political gains by the various stakeholders involved TT activities. Though this evaluation criteria is more realistic, it does not yield systematic evaluation (Bozeman et al., 2015)
- *Development of scientific human capital* ~ effectiveness criteria to quantity the absorptive capability to perform and utilise R&D outputs (Bozeman et al., 2015; Lundvall et al., 2002)
- *Opportunity cost*~ Bozeman et al. (2015) perceives this effectiveness criteria to be difficult to measure due to the "counterfactual". Assess if the resources used for TT could have yielded an enhanced impact if were used in an alternate area
- *Public value* ~ effectiveness criteria to assess if TT outputs have helped address societal challenges as outlined in the IPR_Act (2008). This effectiveness criteria is difficult to measure and thus proxy's for social impact need to be defined within the respective contexts.

The contingent effectiveness model for TT by Bozeman et al. (2015) will be adequate to use as conceptual framework to assess TT effectiveness at South African TTOs. In the Annexure to the Frascati manual (OECD, 2012), it is cautioned that when assessing TT effectiveness in developing countries the metrics used to assess effectiveness in developed countries are inadequate to use as developed countries have mature NSI and the TT is more relatively old. TT is new in SA, thus the use of a conceptual framework that takes into account the contextual background (i.e. barriers experienced by the TTOs to execute the core function) to assess TT effectiveness is adequate to use as the outputs of the assessment can be used to implement strategies that will enhance TT effectiveness in SA. An advantage of using the Bozeman et al. (2015) contingent effectiveness model for TT is that effectiveness is measured using various multiple criteria and impact of determinants on TT effectiveness is integrated .

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3. CHAPTER 3: RESEARCH STRATEGY AND METHODOLOGY

3.1. Introduction

The objective of the research study is to assess TT effectiveness at TTOs based at HEIs. The TT effectiveness will be assessed using the IPR-Act (2008) and contingent effectiveness model of TT developed by (Bozeman, 2000; Bozeman et al., 2015). The methodology and strategy followed to conduct the research study is outlined in this chapter.

The tools and the techniques that were used to gather empirical data used to answer the research questions are discussed. The sample frame selection criteria, ethical considerations, and reliability and validity of the empirical data collected are also discussed.

3.2. Research Strategy and Design

The core functions of the TTOs and the challenges experienced in executing the core functions will be determined using qualitative research method. The qualitative research guidelines by Onwuegbuzie, Leech, and Collins (2010) and Bowen (2005) were used to ensure the research study is conducted in a satisfactory manner. The qualitative research method is used for the study because TT is new in SA (relative to the developed countries) and some of the metrics used to measure effectiveness are under developed (CeSTII et al., 2015). Hence exploratory qualitative research method is used to assess TT effectiveness at the TTOs.

The empirical data for the research study was collected using structured interviews. Stakeholders involved in the TT ecosystem such as TTOs, TIA, NIPMO and the IDC were interviewed. Thematic method was used to analyse the empirical data. The themes that emerged from empirical data analysis were reported using descriptive method. The IPR_Act (2008) was used to provide a contextual assessment criteria for TT effectiveness as TTOs were mandated to be established at HEIs post the adoption of the IPR_Act (2008). The themes that emerged were discussed with reference to literature study outcomes (i.e. Chapter 2).

The contingent effectiveness model for TT developed by Bozeman et al. (2015) was additionally used as a conceptual framework to assess TT effectiveness. The research methodology employed in this research study takes into account the outcomes of the work by Mowery and Sampat (2004), that the IPR_Act (2008) has to be contextualised to assess TT effectiveness. Both the IPR_Act (2008) and the contingent effectiveness model for TT

(Bozeman et al., 2015) are anticipated to provide a holistic assessment criteria for TT effectiveness. The advantage of the Bozeman et al. (2015) model is that it accounts for the interdependencies of various inputs that have impact on TT effectiveness, thus allowing for a holistic assessment of TT effectiveness.

Borge and Bröring (2017) used the contingent effectiveness model for technology transfer as a conceptual framework to assess the effectiveness of technology transfer in the biotechnology sector. Borge and Bröring (2017) indicated that the model is suitable to use to assess TT effectiveness in the in biotechnology sector due to the interdisciplinary nature of the sector. The assessment criteria is dependent on contextual dimensions such as transfer agent, transfer environment, transfer recipient, transfer media and transfer object. Smart and Benaroya (2016) also used the Bozeman et al. (2015) model as a conceptual framework for comparative analysis of the TT effectiveness in the space sector. Smart and Benaroya (2016) indicated that variety of factors affect TT effectiveness, with effectiveness perceived differently by the various stakeholders involved in the TT ecosystem. Thus the use of the effectiveness contingent model for TT takes into account the externalities prior to the TT taking places. The model was thus chosen to be used for the research study to evaluate TT effectiveness taking into account the barriers experienced in executing the TTO functions. This assessment criteria was deemed correct to use as the NSI in SA is fragmented and TT was officiated less than a decade ago.

Bozeman et al. (2015) categorised the metrics for effectiveness into seven criteria, namely, public value, opportunity cost, political, out the door, market impact, and economic development, scientific and technical human capital.

3.2.1. Selection of Participants

The HEIs were merged between a period of 2001 and 2007 to undo the education system that was engineered by the apartheid government to segregate based on the race (Ministry_of_Education, 2002), resulting with some of the HEIs inadequately resourced relative to the others. The HEIs were merged as part of the transformation agenda for SA to generate the human source capital to participate in a democratic society to meet the socio-economic agenda (Ministry_of_Education, 2002). The HEIs merger resulted with four types of HEIs, namely (Ministry_of_Education, 2002);

- *Universities* -traditional universities which existed prior the merger in 2004 (Ministry_of_Education, 2002). This type of HEIs is characterised to be highly research intensive based on the number of publication (DST_HSRC, 2014/2015)
- *University of Technology (UoTs)* (*previously known as Technikons)* strategic mandate was to generate the human resource capital and vocational training (Ministry_of_Education, 2002). The research output of the UoTs has increased during a period of 2011to 2015 with the DST_HSRC (2014/2015) stating the increased research output to be due to the DHET and NRF incentive structure. The Technikons that existed within the same region were merged.
- *Comprehensive Institutions* - resulted from a merger between the institutions that were referred to as Technikons pre-2004 and university(ies) (Ministry_of_Education, 2002).The objective of this type of merger was to strengthen the research background and achieve the race transformation agenda (Ministry_of_Education, 2002). Though the merger is perceived to have affected the research output from the comprehensive university (DST_HSRC, 2014/2015 pg. 28)
- *National Institutes for Higher education* ~ existed post the merger of the HEIs and is mainly a tuition based institution (Ministry_of_Education, 2002).

The merger resulted with the number of the number of the HEIs in SA being reduced from 36 to 23 (CeSTII et al., 2015; Ministry_of_Education, 2002). The sample frame was selected such that it represents TTOs from the various types of HEIs in SA as they were all mandated to establish TTOs (IPR_Act, 2008). The National Institutes for Higher learning were excluded from the study as they are mainly tuition based institutions. The sample frame was selected such that there will be a contrast between the same type of HEIs located in the same region. Some of the selected TTOs are based at the universities that were not affected by the merger. The sample frame for the study is given below;

- **Traditional universities**
    - University of Cape Town (UCT)
    - University of Free State (UFS)
    - University of Pretoria (UP)
    - University of the Witwatersrand (Wits)
    - Stellenbosch University (SU)
    - University of the Western Cape (UWC)

- **Comprehensive Institution**
    - University of Johannesburg (UJ)
    - Nelson Mandela University of Technology (NMUT)
- **University of Technology (UoT) previously known as Technikons**
    - Cape Peninsula University of Technology (CPUT)
    - Tshwane University of Technology (TUT)
    - Mangosuthu University of Technology (MUT)
    - Vaal Triangle University of Technology (VUT)
    - Tshwane University of Technology (TUT)

A total of 13 TTOs were envisioned to be interviewed. Interviews could not be secured with the University of Kwa-Zulu Natal (UKZN). It was desired that a minimum of 12 HEIs be interviewed to minimise response bias as there are 23 HEIs in SA.

The selected sample frame is envisioned to help provide context that can be used to evaluate TT effectiveness at TTOs based at HEIs. The selected sample frame represents approximately 56% of the HEIs in SA which are funded by government. Thus the data will used with the official DST and DHET reports to minimise biases.

3.2.2. Profile of Interviewee

The directors (some in acting positions), TT managers and TT officers/professionals of the various TTOs were interviewed. Most of the interviewees have previously worked at various TTOs or worked at the PROs in technical disciplines. Some of the directors interviewed have PhD in technical disciplines, masters in entrepreneurship venture development and management business administration (MBA). Interviewees with prior experience in other TTOs gave a contrast relative to the prior TTO experience. Their views about their previous office were found to be valid during interviewing those particular TTOs.

3.2.3. Profile of Interviewees Technology Transfer Stakeholders

NIPMO as the statutory body responsible for the establishment of the TTOs in SA was interviewed to provide a view on the status quo of TT effectiveness at the TTOs. The functions of the directorate of advisory support of NIPMO are to finance the establishment of the TTOs, re-capacitate the TTOs staff through training and workshops and conduct IP awareness to ensure that the various stakeholder understand and comply with the IPR_Act (2008). The

interviewee had over 15 years of prior working experience and previously worked within the South African NSI.

Technology Innovation Agency (TIA), established based on the Technology Innovation Agency Act of 2008 was interviewed. The mandate of TIA is to promote the development and exploitations of the R&D outputs generated using public funds for the interest of the people of the republic. TIA's mandate is to assist the state to stimulate innovation and ensure the IP generated from research is translated into products and service that will enhance economic growth ("Technology Innovation Agency Act," 2008). An executive of innovation funding and pre-commercialisations support unit of TIA was interviewed.

The Industrial Development Cooperation (IDC), with the vision to "support commercially sustainable industrial development and innovation" was also interviewed. The interviewee from the IDC's new industry development unit works with the various TTOs and other stakeholders in the TT ecosystem. The collaborative that is done with TTO space entails industry development in the energy storage, fuel cell and renewables. The interviewee has prior experience in the private sectors and over 15 years working experience.

The director of innovation and technology policy from the Department of Trade and Industry (the dti) was interviewed to provide an overview of the support services provided by the department in the TT ecosystem. Also the interviewee was to provide an overview of the role of Companies and Intellectual Property Commission (CIPC) and Support Programme for Industrial Innovation (SPII) in the TT ecosystem. The SPII is a funding programme responsible to promote technology development by providing development funds for innovative products/process. The TTOs register the patents with the CIPC.

South African Venture Capital Association (SAVCA) was contacted to assist with list of the venture capitals (VC's) who are playing a role in the TT space through funding technology start-up companies in SA. There is approximately a total of 85 VCs in SA with only five participating in the early technology start-up funding (SAVCA, 2013).

SUCA, a start-up CEO Advisory company, providing advisory services to entrepreneurs in the technology start-ups and assisting with securing funding for technology development and starting new business. The objective of the interview was to contrast what the private sector is doing to transfer technologies into the market vs TTO activities. The interviewee previously worked in the venture capital sector.

3.3. Research Methodology

TTO directors and TT managers were interviewed to collect empirical data for the study.

3.3.1. Primary Data: Structured Interviews

The empirical data was collected using structured interviews method. The guidelines for structured interview method were adopted from Price (2002) to minimise the researcher's bias.

The interview where conducted telephonically, using skype and in person at the respective offices of the participants. A consent to record the interview was obtained from the interviewees. The recordings were only used for recollection of by the researcher when presenting and analysing the outcomes of the research study. The recording where supplemented by the notes taken during the interview, the notes were used to structure follow-up questions during the interview. The interview questions used for the respective stakeholders are given in Appendix 1, Appendix 2 and Appendix 3.

The interviews ranged between 30 minutes to one hour. The interview questions were asked in no sequential order to allow for flow of the interview process.

3.3.2. Secondary Data: Policy Documents

The government documents and IP policies of the various HEIs were obtained from the webpages of these respective institutions. The figures and some of the quantitative data was sourced from government documents was used as secondary data. The following official reports from the DST used;

- South African National Survey of Intellectual Property and Technology Transfer at Publicly Funded Research Institution (CeSTII et al., 2015).
- South African National Survey of Research and Experimental Development(DST_HSRC, 2014/2015).
- South African Science, Technology and Innovation Indicators (NACI, 2016).

3.4. Data Analysis

3.4.1. Analysis of the Interview Data

The interview recording were self-transcribed using Google documents voice editor. The various themes emerging from the interviews were coded and categorised using Microsoft Excel. The themes were grouped in various sheets according to the type of HEIs i.e. UoTs,

traditional research universities and comprehensive universities. The themes were grouped per type of HEI to assess if there is a correlation of the research outcomes within a group of TTOs from the same type of HEI.

Thematic analysis was used to deduce the finding of the research study. The data collected from the interviews with other TT stakeholders such as NIPMO, IDC and TIA were used to complement and contrast the themes emerging from the TTOs interviews.

Various official government reports and figures, recommendations and the conclusions from these report were used as secondary data to complement themes that were emerging from the empirical data i.e. interviews.

3.5. Ethical Considerations

The qualitative research methods guidelines given by (Bowen, 2005; Onwuegbuzie et al., 2010; Price, 2002) were used to minimise the likelihood of the researcher to influence the outcome of the results. The interview questions were kept consistent to avoid biasness by the interviewer, however the order was not kept the same depending on the responses of the interviewees to avoid discontinuity during the interview process.

Permission was requested from interviewee prior to conducting the survey and the interview. Consent letter is given in Appendix 5 was send prior the data collection. The participants are only be mentioned in the sample frame and the results are presented in an anonymous fashion to protect the integrity of the participants. Though the views of the TT stakeholders such as TIA, IDC, and NIPMO were presented in an anonymous fashion, it may be viewed that they are not as these stakeholder exists as singular entities.

3.6. Reliability and Validity

3.6.1. Triangulation

Triangulation is method used to enhance the validity of the data to ensure that the results are reliable and not one dimensional. Thus the various participants in the TT ecosystem were interviewed to generate data for contrasting the views of the TTOs.

NIPMO has an oversight role on the management effectiveness of the TTOs as outlined in the IPR_Act (2008), thus to generate data that provides a holistic view of the TTO mandate, a representative from NIPMO was interviewed.

Technology development requires an ecosystem that enhances commercialisation (Chris Freeman, 1995), thus the innovation funding and pre-commercialisations support unit of TIA was interviewed to provide data for assessing technology development fund in SA and the criteria used for project funding.

The IDC's mandate is to provide funding for development of new industries and thus enhance the economic sustainability of the country. The role of the dti entail providing frame of reference in areas such economic empowerment, industrial development, legislation and business regulation. Thus these stakeholder will be interviewed for generate data for triangulation.

3.7. Limitations of the Research Study

The study is subject to following limitations and thus they need to be accounted for when adopting the outputs from this research study;

- The sample consisted of only 52% of the HEIs in SA. The traditional universities where fairly represented and some of the previously advantages HEIs are not included in the sample frame.
- The DST reports and the some of the secondary data used in this study was reported in 2014/2015, thus have time frame limitations. Thus most of the values quantified in this study might have changed.

3.8. Summary

There is an imperative for South Africa to invest in technological innovation and build the competitive advantage to transition from a resource based to a knowledge based economy. Assessing the barriers that affect TT will help create improved management systems that can be used to enhance TT effectiveness and help achieve the socio-economic goals.

4. CHAPTER 4: RESEARCH FINDINGS AND DATA PRESENTATION

4.1. Introduction

The primary data collected during the interviews is presented in this chapter together with the secondary data sourced from "relevant" government official reports. The data is presented using descriptive method. The IP policy documents of the various HEIs were also used as secondary data. The results are presented according to the themes that emerged from answering the following research questions;

- What are the core functions of the TTOs?
- What are the barriers/challenges experienced by the TTOs when executing their core functions?
- What are the metrics used to quantify effectiveness at the various TTOs?
- How does the ecosystem enhance TT effectiveness at the TTOs?

The views of the interviewees from the dti, IDC, NIPMO and TIA were used where there was coherence with the views of the TTO interviewees. The views of these stakeholders were also used to provide contrast so there is a holistic representation of the results.

The research study is limited to the TTOs based at various HEIs. The HEIs were merged and restructured to leverage the strengths of the various HEIs (Ministry_of_Education, 2002). The impact of the historical background of the respective HEIs on TT effectiveness at the various TTOs is also reported.

4.2. The Core Functions of the TTO

The core functions of the TTOs are outlined in the IPR_Act (2008) and they are, namely; identify, protect, manage, transact and commercialise IP generated using public funds (IPR_Act, 2008). The interviewees from the various TTOs mentioned that their core functions are as outlined in the IPR_Act (2008). Only one participants mentioned not having a dedicated personnel assigned to conduct the TTO functions; that the TTO functions are executed by the research office. The interviewee mentioned that this inhibits execution of the TTO functions as outlined in the IPR_Act (2008) due to lack of the human resource capital. The TTOs based at the traditional research HEIs offer short courses in addition to executing the functions outlined in the IPR_Act (2008).

The interviewees mentioned they conduct IP awareness campaigns to encourage the researchers and students to disclose their inventions. The IP awareness campaigns are also aimed at educating the university community about the TTO services and promoting the IPR_Act (2008). The TTOs use various platforms such as newsletters, breakfast shows and meetings with the various research faculties to promote IP awareness.

The TTO services various faulty offices of the HEI by ensuring that IP is disclosed, protected, managed, marketed and transferred for market use. TTO personnel conducts due diligence to identify the uniqueness of the disclosure, conduct market analysis to determine the best possible route to protect the IP and engage with the industry to identify partners that are more likely to utilise the IP. In cases where the IP disclosed requires further development, the TTO is responsible for administering and sourcing development funds to ensure technology is developed and packaged adequately to attract potential investors.

The interviewees from the various TTOs mentioned that they are responsible to ensure that they operate in sustainable manner and produce return on investment for the R&D conducted by the HEI researcher. Two of the participants mentioned that their TTO's are one of the income generating streams for their respective HEI. The challenges/barriers experienced by the TTOs when executing their core functions are detailed below.

4.2.1. Disclosures

Most of the disclosures received at the TTO are fundamental, and most are at Technology Readiness Level (TRL) 2 to 3 (refer to the commercialisation framework in Figure 1), which is mainly a proof of concept. The challenge with fundamental research disclosed to the TTO at an infancy stage is that the disclosure maybe viewed to have a commercialisation potential while it does not due to lack of competent personnel to conduct due diligence at the TTO. Also, IP may be rejected during the disclosure phase while it has the potential to be commercialised. The TTO service the entire university community and conduct due diligence for disclosures across all the various faculty offices. The disadvantage about this is that The TT professionals have limited technical expertise across the various sectors, limited exposure (most on average have working experience of a minimum of seven years) and have narrow network.

In some cases, the disclosure due-diligence process is rushed to allow researchers to publish. This creates a situation whereby an adequate "follow-up" due-diligence process is conducted post publishing to understand and identify the potential to commercialise the technology. It is critical for the disclosure due-diligence to be conducted satisfactorily as the outputs affects the

entire TT value chain. The main disadvantages of poor disclosure due diligence due to lack of the required proficiency (ies) at the TTOs were stated to be;

- Inability to package a technology in way that it demonstrates value and communicates a positive message to attract the potential investors.
- Increased TTO operating cost due to accepting the disclosure that have no commercialisation potential. The opportunity cost will be lost during the technology development and patent cost maintenance.

NIPMO mentioned that only a limited number of the TTOs are competent to conduct due diligence upon receipt of the disclosures. NIPMO is of the view that improving the capability of the TTOs to conduct due diligence has the potential to enhance TT effectiveness.

4.2.2. IP Protection

Post the disclosure due diligence, a suitable route is identified to protect the IP. The protection mode is selected such that it will enhance the likelihood of the technology to be commercialised. The TTOs based at the traditional research universities have in-house lawyers responsible for IP protection and other legal matters pertaining to TT process, e.g. Memorandum of Understanding (MOU), Non-Disclosure Agreement (NDA). The TTOs based at the UoTs mentioned have limited resources for IP protection; with some outsourcing the IP protection function. The challenge experienced with outsourcing the IP protection function is that the UoTs have to adhere to the Public Management Finance Act (PMFA); which requires the TTOs to procure the expertise in line with the guidance of the act. The challenge with this process was stated to be the inability to procure services of a suitable patent attorney with the required expertise. This was mentioned be a potential risk that may lead to an inadequate IP protection and later affect the IP commercialisation potential.

The IP protected is lodged with the CIPC. An interviewee from the dti explained the role of the CIPC in the TT ecosystem in SA. It was stated that the role of the CIPC is to conduct examination and registration of IP, however CIPC is currently building capacity for patent examination. The interviewee mentioned the disadvantage of a lack of an examination office is that it is hard to derive economic benefit from the IP portfolio registered by the TTOs at CIPC. The interviewee stated that;

> "*It is more like a library of patents with no commercialisation potential. The examination office determines the novelty of IP registered*"

The dti interviewee is of the view that lack examination in SA encourages people seeking market to register their IP and thus inhibiting the technologies with market and scalability potential from penetrating the market. Some of the interviewees from the TTOs mentioned registering their IP at creditable international patent office's to hedge against lack of patent examination capability in SA.

A stakeholder from the IDC is of the view that IP protection should not be at the detriment of technology commercialisation, stating that;

> *"IP protection generated using public funds takes priority relative to technology commercialisation in SA. This may lead to missing entry to markets at the opportune time"*

IP was perceived by the various interviewees as an enabler to be competitiveness and for industry (ies) to thrive, there is need for a competitive advantage.

4.2.3. IP Marketing

Market analysis is conducted to understand and identify an optimum commercialisation route. The various TTOs use platforms such as innovation bridge and innovation summit to market their technologies and to enhance the industrial linkages. One interviewee mentioned that the challenge experienced with the innovation bridge is the management of the IP portals to ensure that they communicate the correct message to the potential investors. This may infer that the platforms used to market the IP are underdeveloped.

The challenge experienced with IP marketing is lack of staff with the appropriate competencies to market the IP and insufficient funding for marketing. The interviewees mentioned that marketing may be augmented by involving external stakeholder (e.g. technology recipients and industry partners) during the development phase; however though ideal, the challenge is ensuring that IP is not disclosed to third party. Involving the stakeholders at an early stage was perceived to have potential increase the TTO administration duties as they have to manage MOUs and NDAs signed by the various stakeholders. Involving the technology recipients at an early stages of development was envisioned to enhance the likelihood of technologies to be easily marketable.

Some TTOs have monthly forums where they invite the researchers to present their research outputs to industry stakeholders. These forums are aimed at creating an awareness of the technology expertise within the HEI to external stakeholders. Various TTOs publish their IP portfolios on their websites, detailing the stages of development/ progress along the TT value

chain. However some do not have such platforms (approximately 50% of the participants), especially the TTOs based at UoTs.

In some cases, the public is allowed to use IP for a limited duration (e.g. year) to provide user feedback to the TTO. The user feedbacks are used to enhance technology development, improves technology awareness and enhance the probability of technology (ies) to be absorbed by the end users.

4.2.4. IP Commercialisation

The TTO use outputs from market analysis study, techno-economic analysis, and financial projections to determine a suitable mode for TT. Most of the interviewees mentioned using either licensing or the spin-outs as modes of TT. The other modes of commercialisation mentioned by the interviewees are in-house incubation and collaboration with the industry. The commercialisation mode vary from project to project and it is handled case by case. The commercialisation mode is also dependent of the technology type, regional economic outlook, characteristics of the researcher and availability of development funds.

The interviewees are of the view entrepreneurial skills have an impact on IP commercialisation. Almost 90% of the participants mentioned that researchers do not have the entrepreneurial mind-set, with researchers referred to as serial publishers because of the "short term" incentives offered for publication by the NRF. The interviewees (80%) mentioned that researchers do not have the time for the lengthy TT process and this affects the commercialisation strategy as they default to publishing. At times to accommodate the needs of the researchers and allow them to publish, the due diligence process is rushed. One of the participants mentioned that;

> *"The problem is we are looking at how do we quickly tick the boxes and close the project, which is really bad because that is not what the system of TT was implemented to do."*

The TTOs that existed prior the adoption of the IPR_Act (2008) mentioned having a commercialisation sub-unit. It was mentioned that the commercialisation team is tasked with;

> *"administering the TIA seed fund, move different technologies across the various TRLs, align the technologies for next stage funding, interaction with the potential licensees or assisting entrepreneurs who are considering establishing start-up company".*

Having a dedicated team of professional focusing on technology commercialisation was deemed to enhance TT effectiveness.

The UoTs interviewees stated that the presence of the Technology Stations enhances the commercialisation potential of the technology as they are able to develop the prototypes. The prototypes are used as bargaining power during the negotiations with potential investors to demonstrate the usability of the product.

It emerged from the interviews that the spin-outs are opted for creation of new markets. For incremental innovations, competitors are used to determine the commercialisation strategy as they offer an opportunity to develop the technology to enhance market adoption. Thus in such scenarios, technology is licensed to augment products and services of the existing market. If a spin-out is opted as the mode for transfer, some of the TTOs conduct skill audit to determine the competencies of the "new entity "absorbing the spin-out, with the objective to enhance the success rate of the spin out company. In other cases, the HEI form a joint venture to enrich the composition of the spin-out team with the objective to increase the success prospect of the spin out company.

The innovation funding and pre-commercialisation and support business unit of TIA indicated that the role of TIA in the TT ecosystem is to offer both financial and non-financial support to ensure that technologies enter the pre-commercialisation stage (i.e. TRL 8 in Figure 1). Below are some of the challenges experienced by TIA;

- The IP portfolios received by TIA from the TTO are on the lower part of the innovation chain (i.e. TRL < 8) and thus not meeting TIA's minimum requirements for seed funding
- The projects teams lacking the competencies to develop technology driven projects for commercialisation.
- The technology intent not articulated well by the various applicants.
- Insufficient funding for technology development

The challenges outlined affect the potential for the technology to be commercialised and thus also affecting the commercialisation mode. It was indicated that TIA has established technology stations and platforms as a mitigation strategy to counteract some of the outlined challenges.

4.2.5. IP Management

The TTO directors are responsible to ensure that their units are managed sustainably. Most of the TTOs are self-reliant and get little support from the respective HEIs, especially with the staff complement required to operate the TTO. The major themes that emerged with the

management of IP were lack of human resource competencies, lack of finance and lack of alignment with the HEI executives. The TTOs have various strategies for managing their human resources and financial resources to ensure that they are able to execute their mandate. To leverage the skill base at a TTO, an interviewee stated that;

> *"To leverage the skill balance we have operation and project meetings, the objective of these meetings is to provide feedback, challenges and networking within the TTO so that everyone in the office is aware of the status of the project and where they can be able to contribute their expertise".*

To leverage and maximise resources, some of the TTOs work with the researchers who are willing to work with the TTO and are excited about their inventions. Some of the interviewees mentioned that;

> "*These are the best people to work with* ".

Finance was identified as a major challenge experienced for management and execution of the TTO core functions. The TTOs that existed prior the adoption of the IPR_Act (2008) seemed to have control of their operational finances; with some mentioning that they have buffer/ reserves from the previous years to enable them to operate sustainably. These TTOs mentioned that they have income generated from royalties or licenses agreements and this additional funding helps with effective management of TTO functions. The new TTOs (i.e. established post the IPR Act), do not have reserve funds due to the time it takes before revenue can be realised from licensing technology as technology (ies) have long lead times.

All the interviewees mentioned their TTOs administer the TIA seed fund aimed at technology development. Some of these funds are perceived by the HEI executives not aligned with the TTOs mandate to be "money bags for research unit rainy days". NIPMO advised that the budget that was used for rebates for the IP registered is no longer available due to government budget cuts. The interviewees mentioned that the cut of rebates has affected IP financial management at the TTOs.

Most of the TTOs rely on NIPMO for staff financial support and some HEIs management support the staff complement required to execute the TTO functions while others do not. Thus the various TTOs have different management styles based on the characteristic of the HEI and the historic background of each HEI.

The TTOs conduct IP awareness campaigns, however disclosure is not enforced amongst the researchers. The TTOs have links with the industry to enhance the probability of technology to be absorbed to the market. The links are done at late stage of technology development and an interviewee mentioned that

"*It will be nice for the researchers to be present when receiving the industry feedback. It will be ideal to get industry involved during research phase"*

4.2.6. IP Management in the Private Sector

SUCA, a private company offering innovation advisory, start-up strategy and advisory services, entrepreneurial ecosystem and start-up community advisory (SUCA, 2018) was interviewed to contrast the services offered to entrepreneurs by the private sectors with those offered by the TTOs. SUCA conducts the same functions as the TTO (except for disclosures due-diligence and management), they assist the private sector or individuals who approaches them with technology development with the objective of commercialisation. The challenge that they experience is that various entrepreneurs do not approach entrepreneurship as a profession but a means to an end. Also failures of the ecosystem was mentioned as major challenge inhibiting the TTOs from executing their functions. Some of the ecosystem failures that were highlighted are insufficient funds and low TRL requiring development funds for modification.

The challenges experienced by the TTOs when executing the core functions are outlined in section 4.3. The challenges were identified through analysis of the various themes that emerged from the interviews.

4.3. Challenges/Barriers Experienced Executing the TTO Core Functions

4.3.1. Organisational Structure

The primary mandate of the HEIs in SA is teaching and producing graduates that can be absorbed in the various sectors of the economy. The interviewees are of the view that this mandate takes priority when allocating the resources for executing various functions within the HEIs e.g. staff complement required to execute TT functions not a priority. Some of the interviewees were of the view that the executive management at HEI are not acquainted with the functions of the TTO, hence there is a misalignment in what is perceived to be the objective of TTO.

The TTOs that participated in this research study have various organisational structures and some with defined organograms displayed on their webpages. The prevailing structures that emerged from the interviews and confirmed from the webpages of the various institutions are;

- TTO reporting to Deputy Vice Chancellor (DVC) of research and integrated with the research unit.

- TTO reporting to DVC of research with the sub-division of innovation support unit.
- TTO existing as private company owned by the HEI, some reporting to CEO and some to the DVC of research and innovation. Some of the TTOs operate as private company of the HEI and report to a board of directors comprising of the heads of department from research, legal, management and commerce schools of the respective HEI.

The interviewees are of the view that the organisational structure within which the TTO exists affects the IP management and TT effectiveness. The interviewees reporting to the DVC of research viewed this structure to be an impediment to executing their functions, stating that,

> "*The grey area is that we are tasked to do certain things because we are perceived to be an office of doers. There is a disconnect between the upper management and what the TTO is supposed to do"*
>
> *"We do not have a TTO but a research office. What we do at the research office is more linked with the activities at the TTO. We have issues with resource and competency building. The university as a whole including the management to come up with a strategy for TT".*

The interviewees that do not receive support from the top executive, mentioned they were negatively affected by this organisational structure (i.e. reporting to the DVC of research). However, some interviewees reporting to the DVC of research viewed the structure as an enabler for TT, as it allows the TTO to direct R&D within the HEI, thus ensuring that R&D efforts are aligned with the industry needs. These interviewees stated that;

> "*Our major differentiator is that we are involved in the conception phase of the IP i.e. we offer direction to research fund. The functions of our TTO are slightly different to the other TTOs because the TTO is integrated within the research office. The research objectives are clearly outlined from the onset so that there is a clear research pipe line aligned with the industry needs. The research unit is aware of the TT services and thus this helps to control publication"*
>
> "*Innovation office is merged with research office, this structure allows for engagement with researchers and ensures that R&D is industry focused. We stimulate innovation among the researcher's and our interaction with the industry enables us to bring in research industry problems"*

The TTOs reporting to the DVC of research viewed this type of structure as a positive enabler to control publications and improve research pipeline. Being part of the research unit provides the TTO control over the research, ensuring that R&D outputs are not in the public domain prior being protected. These interviewees mentioned that they have industrial linkages and the research conducted at their HEIs is aligned with the regional economic developmental goals.

The TTOs that operate as private companies have defined organisational structure; with the defined sub-division such as IP management, IP commercialisation and legal contracts. These sub-units have dedicated personnel to conduct specific functions. The interviewees from TTOs that operate as private enterprises of the HEI mentioned that this type of structure leverages their negotiation with the industry. This kind of structure eliminates the bureaucratic university lengthy approval process as it viewed to prohibit the industry from doing business with the TTO.

Some of the TTO with the defined organisational structures have support services sub-units such as administrators and accountants to manage the TTO finances. However, these support functions were not observed at some of the TTOs (based on the webpages of the various HEIs), with some only indicating two or one personnel conducting the TTO functions. This was observed at TTOs that were established prior to the adoption of the IPR_Act (2008).

4.3.2. Culture

The HEIs are rated based on the number various publications and publication is heavily incentivised. The researchers are rated by the National Research Fund (NRF) based research and publication, thus publication is the predominant culture within the HEIs. The TTOs find it challenging to engage researches to persuade them to disclose and protect their IP prior publishing. With no incentive structure for disclosures and the rewards for disclosing taking long to manifest, most researchers default to publishing without disclosing. It was stated that technology (ies) have long lead times to generate revenue and thus researchers default to publishing for quick tangible rewards i.e. both monetary and credibility of the researcher. Publishing affects IP pipeline at the TTO.

It was mentioned that the culture of conducting blue sky research is embedded in academia and most of the researchers are conducting fundamental research with the end goal of teaching not for commercialisation. Hence most of the research outputs disclosed to the TTOs is fundamental and does not have the potential to be taken in the market.

The TTOs interviewees were of the view that most researchers are not entrepreneurial and view the TT process as time consuming exercise. However there are rare cases where researchers are entrepreneurial with one interviewee mentioning that;

"True researchers find good industry partners"

An interviewee from the IDC is of the view that to improve TT effectiveness, the various stakeholder within the ecosystem need to have a risk appetite. The interviewee was of the view that the TT ecosystem has a low risk appetite and this is evidenced by the funding criteria by most technology development funds where return on investment is highly prioritised. To enhance technology commercialisation, some of the interviewee proposed that entrepreneurship to be introduced at an undergraduate level for all disciplines to educate the researcher prior they transition into postgraduate degrees. This is envisioned to instil entrepreneurial culture among the researchers.

The interviewees stated that TT happens through relationships; and hence TT professionals need to interact with the researchers, take curiosity in the researchers work, continuously learn and enhance the networks within ecosystem. Most of the interviewees are of the view that researchers are not aware of the services offered by the TTOs. TTOs interviewees mentioned that they do a lot of IP awareness campaign on campus to clarify the role of TTO.

One interviewee cautioned against the predominant culture within the TTOs of using number of spin-outs and licenses to measure effectiveness, proposing that the socio-economic impact be used as a measure for effectiveness.

4.3.3. Incentive and Remuneration

The interviewees are of the view that researchers are poorly incentivised for disclosing their IP or commercialising IP. The publication culture is adequately incentivised and it is viewed to be contributed by the primary mandate of the HEIs, which is teaching and generating the graduates that can be absorbed into the various sectors of the economy. The TTOs that are supported by the top executive management of the HEI have IP commercialisation as part of the KPIs of the researcher's. Some of the TTOs interviewees have cautioned on the incentives structures for researchers working with the TTOs as it may attract disclosures that have no commercialisation potential and strain the limited financial resources within the TTOs. An interviewee from the dti stated that the non-examination of IP by the CIPC encourages the

knowledge creators to "*patent for the sake of patenting*" with some driven by the objective to meet the scorecards of their respective institutions.

It was stated by some of the interviewees that the remuneration policy of the HEIs inhibit the TTOs from hiring professionals with appropriate competencies at a competitive market salary; especially for the TTOs which exist within the research unit of HEI and do not have reserve funds to manage TTO activities. An interviewee proposed that NIPMO should regulate the pay scales at the TTOs to minimise poaching of good performing TT professional by TTOs that can afford higher salary scales. An interviewee suggested that;

> *"Human resources at the HEIs have to be notified that the technology transfer professionals will be paid at a higher salary scale because that is mandated by a regulatory body for example NIPMO. Whereby NIPMO will regulate the remuneration salary so the TT professionals are adequately incentivised".*

The regulation of TT professionals' salaries by NIPMO will enable the various TTOs to adequately incentives their staff without worrying about non-compliance to the HEIs incentive structures.

4.3.4. Capacity and Capability

Almost all of the interviewees were of the opinion that capacity was a major issue with only interviewee mentioning that,

> *"I have previously worked at a TTO with four professionals and we managed to do the work. All that we need is a team of motivated and capable people to execute the work that they do"*

To address the skill shortage, the UoTs interviewees mentioned that they work with other TTOs, especially in areas where they lack competencies. Some of interviewees mentioned that they work with the TTOs based at PROs. The critical skills or competencies required to execute the TT core functions are (according to the interviewees) are technical skills, negotiation skills, soft skills (writing & presentations), emotional intelligence, inter-relational , business and marketing skills, legal, project management, exposure and wide network.

The interviewees mentioned that it is impractical to have TT professional with a combination of all the skills, especially in SA where the TT is still new. A skill compromise is usually reached when recruiting personnel to execute TTO functions. The remuneration policies of the HEIs disadvantages the TTOs to hire the best professionals with the required competencies.

The TTOs that afford the salaries expectations retain the best staff and those who cannot afford have small pool of professional who are not exposed or mentored.

The interviewees mentioned that NIPMO plays a pivotal role in enhancing the TT skill development in SA. Most of the interviewees mentioned that they have been exposed and have acquired training from international TTOs due to the efforts of NIPMO. The learning from the international offices are shared within the respective TTO and not shared across the TTOs.

4.3.5. South African Economic Landscape and Infrastructure

Some of the interviewees were of the view that the economic set-up in SA does not have absorptive market for high technology businesses. High technology business sectors such as the Information and Communications Technology (ICT) was given as example of a sector that is doing well due to the availability of absorptive market. Other high technology business sectors such Bio-technology and pharmaceutical are not. The reason for the poor performance in these sectors was attributed to be due to lack of infrastructure to support high technology based start-ups. The high technology business require high capital costs and the interviewees were of the view that there is insufficient budget to invest in the development of these businesses. The sentiment shared by these interviewees is that the venture capitals (VCs) are risk averse and do not invest in the high technology-start-ups. Due to of lack of capital development funds, the TT professionals use IP licensing as an optimum way to commercialise high technology IP.

4.3.6. Technology Development Funds

Most of the technology (ies) are received at TRL 2-3 (especially the high complexity technologies) and development funds are required to take the technology to a stage where it can be absorbed by the industry (refer to Figure 1). The interviewees mentioned that they are perceived by the government and various stakeholder to have IP collecting dust on their shelves. The interviewee stated;

> *"What we have on our shelves is flour, eggs and sugar and we require the development funds to make a cup cake. We need the development funds to take the IP to a point that can be absorbed the industry"*

The interviewees (almost all) mentioned TIA as the major stakeholder supplying technology development funds. TIA supplies various TTOs with seed funding for technology development. The challenge with TIA being the only major stakeholder supplying technology development funds for publicly funded research is that only a limited number of projects are funded (most

interviewees mentioned two per HEIs with a budget cap of R650 000). It emerged from the TIA interview that they have budget constraints and proposed for the private sector to also play a role in supplying technology development funds. The interviewees mentioned that they have more than two project in their portfolios requiring development funds. The concern raised by the interviewees was that the technologies that are not funded stay longer in the TT value chain and may miss market entry at the ripe time. An interviewee mentioned they established a pre-seed fund to assist with technology development and the benefits are substantial, the interviewee stated that;

"It is actually amazing what can be done with small amount of money"

The pre-seed fund is only available at TTOs that perceived themselves as income revenue generating streams for the HEIs and have been in operating prior to the adoption of IPR_Act (2008) An interviewee from Innovation Funding and Pre-Commercialisation and Support unit of TIA mentioned that the following selection criteria is used to allocate seed funding for various projects (not in any sequence);

- Alignment with the national priority for development
- Commercial due diligence output report (target market, return on investments)
- Operational issues i.e. IP ownership and the freedom to utilise IP.

Some of the challenges experienced by TIA are that the proposal received are not meeting the above minimum requirements and are on the lower part of innovation value chain. Also, it was mentioned that lack of experience in developing technology driven business within the various project teams has a negative effect on technology transfer. The interviewee from TIA is of the view that most of the researchers conduct research with no intention to commercialise the research outputs hence most of the technology(ies) do not meet the requirement for seed fund allocation.

Only one of the respondents mentioned to approaching IDC and SEDA for development funds. A representative from the IDC's New Industries business unit was interviewed to assess the role of IDC in TT. The unit support emerging industries with the potential for significant impact on the SA economy. It was mentioned that the IDC supports technology development in the emerging industries and strategically work with the various centres of excellence at the HEIs and PROs to holistically build required competencies that will enhance technologies to be transferred to the market. It was also mentioned that the IDC funds technologies at the

development stage. The IDC uses the below assessment criteria for allocating funds for development;

- The project's market entry strategy.
- TRL (to extent to which the technology is developed for market adoption).
- Availability of regulatory framework (create an enabling environment for technology development)
- Alignment with strategic mandate (e.g. 10 year innovation plan and NDP)
- Viability of the opportunity both from financial and value chain perspective.

The interviewee stated that IDC has improved its risk appetite and is investing in technology development prior to proof concept as they are of the view that other technology development funds such as TIA may not have the same financial muscles as the IDC.

The dti also has technology development fund called SPII. The objective of the SPII is to fund projects post proof of concept with the objective of developing prototypes to package the technology such that it demonstrate commecialisation potential to investors. The assessment criteria used for allocation of SPII fund are the nature of the technology innovativeness (radical, breakthrough, incremental), characteristics of the research team, type of the market, manufacturing ability of the product, business proposition and alignment with the priority areas of the dti. The SPII is not allocated to the TTOs, but to ordinary citizens or entities who have potential IP that requires development.

SAVCA was contacted and documents from their website were used to determine a list of VCs participating in the TT ecosystem in SA. Based on the review of documents on the public domain, there are only five VC's involved in the early stage technology funding in SA out of 87 (SAVCA, 2013). These VCs were contacted to establish their views on technology development funds in TT ecosystem in SA and identify the challenges they experience in funding these projects. Interviews could not be secured the VC's, hence the webpages of these VCs were used to identify the type of technologies they fund and the selection fund criteria. The funding selection criteria by these VCs entail patent strength, team composition, market and scalability potential (Barnardt, 2017).

4.3.7. Regulatory Framework

An interviewee from the IDC mentioned that government is responsible for creating regulatory framework that enhances technological development. The Paris Acord and the Independent Power Producer Procurement Programme (IPPP) were given as examples were government has failed to provide regulatory framework to promote technology development in the energy sector. Some of the interviewees from the TTOs mentioned lack of absorptive market for the technology (ies) developed to affect TT.

IPR_Act (2008) is one of the regulatory framework introduced in SA to enhance the utilisation of R&D outputs generated using public funds. Some of the external stakeholders interviewed were of the view that IPR- Act does not enable TT in SA because it imposes IP to be owned by HEIs. The HEIs do not have effective management mechanisms for TT e.g. ensuring that disclosures are reported within 90 days from discovery as stipulated in the IPR_Act (2008). These interviewees stated that the IPR_Act (2008) should make provision for IP to be owned by private entities to enhance TT effectiveness. When IP is owned by HEIs, the movement of researchers from one institutions to the other was identified as a challenge as it destabilises the research team.

NIPMO is responsible for promoting the IPR_Act (2008) and creating an awareness of the Act. An interviewee from NIPMO mentioned that one of the challenges that inhibit TT at the various TTOs is the IP policy of the various institution. The interviewee is of the view that IP policy (ies) are not practical especially with reference to the remuneration and incentives. The IP policy documents of the various HEIs were sourced from the webpages of the respective institutions and were reviewed. IP policy documents of most of the UoTs could not be sourced from public domain, some of interviewees from these TTOs mentioned the IP policy documents were being drafted. Most of the traditional universities IP policy documents were easily accessible from their websites. The policy documents outline frame of reference with respect to IP ownership, profit sharing, working with external stakeholders and modes of commercialisation. The profit sharing varies among the HEIs, however within the acceptable range of the guideline provided by the IPR-Act. The IPR_Act (2008) endorses 80%:20% profit sharing between HEI and inventors. An interviewee mentioned they are proposing 60%:40% profit share between HEI and inventors to adequately incentivise researchers.

Another regulatory framework mentioned to have a negative impact of TT is the section 3.4.5 of the High Education Institution Act of 1997. The DHET minister determines the scope for HEI, which at times it is not aligned to the TTO mandate.

4.4. Effectiveness Metrics

Various outputs are used by the TTOs as Key Performance Indicators (KPIs) and, only a few are aligned with the mission statement of the respective TTO. The number of disclosures, number of patents, license income, number of spin outs and number of industrial partnerships are the widely used KPIs in South African TTOs. Some interviewees mentioned using the Association of University Technology Managers (AUTM) indicators as benchmark for their KPIs. NIPMO made reference to using AUTM as benchmark to develop metrics for TT effectiveness in SA. NIPMO uses the number of disclosures to measure effectiveness, mentioning that an increase in the number of disclosures is an indication that researchers understand the objectives of the IPR-Act. This measure provides an indication of the interventions by NIPMO to create IP awareness. The number of the disclosures is used as an indicator for effectiveness as it is viewed as a measure for TTOs effort to encourage the researchers to disclose despite the desire to publish. NIPMO mentioned that the quality of the R&D outputs needs to be improved to develop adequate metrics for effectiveness.

An interviewee from TIA is of the view that the following metrics should be used for TT effectiveness;

- The investment amount relative to the turnover of projects into commercial projects/services.
- The milestone and the value added to various projects i.e. the number of projects that are the TRL 8 (ready for commercial uptake).
- The extent to which projects are from achieving their mandate
- Number of SMEs assisted by TIA and number of high technology jobs created due to allocation of the TIA technology development funds.

The metrics used for TT effectiveness at IDC entail the long term view of the deal's profitability, sustainability of the deal and the strategic assessment (from both risk and market assessment). An interviewee from the dti proposed the following metrics to be used to enhance utilisation of IP generated using public funds;

- Potential to commercialise the patents (establishment of an examination office envisioned to enhance this).
- Commercialisability/transferability of technology (ies) (determine if economic benefit is derived from the IP, taking into account that technology has long lead times).

4.5. Technology Transfer ecosystem

The interviewees mentioned that TT is not a linear process and involves interaction with other stakeholders. The following stakeholders were identified as the required participants in the TT ecosystem;

- Government departments (Department of economic development, department of higher education and department of science and technology).
- Funding (IDC, TIA, VCs, NRF, Chamber of commerce and the banks).
- HEIs (researchers, HEI executives, head of departments, faculty of business & economics, technology stations and incubators)
- Knowledge creators (academia, indigenous, garage and grassroots innovators)
- Industry networks, manufacturing sectors and SMEs
- Various government roadmaps and regional economic development plans (e.g. National Development Plan and ten year innovation plan)
- Regulatory institutions like NIPMO and CIPC
- Patent attorney, ordinary customers, entrepreneurs, techno-preneurs

Policy frameworks by the various government departments are important to generate an environment that enhances TT. HEI internal and external ecosystem are required for effective TT. The internal HEI ecosystem to comprise of the TTO, various research faculty offices, HEIs executives, university academics (both students and staff), technology stations and incubators (for HEIs who have these facilities). Two interviewees mentioned that the involvement of the business schools in the internal HEIs TT ecosystem has the potential to improve TT effectiveness. The business schools will be tasked with building the entrepreneurship skills capability and developing business models that can used to establish technology based enterprises.

The interviews (90%) view the HEIs internal ecosystem to be fragmented and non-existent. Some of the interviewees mentioned that there is no coherence among the various research

programmes at the HEIs. It was mentioned that it will be ideal for the top management at the HEIs to have strategic research focus areas to enhance the R&D outputs;

> *"Currently we do research in all the areas and do not have focus areas. It will be ideal to have strategic alignment and this will enhance the probability of research to be commercialised"*

Some of the interviewees were of the view that the external ecosystem is non-existent and there are conflicting mandates amongst the various departments (e.g. DHET and DST) with no coherent structure.

> *"The research done at the various HEIs is repetitive with no commercialisation potential. The DHET and DST funds various research programmes and there is no alignment"*

The interviewee from the IDC supported the comment above, giving an example of research done by the HEIs in the energy sector; that the HEIs are competing for limited financial resources and not exploring avenues to differentiate themselves by offering specialised services along the TT value chain. The need for collaboration and not competition was emphasised by an interviewee, mentioning that;

> *"The establishment of new technologies is achieved through a conglomerate of the various roles players".*

An external ecosystem is required to for strategic alignment, enhance the R&D outputs, create new market for technology absorption, a legislation to promote TTO activities and coherence among the various structures in the ecosystems. An interviewee from the TTO mentioned that

> *"Research must fit the problem. What we have in SA is technology in search of problem vs a problem in search of solution. The latter is how research must be approached, hence it is important to have the industrial linkages along the TT value chain"*

4.6. Summary of the interviews respondents

The core functions/activities of the various TTOs are managing disclosures, IP protection, IP commercialisations and IP management with only one interviewee mentioning that there is no dedicated personnel to conduct the TTO activities. This TTO thus performs limited functions outlined in the IPR-Act. Some of the TTOs offer short courses as an extension of their services, especially the TTOs based at traditional research HEIs. Most of the TTOs are inward looking

i.e. only providing services to the respective HEIs and only a few (three) are outward looking (i.e. offering services non-members of the university). Below is a summary of the common challenges experienced by the TTOs, irrespective of the historical background of the HEI they are based at.

- **Organisation structure and culture.** The lack of support and alignment with the university top management. The culture at the universities is more academic focused with minimum desire for commercialisations. The incentive and the remuneration structure promotes an academic predisposition and publishing culture.
- **Capacity and capability**. Some of the participants mentioned capacity problem as mythical, and that a competent and capable team can execute core functions. However, most of the participants mentioned that capacity and capability impairs TT effectiveness.
- **South Africa economic landscape and lack of infrastructure.** Most of the respondents mentioned it is easier to license IP at the international market as SA does not have the absorptive capacity for IP in high technology industries such as the biotechnology sector.
- **Technology development fund.** TIA was mentioned as a major supplier of technology development fund and that there is need for the private sector to also get involved. It was suggested that the VCs can be the ideal stakeholder, however, the challenge is that the TTO IP portfolio comprises of technologies that still need further development (TRL2-3). The VCs are perceived to be risk averse and thus may not invest in these projects due to the high uncertainty.
- **Regulatory framework.** Regulatory framework is required to create an enabling environment that enhances technology transfer. The IPR-Act of 2008, High Education Institution Act of 1997, Technology Innovation Act of 2008, Public Finance Management Act of 1999 are some regulation mentioned by the various interviewees that they play a role in TT ecosystem. There are other regulatory framework in the various sectors that affect TT e.g. The Paris Acord and the Independent Power Producer Procurement Programme (IPPP) in the energy sector. It was mentioned that the various government departments need to develop regulatory framework that is not conflicting each other. What emerged from the interviews is that regulatory framework is required to harmonise the metrics used across the various TTOs and remuneration scale of the TT professionals**.**

The IP policy document of the various HEIs is used as regulatory framework within the HEI ecosystem. These policy (ies) outline the following key areas; benefit sharing, working with external stakeholder and some detailing the TT value chain steps.

The interviewees from the UoTs mentioned lack of research background and being rated at the lower end of the HEIs list (based by the quality of the researchers as per the NRF ratings) affect execution of the TTO core functions. Insufficient IP pipeline was affecting the TT; with various UoTs developing strategies to improve the quality of research emanating from the faculty offices. It was mentioned that these strategy (ies) will be detailed in the IP policy documents that are currently being drafted.

The metrics used for TT effectiveness vary among the TTOs and dependent on the various challenges experienced.

5. CHAPTER 5: ANALYSIS OF RESEARCH FINDINGS

5.1. Introduction

The results presented in Chapter 4 are analysed in this section of the report. The objective of the IPR-Act is to provide an effective utilisation of the IP emanating from public financed R&D (IPR_Act, 2008); hence TT effectiveness will be evaluated using the IPR_Act (2008).The core functions of TTOs in SA are receiving disclosures from researchers and conducting IP protections, IP marketing and IP commercialisation as per IPR_Act (2008). The TTOs are conducting these functions and thus the TT activities will be discussed taking into account the challenges experienced when executing these core functions and how they affect effectiveness.

Also the mechanism that can be introduced to enhance effectiveness are discussed.

The externalities and the contextual factors affecting TTOs from executing their core functions were assessed using the Bozeman et al. (2015) contingent effectiveness model for TT. The model can be used to assess TT effectiveness of state funded research and it entails externalities such as who doing the TT, what is transferred, how the technology is transferred; and the environment under which technology is transferred. These inputs determines the effectiveness criteria.

5.2. Assessing Effectiveness Using the Contingent Effectiveness Model for and the IPR-Act

5.2.1. Modes of Transfer

Technology is transferred using various modes such as patents, copyrights, trademarks, industrial designs and spin-outs. The interviewees from the TTOs mentioned using the various modes to transfer technology, however, from the interviews it emerged that the popular modes used by the various TTOs are patents, license and spin-outs. The challenges experienced with these modes of TT are discussed below;

- The R&D outputs disclosed to the TTOs are fundamental, with some of the disclosures not having a commercialisation potential. This affects the TT value chain IP pipeline. The fundamental research disclosures may be attributed to more than 50% of the GERD spent on fundamental research at HEIs (DST_HSRC, 2014/2015). The business sector GERD in 2014/15 was reported to be 6.4% on basic research, 57% on applied and 37% on experimental development (DST_HSRC, 2014/2015, p. 16). The GERD at the HEIs was

reported to be 32% on applied research and 13.5% on experimental development (DST_HSRC, 2014/2015, p. 16).

There is a need for collaboration between the industry and HEIs to conduct research that is market orientated (i.e. applied research and experimental development) to enhance the probability of R&D outputs to be absorbed in various business sectors. It is reported in the DST Ministerial_Review_Panel (2017) report that the R&D in SA need to be market push orientated to strengthen the NSI. It is proposed that R&D at the various HEIs be aligned with the regional economic development roadmaps to create research outputs that are targeted towards addressing some of the socio-economic challenges.

- Publication is a form of knowledge transfer (Bozeman et al., 2015), however, it is viewed as detriment to TT effectiveness. The researchers prefer to publish their discoveries as opposed to disclosing to the TTOs. This is contributed by the NRF incentive structure to increase the knowledge creation in SA. Friedman and Silberman (2003) are of the view that incentivising the researchers for patenting their inventions affects the operation budget of the TTO. The various TTO interviewees are of the view that incentivising researchers for disclosing their inventions has the potential to attract non-commercialisable patents. Incentivising researchers for patenting their inventions, especially in SA where there is no patent examination office may not enhance the utilisation of the R&D outputs. This may lead to a fruitless expenditure whereby funds are spent incentivising researchers and not reaping the rewards due to lack of commercialisation potential by some of the patents registered with CIPC.

The commercialisation potential can be enhanced by aligning R&D to the regional economic development maps and collaborations with the industry. A market push oriented research is required to enhance commercialisation potential of R&D outputs. This was observed in the US prior the adoption of the Bayh-Dole Act in 1980 (Mowery & Sampat, 2004), where R&D was focused on addressing the societal needs. A market push will increase the filtration of "proudly South African" produced technologies to users; this can be used to strengthen brand loyalty and build reputational brand for the forth coming technologies i.e. market pull.

An interviewee mentioned that the patents registered can be used as an indicator for knowledge generation but not for deriving the economic benefit as this cannot be

guaranteed due to lack of examination office. Thus a combination of patents and publication can be used as a proxy for technical competence in the ecosystem to enhance TT effectiveness. However this will require the DST (reporting department for the TTOs) to align its mandate to that of the DHET with the objective of enhancing coherence and establishing synergy among the government structures. There is already a constrained budget in the TT ecosystem in SA, thus an alignment of the TT mandate with that of the HEIs can help leverage the NRF budget for incentivising researchers. The NRF incentive structure can be revised and the researchers be incentivised for generating knowledge that enhances the socio-economic outlook of the various regions and solves challenges experienced by ordinary South Africans.

The DHET is responsible for setting the mandate of the HEIs (High Education Institution Act of 1997) and thus the DHET will need to align the scope of the HEIs with the regional economic development plans. It is stated in the DST_HSRC (2014/2015) report that publication has increased (used this metric to measure of research outputs from the various HEIs), however this does not correlate with the rate at which technology is transferred for utilisation. This will infer that the research conducted does have market absorption orientation. Conducting R&D that is aligned with the regional economic development plans will improve the likelihood of technology being absorbed and researchers publishing R&D that has the potential to be commercialised. It may be argued that the HEIs are supposed to conduct fundamental research, as their primary mandate is teaching. However the HEIs are mandated to produce graduates that have the potential to be absorbed to the various sectors of the economy; thus conducting research that is aligned with the regional economic needs will enhance the employability of the graduates.

The movement such as "# Fees must fall*"* may drive the HEIs in SA to shift towards the entrepreneurial paradigm so they can operate sustainably. To enhance the entrepreneurial paradigm, alignment between the TTOs and HEIs is required and the business schools can assist in achieving this mandate.

R&D focused on regional economic development mandate may constrain SA to enter the global frontier market (Audretsch, Lehmann, & Wright, 2014) as the research conducted at the HEIs will be inward looking. However, innovation is a cumulative process and TT is at its infancy stage in SA requiring finance to grow. Rajan and Zingales (1996) stated that finance follows growth, and thus focusing on shorter technology cycles aimed at enhancing

utilisation of IP within the regions is anticipated to lead to GDP growth. This will in the long run generate revenue that can be used to enter the global frontier market (Audretsch et al., 2014).

- Patents registration decreased for the period of 2011/2015 relative to 2006/2010 (NACI, 2016, p. 36) and this was attributed to the publication culture within the HEIs. The industrial designs have decreased to 2 323 in 2011/2015 relative to 3 199 in 2006/2010 (NACI, 2016). This will infer the transfer of technology using industrial designs decreased post the adoption of the IPR-Act. With the lack of a patent examination office (NACI, 2016, p. 35), most of the patents registered with CIPC do not have commercialisation potential and thus affecting TT effectiveness as the tangible outputs cannot be derived from the patents registered in SA. Examination and legislative framework is required to improve patent application.

The TTOs in SA transfer physical technology and technical knowledge. Other modes of technology transfer such human capital developments were not mentioned during the interviews. Though not mentioned, this mode is critical for SA to have competencies required to adsorb graduates in various sectors of the economy. The human capital transfer mode is also important for medium to high TT as both the tacit and codified knowledge are required for effective TT (Lundvall et al., 2002). The dti has programmes such Technology and Human Resources for Industry Programme (THRIP), aimed at enhancing the technical skills of interns or graduates. The THRIP candidates can be utilised during technology development to enhance the transfer of technology into the industry, especially with the high technology (ies) where tacit knowledge is required to ensure success of TT. There was no mention of the THRIP by the TTO interviewees, and this program envisioned to enhance the HEI-industry collaboration. To enhance the efficiency of the programmes and effectively use the resources within the TT ecosystem there is need for alignment between the dti, DST and DHET. The initiatives and programmes by the various government departments are necessary to enhance TT effectiveness, however the implementation and administration of these initiatives is not synergised. The system is fragmented (Minesterial_Review_Committee_DST, 2012; OECD, 2012).

5.2.2. Characteristics of the Transfer Agents

The TTO professionals are to have multi-disciplinary skills to be able to execute the core functions of the TTO (IPR_Act, 2008).The interviewees have more than ten year working

experience, and most have worked at the various PROs. The TT professional do not have the competencies to execute some of their core functions e.g. disclosures due-diligence to lack of technical background in some of the technical fields. Approximately 43% of the TT professionals have undergraduate degrees in natural sciences (CeSTII et al., 2015). The distributions of the undergraduate qualifications of the TTO professionals is given in Figure 3 and the data used to plot Figure 3 was sourced from the CeSTII et al. (2015). It can be inferred that TT in the natural sciences is unlikely to be affected by shortage of the technical skills as more than 40% of the TT professionals have technical knowledge in natural sciences. The research spending per sector in year 2014/15 is given Figure 4.

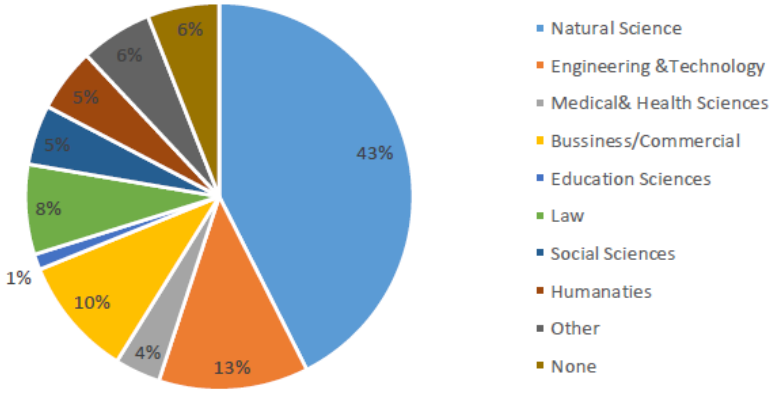

Figure 3: Distribution of the undergraduate qualification of the TT professionals at South African TTOs

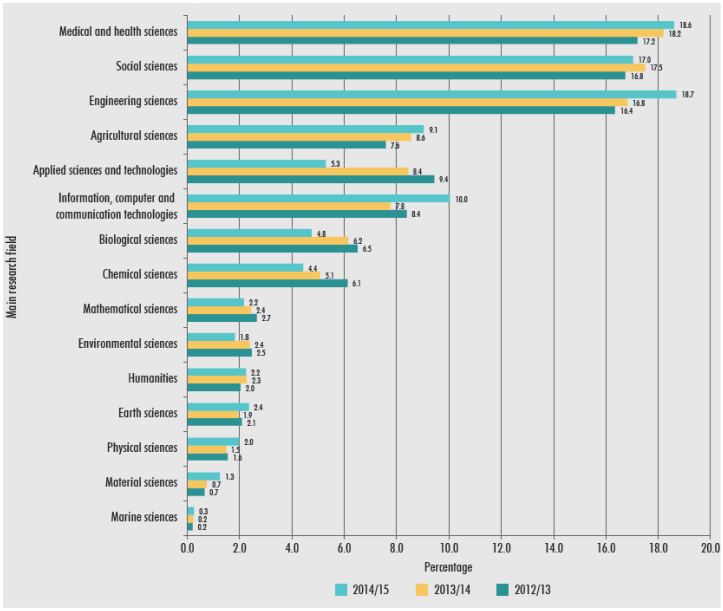

Figure 4: GERD per research field in South Africa (DST_HSRC, 2014/2015)

High R&D outputs can be anticipated from the medical and health sciences, engineering and the applied sciences (with reference Figure 4). Based on Figure 3 and Figure 4, the TT skills do not match with the anticipated R&D outputs. The technical skill misalignment can be an impediment for TT effectiveness, especially at the TTOs that have limited capacity.

Landry et al. (2013) suggests that the strengths of the various TTOs can be leveraged through dismantling the technology transfer value chain in SA, and distributing the various function based on the strengths of respective TTOs. This process is dependent on the capability and the capacity of the TTOs and it is anticipated to offer tailor made value proposition for various clients aimed at enhancing TT effectiveness. In areas where the TTOs lack the required competencies, virtual team may play a vital role in addressing the skill deficiency (Salter & Martin, 2001).

Entrepreneurship and business skill were among other skills that were named to be critical to enhance TT effectiveness. TT professionals are only conduits; offering support to the knowledge creators to commercialise their technologies. Thus it can be argued that TT professionals need to have business knowledge competencies as their only conduits. It was deduced from the interviews that the knowledge generators view the TT personnel as the entrepreneurs to commercialise their technologies. Techno-preneurs can be incorporated in the TT value chain to act as conduit between TT personnel and the knowledge creators; and they will be responsible to champion the technology to ensure that it is commercialised. This will align the expectations of various stakeholders, especially i.e. TTOs and knowledge creators.

Lateral thinking and prior technical knowledge are required for effective TT (Hindle & Yencken, 2004); and the techno-preneurs can offer this skill gap and thus enhancing TT effectiveness.

5.2.3. Environment for Technology Transfer

The challenges experienced in executing the TTOs functions are interdependent and have spill-over effects on each other. Geels (2002) state that technological transitions are achieved because of the interlinkages of heterogeneous sets of elements. The externalities that affect TT effectiveness are discussed below;

5.2.3.1. Organisational Structure

Different types of TTOs have different types of business models and organisational structures to offer complementary service to their clients. These organisational structures vary among the

UoTs, comprehensive universities and traditional universities. At most of the UoTs, TTO is operating within the research units of the HEIs. Some of the interviewees perceived this structure to affect the technology transfer effectiveness especially HEIs were top executives do not support the TTO. However some perceived this structure to enhance collaboration and synergy between the research office and the TTO. Integrating the industry linkages with R&D seem well executed in this type of structure when there is a strategic alignment with the executives of the HEI. Thus to enhance TT effectiveness at TTOs based in research unit, an alignment with the HEI executive is required.

Organisational structures are also helpful to assign the resources and effectively utilise the resources. The TTOs with a defined organisational structures, have defined tasks for TT professionals outlined and this was perceived to enhance effectiveness.

Some of the TTOs are operating as private enterprises of the HEIs; this type of structure was observed to most prevalent at traditional research HEIs and at TTOs that existed prior the adoption of IPR_Act (2008). These HEIs mentioned that the structure enhances TT effectiveness as it eliminates the bureaucratic HEIs approval structure, thus enabling the TTO to conduct business more effectively. This is more in line with the study by Siegel, Waldman, and Link (2003), which noted that the bureaucratic HEIs structures affect TT effectiveness. Thus a hybrid of research unit integrated with private enterprise structure to enhance industrial linkages and de-centralise the TTO activities may enhance TT effectiveness.

The TTOs have to be sustainable and some stated conducting short courses, especially those at traditional research and operating as private enterprises of the HEI. The courses are turn-key, aimed at professional training. Assessing the types of course offered from the various webpages of these institutions, it can be deduced that they are not aligned with the TTO functions as outlined in IPR_Act (2008) but are revenue creation stream. Though these courses are offered to the public, the TTO only service their respective institutions, hence the deduction made above as the intangible course outputs (i.e. skill transferred) are not internally accrued to the HEIs. However, it may be argued that it is human resource TT mode. These courses can be enhanced by aligning them with the TTO functions e.g. training the techno-prenuers.

5.2.3.2. Characteristics of the HEIs

It was observed that the age and research strength affects TT effectiveness, with the TTOs that existed prior adoption of the IPR-Act reporting to have management strategies and reserve

funds that enhance TT effectiveness. The age of the TTO contribute towards the sustainability and the profitability of the TTO (Friedman & Silberman, 2003; Siegel, Waldman, & Link, 2003). Age has an impact on the organisational structures of the various TTOs. The TTOs that have been operating longer have sub-divisions to enhance operational mandate e.g. the introduction of a commercialisation unit.

The HEIs with top A-rated NRF researchers have a large number of IP portfolio displayed on their webpages. This was attributed to the research strength of the various HEIs. The research output from various HEIs for the period of 2014 and 2015 is given in Figure 5 and the data was sourced from DST_HSRC (2014/2015, p. 29).

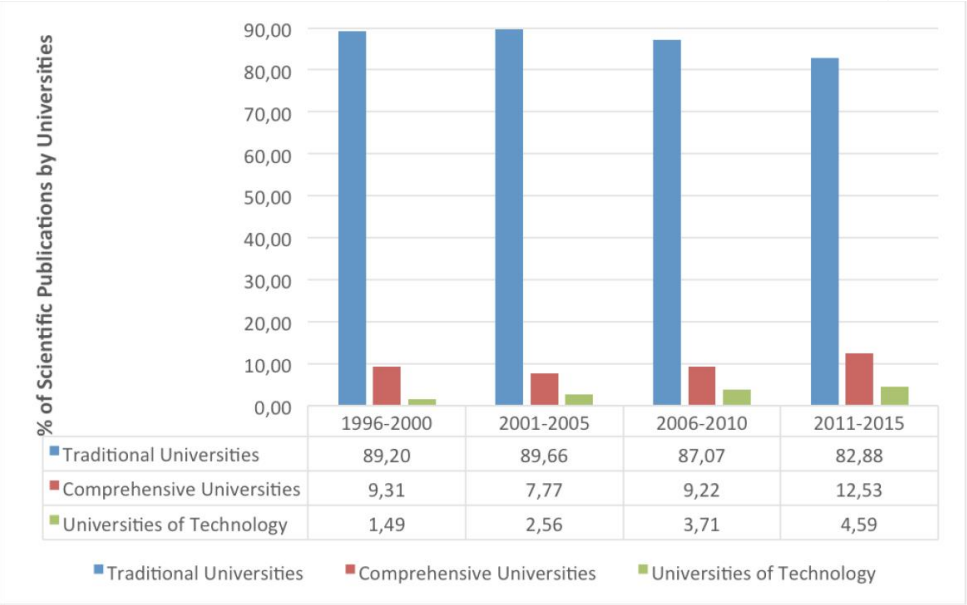

Figure 5: Proportion of scientific publication by HEIs in SA (DST_HSRC, 2014/2015, p. 29)

Based on the research output from the HEIs (publication used as a proxy), the one size fits all approach for TT as outlined in the IPR_Act (2008) is an impediment to TT effectiveness at the various TTOs (IPR Act mandated all HEIs to have TTOs irrespective of the research strength). The UoTs interviewees mentioned the R&D output as an impediment to TT due to weak research strength. The HEIs that are still to stablish TTO (e.g. University of Limpopo) need to focus on enhancing their research strength. Enhancing the research strength is anticipated to outdo the TT "box-ticking" culture at the TTO.

The HEIs were merged and restructured to leverage the strengths of the various HEIs (Ministry_of_Education, 2002) ,thus ensuring that the HEIs are capacitated to generate the skill

set required to meet the socio economic goals in SA. The merger was done before the adoption of the IPR-Act. It was observed that the historic background of the HEI affects TT. TTOs based at traditional research universities exhibited better TT management strategies relative to the UoTs. The executives at the traditional research HEIs seem to support the TTO activities, while those of the TTOs at UoTs are not to some extent

An interviewee from NIPMO named the following to be challenges that affect TT effectiveness at TTOs based at HEIs;

- Executive management of HEI not supporting the TTOs,
- Researchers not willing to participate in the TT value chain
- Insufficient capacity to adsorb the interns,
- IP policy of the respective institutions i.e. remunerations and incentives not practical.

The industrial linkages seem to be strong at the UoTs, and this may be attributed to the UoTs pre-merger historical mandate of providing vocational training.

5.2.3.3. Geographic location

The geographic location seem to have an impact on TT effectiveness, with the TTOs based in Gauteng and Western Cape having enhanced TT (using licensing, spin-outs and social impact as a proxy). The Western Cape provenience seem to be doing well relative to Gauteng. This may be contributed by a number of the VCs in early-stage technology funding concentrated at the Western Cape.

The geographic locations may be used to cluster research. The DHET proposed a R&D collaborations for the various HEIs (Ministry_of_Education, 2002) and they are given in Appendix 6. This was envisioned to enhance the competencies among the various HEIs. The collaboration proposed by the Ministry_of_Education (2002) need to be revised so they are relevant to the current regional needs and are aligned with the research strength of the various HEIs.

Most of the UoTs are embedded within the communities that have various challenges and have been socially excluded from the main stream economy (e.g. Umlazi, Soshanguve, Sebokeng). The geographical locations of the TTOs and regional economic road maps can be used as enablers for TT. An example is the University of Vhenda/Limpopo, where the strategic research focus area will be in food security based on geographical location i.e. Limpopo

province referred to SA's Eden. Also, these universities are based around rural communities that informally participate in the agriculture sector. Thus there is market and land to test the R&D outputs and implement the outcomes. This will provide food security around the region and upskill human resources agricultural competencies.

Human resource can be used as an output measure for TT effectiveness. The human resource development is anticipated to enable the community and the technology developer's skills so they are capacitated to develop sustainable business. Some of the scholars have stated that innovation is a cumulative process (Bozeman et al., 2015; Lundvall et al., 2002), thus the human resource development initiatives are anticipated to create an absorptive capability to enhance technological innovation advancement (Roessner & Porter, 1990).

5.2.3.4. Incentive structure and culture

The prevailing culture among the various HEIs is that publication is viewed more superior than co-labouring with the TTO to protect and commercialise inventions. This secondary belief is enhanced by the incentive structures by the NRF for publication. This belief can be changed by introduction of regulatory framework that aligns with the strategic mandate of both the TTO and HEIs.

Studies conducted in the US have shown that there is a negative correlation between TT effectiveness and incentive structures (Friedman & Silberman, 2003), with the incentive structures affecting operation budget. For countries like SA where there are limited financial resources, the introduction of invectives may be at the detriment of TT effectiveness. Patent and publication strategy can be adopted as proxy for technical competence, whereby researchers are incentivised for collaboration with MNCs for skill transfer and reverse learning. This is anticipated to strengthen the absorptive technological capability of SA.

The incentives structures for the TT professional needs to revised to regulate the movement of TT professional thus ensuring that the skill balance within the various TTOs is normalised. As proposed by the interviewee, NIPMO to regulate the TT salary by stipulating a minimum requirement. The various TTO need to have value propositions and strategies as differentiators to align with the career aspirations of the TT professionals. Fulga et al. (2016) conducted a study to evaluate business models that can be used to enhance TT in Romania and the outcomes of the study postulated that some aspects of the business model canvas i.e. defining the value proposition of the TTO can be used to enhance TT effectiveness. Fulga et al. (2016) proposed the business model canvas can be used by TTOs to develop value propositions that are centred

on the challenges that are experienced by the TTOs. The challenges experienced by the TTO and the strengths of HEI are used to identity customer segments that align to the value proposition of the TTO.

The introduction of R&D aligned with regional economic developments will attract TT professionals work at TTOs that offer specialised services. The proposal is based on the view by of some of the interviewees who stated that a team of dedicated professional can execute the TTO function and capacity shortage is mythical. This would infer that the Maslow's hierarchy needs theory can be used to structure the TT professional incentive packages. The Maslow's hierarchy needs theory postulates that people are motivated by the following needs; physiological, safety, love/belonging, esteem and self-actualisation. The value proposition is anticipated to align the TT professionals to their needs and keep them motivated.

5.2.3.5. Characteristics of the HEIs

A summary of the characteristics of the HEIs used in the samples frame is given in Appendix 7. The information given in Appendix 7 was sourced from the webpages of the various HEIs and their factsheets

The South African government is playing its role as an entrepreneurial state as proposed by Mazzucato (2013), funding R&D at various public HEIs (DST_HSRC, 2014/2015). The IPR-Act of 2008 mandated the HEIs to establish TTOs irrespective of their research strength. Some of the UoTs find it impractical to implement the IPR_Act (2008) due to lack of research strength and mentioned that their institution have technology stations which are funded by TIA. The objective of the technology stations is to enable various stakeholder to engage in innovation, however if there is no strong research background the technology stations are not optimally utilised.

The innovation system within the HEIs was implemented with good intensions (e.g. technology stations, TIA seed fund, Incubators, Innovation Hub), however due to the lack of synergy of these initiatives with the research agenda, SA may be not utilising their insufficient resources adequately (i.e. lack of development funds and GERD of 0.77% of the GDP).
Some of the research focus areas are not aligned and there is no collaboration among the various HEIs. Respondents have mentioned that the research at the HEIs is repetitive with no intent to commercialise. An interviewee mentioned that the research is repetitive with the HEIs competing for limited resources. An example of the HySA programmes was given, where to

enhance TT effectiveness the various HEIs focused on niche areas along the value chain where they have expertise.

The IP strategy should be focused on building competencies among the various HEIs to enhance collaborations and eliminate repetitions.

5.2.3.6. Regulatory framework

The TUT Technological Innovation and TT Strategy (accessed on the public domain) posits that the regional economic clusters can enhance TT effectiveness. Singapore economic growth is attributed to policies that promote industrialising countries (Soon & Huat, 1990). The various respondents mentioned the SA economic landscape as a detriment for effective TT. One of the criteria's used by TIA to provide seed fund is alignment of the project with the national priority for development. Most respondents mentioned TIA as a major stakeholder in providing technology development funds. This will infer that the project funded by TIA have strategic alignment and thus have potential to be "pushed" to the market. The IDC however highlighted that the projects from TIA do not meet their requirements (section 4.3.6 for minimum requirements of both stakeholders), hence the IDC has launched the New Industries unit to also participate in the TT value chain. TIA mentioned that the TTO outputs are not meeting their minimum requirement. There seem to be disjuncture in the ecosystem, with the various participants within the ecosystem predecessors not meeting the minimum requirements for the successors. This may infer that there is no collaboration within the ecosystem and the various stakeholders are working in silos. The dti is of the view that collaboration is important at the commercialisation phase.

For the IPR-Act to be effective, there need to be coherence among the various actors within the ecosystem. This view was also shared by SUCA. This is further emphasised by Mowery and Sampat (2004) that the IPR-Act alone may not be the reason for improved TT in the US. The system is fragmented and thus there is a need for regulatory framework to enhance effectiveness. There is a need to enhance the links and platforms that will encourage the various stakeholders to work together.

High percentage of spending is devoted to the "hard" science (Figure 4) and most of the TTOs have used the pharmaceutical industry as an example to illustrate that it is difficult to transfer technology in this sector due to the economic landscape, insufficient development funds, infrastructure and regulatory framework. From Figure 4, it can be observed that most of the

research is conducted in this sector, however there is no conducive environment for these technologies to be absorbed in SA. There is a need for the regulatory framework to address this conundrum.

TTO effectiveness may be enhanced when the R&D efforts are interlinked with the regional and national roadmaps e.g. The South African 10 year innovation plan (DST_Innovation_Plan, 2008). This is more substantiated by the outputs of Mowery and Sampat (2004) study.

5.2.3.7. Technology development funds

Technology/ inventions/ discoveries disclosed to the TTO are at TRL 2-3 (proof of concept) and thus require technology developments funds to be developed and packaged for pre-commercialisation. There is need for various technology development funds to be involved in the technology transfer process to enhance effectiveness and patient capital is required as the technology development is uncertain (Mazzucato, 2013). The lack of development funds can be attributed to market failure and information asymmetry. TT is process orientated and involves purposeful interaction among the various stakeholder (Battistella et al., 2016)
The IDC, TIA and the dti are all providing technology development funds, (the dti is not funding the TTOs). The assessment criteria used by these government stakeholders are aligned to their respective government department mandates. The danger with these approach is that there is no coherence among the various government structures and thus there maybe duplication of the efforts. Thus there need to have a strategic alignment among the various stakeholder of government and determine gaps that the private sector can fill.

Technology develop is uncertain, and most of the VC's fund technology at TRL8-9 as it has an increased market potential. Thus the VC's are risk averse and this maybe contributed to a lack of success story in the TT landscape post the adoption of the IPR-Act.

5.2.3.8. Capacity and Capability

Capacity and capability has been cited as a detriment to technology transfer (Alessandrini et al., 2013; CeSTII et al., 2015; Wolson, 2007). Most of the UoTs mentioned that they are in-capacitated and this was contributed to the constrained budgets at these TTOs. The TTOs that have been operating prior the adoption of the IPR-ACT have management reserve funds that are used to hire the staff complement required though not sufficient.
The NIPMO website (NIPMO, 2018), it is stated that there are approximately 85 (+ 19) specialised posts created in the technology transfer space. This will infer that there more than

85 technology transfer professionals in SA distributed among the PROs and the HEIs. The technology transfer professionals are not evenly distributed across the various TTOs, with some TTOs reporting to have one professional or in worst case no one permanently appointed for the role. The TTOs that afford the salaries expectations retain the best staff and those who cannot afford have small pool of professionals who are not exposed or mentored.

The technology transfer profession is not adequately marketed in SA and the internship programmes are perceived ineffective to generate the skill-set required to execute the TTO functions.

5.2.3.9. The technology transfer ecosystem

The TT ecosystem is comprised of an internal ecosystem and an external ecosystem. The internal ecosystem is comprised of the HEIs top executive, research unit, TTO, researcher's incubators and technology stations. The technology stations profiles (TIA, 2018) seem not be aligned with the research strengths of the HEIs at which they are based. The HEIs also have centres of excellence which have to align with the technology stations for optimum utilisation. Also the technology stations need to be aligned with the regional economic development roadmaps. This will ensure that the R&D outputs can be developed into prototypes that can be used to leverage technology negotiations and enhance commercial viability of the products.

The external technology ecosystem comprises of government stakeholder such as the various government departments, the agencies of these departments, private sector and the industry. The IDC and TIA have mentioned that the outputs of the various predecessor stakeholder do not meet minimum requirements of the successors. Thus there is a misalignment in the criteria's used by these stakeholders for technology development and thus alignment is required. An interviewee from the dti stated that there is fragmentation at implementation phase. Regulatory framework is required to enhance effectiveness at these structures.

5.3. Metrics for Technology Transfer Effectiveness

5.3.1. Disclosures

NIPMO and other interviewees mentioned using the number of disclosures as a proxy for TT effectiveness. Some of the interviewees have mentioned that the disclosures received are fundamentals and have no commercialisation potential. The interviewees mentioned that the disclosures are normally received at TRL2-3 (proof of concept) and further development to package the technology such that it can attract potential investors is often required. The objective of the IPR-Act is to provide an effective utilisation of public funded IP (IPR_Act,

2008), thus the use of the number of disclosures is subjective. Increased number of disclosures does not measure utilisation of the IP as per the IPR-Act, however it may infer a measure of IP awareness.

NIPMO mentioned that out of a 1000 disclosures received, 5 to 7% create business, and this view was shared by the TTOs at the traditional research universities and also supported by Heath (2013) presentation. Thus it is important for the TTOs to increase the number of disclosures to have an IP pipeline as not all the disclosure will translate into sustainable business.

The disclosures have to be reported to the TTO 90 days post discovery (IPR_Act, 2008), however, there is no mechanism to ensure that the researchers adheres to this. The international TTOs have a logbook mechanism to ensure that they keep record of the laboratory findings of the researchers (Heath, 2013). This system may be contributed by the entrepreneurial university paradigm (Etzkowitz et al., 2000; Hindle & Yencken, 2004), where there are systems and techniques used for technology assessment (Heath, 2013). In SA, researchers disclose at free will with some preferring to publish. This may infer that the IPR-Act was adopted with administrative oversights that need to be corrected. According to the IPR_Act (2008) IP belongs to the university, however the tacit knowledge reside within the researcher. An interviewee mentioned that the movement of researchers is a challenge for TT as it destabilise the research team. Thus for complex projects, the researchers combination of codified and tacit knowledge affects TT effectiveness.

5.3.2. Patents

There has been an increased number of patenting at international markets (DST_HSRC, 2014/2015; NACI, 2016), however SA still contributes approximately 7 % GDP to technology deficit (DST_HSRC, 2014/2015, p. 45) in 2015 and the Foreign Direct Investments (FDIs) have decreased (DST_HSRC, 2014/2015, p. 45). Alessandrini et al. (2013) is of the view that TTOs in SA do not exploit the commercialisation potential of their IP. The increased patenting and the amount of technology deficit in SA support Alessandrini et al. (2013) views.

Patents are normally used for the following (Goffin & Mitchell, 2016, p. 202)

- Monopoly for a competitive free environment.
- Revenue through licensing or royalties depending on the type of licence i.e. outright sale or buyer IP rights.

- Barging counter for big companies (i.e. allow borrowing of IP rights to inhibit new entrants).
- Technical bargaining power.

From the empirical data collected, it may be inferred that patenting in SA is used for revenue generation. This is supported by most of the TTOs mentioning the revenues accrued from licencing and royalties as a measure of effectiveness. Some of the interviewees mentioned being a third or fifth income stream for the university.

Some of the TTOs mentioned only using the number of patents as a measure of effectiveness. The TTOs lodge the patents with CIPC. The challenge with the patent registration in SA is that it depository system, with an interviewee mentioning that it is a "*library data base of patents"*. The CIPC is supposed to conduct patent registration and examination, however only the former is only conducted. The capacity and capability to examine patents is currently being build. The IPR_Act (2008) was adopted to enhance utilisation of R&D outputs, by protecting the IP thus creating monopoly market. However, SA does not have a patent examining office. The risks associated with this is that the PROs and the HEIs in SA have patents on their scorecards, and may patent to meet the scorecard deliverables with patents that do not have commercialisation potential.

The patents generated maybe used as proxy for knowledge generation. Adopting the IPR-Act without the capabilities to examine patents may be weak a strategy for a resource-constrained country like South Africa. The "defendable" patents are registered at international offices and the TTOs spend huge budgets on translation fees, i.e. money that could be directed to other functions within the TTO. The strategy of patenting at international office is only for protection and not for market entry. This is supported by the technology export as a percentage of the world reported at 0.08% (NACI, 2016). The lack of an examination office make it difficult for the VCs to take part in the TT space due the criteria used by the VC's to fund projects.

It is reported in the OECD (2012) that it is pre-mature for developing countries to use the TT KPIs used in developed countries to measure effectiveness (e.g. the bench marks by AUTM). The TTOs in SA are relatively new and with the challenges such lack of capacity and capability, lack of development fund and an economical landscape that is not absorptive of the local technologies. Alessandrini et al. (2013) emphasised the need to develop metrics for effectiveness at the TTOs. The TTOs may be using inaccurate KPIs to measure effectiveness as the metrics used do not account for the contextual background.

For SA to transition into a knowledge economy, the commercialisation strategy at the various TTOs need to be revised. The high rate of publication (NACI, 2016) and current patent depository system may be used as a bargaining power by SA, i.e. an indicator of technical competency on the global market. This has the potential to attract Multi National Company (MNCs) to SA for the technical competencies and has the potential to increase the FDIs. A decrease in the FDIs (DST_HSRC, 2014/2015, p. 45) may disadvantage SA to grow the competencies it requires to transition into the knowledge economy. Though the research study does not focus on R&D outputs generated using FDI's, decreased FDIs is used as a proxy for decreased capital in flow and lack of investor's confidence in the local economy. A decrease in the FDIs reduce the likelihood of SA researchers to be exposed, learn by doing and improve their competencies (Viotti, 2002).

The strategy of using patents and publication as a poxy for technical competence will help SA to be exposed to the global frontier research and may assist with technological economic-catch up. Sasol used the publication and patenting strategy as an indicator for technical competence, attracted collaborations with (MNCs) and advanced globally (Barnard & Bromfield, 2009).

Soon and Huat (1990) evaluated the role of transitional corporations in transfer of technology in Singapore and the outcomes of the study infer that collaborations with MNC's helped Singapore to transition its economy. The MNCs brought in capital, modern technology and managerial skills (Soon & Huat, 1990), making MNCs necessary for the economic survival of Singapore. SA is a developing country, Viotti (2002) suggest developing countries to adopt the National Learning Systems (NLS) to create the absorptive capability to innovate (Lundvall et al., 2002). Some of the additional benefits accrued from establishing MNC's in host countries include employment for the local people (Soon & Huat, 1990). Thus SA could extensively benefit from attracting the MNCs to lower the current unemployment rate and also position the country on a trajectory of technological catch-up for economic growth. Lee (2005) in his study stated that the Asian tiger countries (Singapore included) focused shorter technological cycles for economic catch-up. Singapore is specifically used contrast TT landscape in SA because it rapidly developed from low to high income country (Lee, 2005, 2013) and enhancing TT effectiveness in SA is targeted towards achieving this objective.

5.3.2.1. Licences and spin-outs

The TTOs mentioned using the licensing and spin-outs as a mode of transfer, with licensing being the preferred mode due to lack of absorptive market in SA. A lack of the absorptive market suggest lack of regulatory framework (Soon & Huat, 1990) that promotes technology absorption and the R&D outputs not aligned with the strategic national development goals. This creates a situation whereby resources are assigned inappropriately thus affecting yielding the desired results

The other reason for using licenses was that the technologies are inadequately developed due to lack of development funds. Licensing generate short term benefits i.e. revenue generated (Heath, 2013). SA need to focus on a long term strategy to eradicate poverty and achieve economic goals. The benefits for spin-out are high, the risks are also high. The companies generated through spins outs will generate employment and contribute to the GDP growth. However spin-outs have high failure rate. The success rate of the spin-out companies from the HEIs is relatively low ("PTiP: A Bumpy Road to Solar Success," 2017) and the contributors to the low success rate are (amongst others);

- Lack of entrepreneurial capacity (Hindle & Yencken, 2004)
- Lack of market trajectory understanding (Heath, 2013)
- The researcher employed as the director /CEO and not focusing on technology development (Heath, 2013; "PTiP: A Bumpy Road to Solar Success," 2017)
- Composition of the team members and the strength (Barnardt, 2017; SUCA, 2018)

To increase the success rate of the spin-out, the HEIs form joint ventures with the knowledge creators where the board of directors of the venture are technical experts from the various faculty offices. The detriment about the constituent of this board is that business sector is inadequately represented. The resources and the competencies within the business schools should be integrated in the boards of these entities to enhance the success rate of these ventures. The spin-outs are used when developed product/service does not align with the strategic mandate of the company (Goffin & Mitchell, 2016). The spin out companies from universities are aimed at exploiting IP from research institutions (Hindle & Yencken, 2004)

5.3.3. Disadvantages of the Patent System within The IPR-Act Context

The disadvantage about patenting is that it takes approximately five years for patent registration in international offices and patents have a time frame of approximately 20 years (Goffin &

Mitchell, 2016, p. 202). The first five years researchers and the TTO spend on defending the patent. The pitfall with this strategy is that problem solving techniques such as TRIZ may be used to reverse engineer the patent and develop disruptors prior to reaping any return on investment (Goffin & Mitchell, 2016).

Patenting is not ideal in business sectors such as the Information Communication and Technology (ICT) as technology is developed at a faster pace and there are a lot of disrupters. The interviewees mentioned the ICT sector to be doing well on TT, however this may be due to the first mover advantage strategy adopted in this sector.

Innovation is a cumulative process, the researcher has to continuously improve the technology to capitalise the market and create monopoly thus avoiding disruptors. The market and the customer needs are changing, thus further development is required to stay relevant. A researcher/ inventor working as a CEO is focused business management and thus negatively affecting technology development ("PTiP: A Bumpy Road to Solar Success," 2017). Creation of a start-up is not the end goal, the IP licensed has to be further developed.

5.3.4. Social Impacts of Innovation

Most of the TTOs mentioned that it is hard to quantify the social impacts of the technologies that they have been transferred to the market. The reasons may be attributed to technologies having long lead times (Mansfield, 1991). Some of the interviewees mentioned that within their region, they also focus on innovation for social purposes e.g. assisting the young adults addicted to drugs. Social innovation was also mentioned, where the products are developed to enhance the lives of the neighbouring communities. However, these measures are not used by the various TTOs as a measure for TT effectiveness. Some interviewees mentioned jobs created as a measure for their social impact, however that could not be quantified. The UoTs mentioned relying on the social initiatives to enhance IP pipeline.

5.3.5. Overview of IPR-Act Effectiveness

The various TTOs execute the functions as outlined IPR-Act, however they have a different indictors to measure effectiveness and with most not aligned with the mission statements displayed on the webpages of the respective institutions. Strategy provides guidance with reference to the type of innovation an entity is focused on, allocation of resources and organisational structure to achieve the strategic mandates. Also the strategy informs the KPI that are used to measure effectiveness.

The HEIs are generating knowledge as evidenced by the increased publication (DST_HSRC, 2014/2015, p. 26) , however these do not translate into technological innovations. Thus the IPR-Act alone cannot be used to assess TT effectiveness (Mowery & Sampat, 2004). As Mowery and Sampat (2004) cautioned that the success of the Bayh-Dole Act has to be contextualised. It can be that the research that is strategically aligned to the regional economic development enhances the probability of R&D outputs being commercialised (Mowery & Sampat, 2004). Thus to enhance the TT effectiveness the R&D outputs have to aligned with the regional economic development roadmaps. Interviewees mentioned having top priority research focus areas will increase TT effectiveness than focusing on research across all the sectors. This strategy will affect the education and training as it will mean that the HEIs will have to be categorised as "speciality HEIs", where the competencies are concentrated within a specific sector.

This type of arrangement will require that the TTO professional employed at these "speciality HEIs" to have "specialised" technical competency skills. This will avoid the TTOs having to do TT activities for sectors they do not have expertise in. The disadvantage of changing the HEIs to be speciality schools, may result with overcrowding of other speciality schools as their careers are more popular. Currently, there is a challenge with the HEIs not able to accommodate the number of matriculants. This is observed in January registration overcrowding phenomenon experienced at the HEIs.

The (Ministry_of_Education, 2002) proposed list of the HEIs programmes to be offered at the various regions post the merger and they are summarised in Appendix 6.

The national working group committee identified these areas for collaboration within the regions with the objective of increasing the strengthening the R&D in the various regions (Ministry_of_Education, 2002). Limpopo, Mpumalanga and Northern Cape are not mentioned because these provinces were not represented in the sample frame. Mpumalanga and Northern Cape do not have the UoTs and traditional research universities.

Post strengthening the R&D outputs, there is need implement administrative systems that will enhance the likelihood of researchers to disclose their inventions to the TTOs. There is a need to enhance collaboration among the various TTO to adequately and effectively utilise the resources within the TT ecosystem.

A patent examination office that has the capacity and capability to assess novelty of inventions need to established.

5.4. The Contingent Effectiveness Model for Technology Transfer

The Bozeman et al. (2015) contingent effectiveness model for TT was used as a conceptual framework to assess effectiveness at the TTOs. The dimensions that affect TT effectiveness are categorised into who is doing the transfer, how the transfer is conducted, what is being transferred, where is the transfer taking place and to whom the technology is transferred to. The assumption made when developing the TT categorised determinants / dimensions used by Bozeman et al. (2015) model is that they adequately represent most of the variables that affect TT activities of government funded research. The dimensions are TT agent, TT media, TT object, TT environment and TT recipient. The dimension have varying impact on TT effectiveness and are interdependent, hence multiple effectiveness criteria is used to adequately quantify TT effectiveness.

TT is affected by the characteristics of the TT agent , technological niche, mission, sector, resources, geographic location, science and technology human capital, funding, regulatory framework, management style and organisational structure (Borge & Bröring, 2017). The Boezman's model takes into consideration that the various stakeholders involved in TT have various expectations of effectiveness criteria. This was evidenced in the study, where the TTOs, IDC and TIA perceive the predecessor outputs not to meet the minimum requirement of the successor. Thus for the purpose of the study, effectiveness will be evaluated using the criteria provided by (Bozeman et al., 2015) within the context of the IPR_Act (2008). The effectiveness criteria will be from the context of the TTO. Based on the views of the interviewees, the following dimensions affect TT effectiveness in SA;

- The history of the HEI affects TT effectiveness. TTOs based at historically disadvantaged HEIs do not have research strength and elaborate management strategies for TT. The research strength has an impact on the absorptive capability to develop novel technologies that can be disclosed to the TTO to increase IP pipeline. The HEIs are conducting basic research, with approximately 50% of the GERD allocated to fundamental research (DST_HSRC, 2014/2015) and this may be attributed to the educational mandate. Basic research is underdeveloped and thus need further development so it can be transferred to end users. The basic research has to be aligned to societal challenges (Mowery & Sampat, 2004) to increase the chances of R&D outputs being absorbed by end users.

- Lee (1996) cited by Bozeman (2000) found a strong correlation between technology based regional economic development and industrial linkages. The outcomes of the current research study infers that there is lack of correlation between research conducted at the HEIs and the regional economic development agenda. This has the potential impact TT effectiveness as there is no conducive environment for market to absorb the developed technologies.
- Rahm (1994) cited by Bozeman (2000) found that the TT attrition rate is high where there are industry linkages. The TTOs need to build strong industrial linkages so there is a market pull for the developed technologies.
- Fulga et al. (2016) used the contingent effectiveness model for TT to develop business models focused on increasing technological transfer effectiveness and proposed the "Orchestrator of local buzz" strategy to enhance TT effectiveness in Romania. The "Orchestrator of local buzz" is strategy focused on technologies that can be absorbed by the local market.
- The concept of entrepreneurial university by Etzkowitz et al. (2000) cited by Bozeman (2000)was found to be conducive for TT, however it is non-existent in the SA TT transfer space.
- Most of the TTOs are incapacited, have inadequate incentive structure to attract the required skill competencies, management styles of the HEIs not supporting the mission of the TTO, the research disclosed to the TTO is at infancy stage and inadequate technology development fund, lack of alignment among the various stakeholders are some of the challenges experienced by the TTO. TT effectiveness is linked to the age of the TTO, the R&D composition, commercial orientation and diversity of the research. Geographical location emerged as a contributing theme with some of the TTOs mentioning their geographic locations offer competitive advantage in TT, especially the ones based at the Western Cape. Based on the various challenges outlined for TT in SA the following effectiveness criteria. Based on these inputs, the effectiveness criteria that is adequate to use tor TT in SA is *out of the door*.

The *"Out of the door*" effectiveness criteria accounts for system barriers and measures the "activity" of technology being transferred and not the impact on the users. TT agents transfer technology because they are required to do so i.e. " tick-box" syndrome (Bozeman et al., 2015). To improve the TT effectiveness as per the IPR_Act (2008), the "*Out of the door*" effectiveness criteria can be used as a proxy, whereby increased "*Out of the door*" improves the competencies

within the TT landscape. The assessment criteria for competence needs to be defined and monitored over a period of time to evaluate if "*Out of the door*" has improved the deficiencies within the system. The "*Out of the door*" effectiveness criteria in sub-categorised into three groups, i.e. *pure out of the door*, *Out of the door with transfer agent impact* and *Out of the door with transfer partner impact*

- *Pure out of the door* ~ the end user not putting to use the technology transferred. This is one of the disadvantages of the *"Out of the door",* as it affects technology development if the TT recipient absorb the technology with the intension to "quash" technology. Licensing technologies, especially to internal national stakeholder may lead to technology "quashing" phenomenon thus affecting the ability of the country to build technological competitiveness. Thus it is imperative for the TTOs to have value proposition that will guide the services offered by TTO and TT strategy that will generate economic impact.
- *Out of the door with transfer agent impact*. This is characterized by most TTOs using patents and royalties generated from IP transactions. This measure of impact in not related to the objective of the IPR_Act (2008) as the only impact generated is revenue for the HEIs. The impact may also be measured using the enhanced capability within the TTO.
- *Out of the door with transfer partner impact.* The TTOs have cited the economic landscape and lack development fund as contributor to why IP is licensed to international market. There is a benefit however the benefit is narrow as it does not create benefit for the people of the republic. The manufacturing companies have high profit margins thus benefiting people countries where IP is licensed not SA citizens.

Bozeman et al. (2015) cautions against this mode of TT as it focuses on the activity rather than the outcomes. TT is at its infancy stages in SA and thus NIPMO measure of number of disclosures may be acceptable as it measures IP awareness outcomes. It is desired for the TTO outputs economic impact thus contribute towards GDP growth.

6. CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1. Introduction

This chapter discusses the conclusions of the research study based on analysis of the empirical data and secondary data using the IPR_Act (2008) and the Bozeman's contingent effectiveness model for TT.

The recommendations are made based on the outcomes of the study and the areas the researcher felt the themes were not sufficiently explored to make conclusions.

6.2. IP Management Strategy

TT effectiveness is affected by various factors which are interdependent with spill over effect. Thus solving one challenges may not yield the intended benefits, hence there is a need for an IP management strategy across all the TTOs to combat the innovation chasm. From the empirical data generated, it can be inferred that the mode of TT varies and is dependent on the challenges experienced in executing the core functions. Most of the TTOs are "ticking the box" and closing the projects i.e. *Out of the door* (Bozeman et al., 2015) TT is done for compliance with the IPR_Act (2008),especially at HEIs that do not have the required R&D strength.

The "box ticking" approach is attributed to lack of strategy, non-alignment of the various stakeholder in the TT ecosystem and the barriers experienced in executing the core functions. Most of the TTOs do not have a well-articulated value propositions that guides their operational strategy, including the allocation of resources. The TTOs conduct TT across all the sectors and do not differentiate the type of technologies that are transferred to the market. This inhabits TT, especially within the context whereby TTO has shortage of resources to execute the core their functions. Thus there is an imperative need for alignment of the TT stakeholders to enhance TT effectiveness. This can be achieved by leveraging the strengths of the various TTOs and develop an IP management strategy. The IP management strategy should be guided by SA's socio-economic needs, such that it may yield sustainable results and enhance SA's competitive advantage.

- The R&D must focused and aligned with the regional economic development maps. This is targeted towards a market push approach where the R&D outputs have the potential to be absorbed by end users. The research can be focused on radical, breakthrough or incremental innovation based on the regional development maps. This

will help develop regulatory framework that will ensure there is a conducive environment for TT.

- The various TTOs need to have value propositions and differentiate themselves from the other TTOs based on their core strength and geographical locations. The TTOs to be outward looking with the TT activities and source IP from the surrounding communities.
- The publication and patents can used as a proxy for technical competence to attract FDIs and enhance SA's image on the global landscape. Patents and publication also to be used as proxy to attract researcher collaborations with MNCs. This will minimise the default mode of conducting fundamental research and the culture of publication.

6.3. The IPR-Act Effectiveness on Technology Transfer

The TTOs experience various challenges when executing the core functions. The impact of the challenges on the TT effectiveness vary as a function of the historical background of the various HEI. The HEIs were mandated by the IPR- Act to establish TTOs irrespective of their historical background. This was a weakness of the IPR_Act (2008) as some of the TTOs are based at HEIs with a weak research strength.

The IPR_Act (2008) was adopted without creating an enabling environment that will enhance utilisation of public funded R&D outputs. There is currently no administration systems to enhance the effectiveness IPR_Act (2008). The IPR_Act (2008) mandates researchers to disclose their findings within 90 days, however there is no monitoring system to ensure that this is done. Researchers still prefer to publish because of the incentive structures for publishing R&D outputs. This will infer that there is lack of coherence between the various controlling institutions to enhance utilisation of IP.

The IP cannot be utilised effectively without an examining office to determine the "novelty" of the IP, this inhibits the market scalability and derails the VC's from participating in the TT ecosystem as market scalability and IP strength are used as funding criteria by the VC's. To enhance the utilisation of IP emanating from the TTOs, a patent examination office, has to be established.

To enhance the effectiveness of TT at the TTOs, the IP management strategy can be revised and regulated such that the output of the process enables SA to transition from resource based to knowledge economy. SA could leverage its publication and patenting as an indicator for

technical competence. This will build the competitive advantage and enhance researcher's exposure to international markets. The strategy will also provide a guideline for the KPIs to measure effectiveness of TT. The KPIs will align the TT activities for effective use of limited resources within the ecosystem. The standardisation of the KPIs may be a challenges as the various TTOs experience various challenges which affect the mode of TT, however, the value proposition of the TTOs will enable the KPIs to be adequately defined.

It is proposed to use subject matter experts to assess technical viability of the disclosures and the faculty office members of the various HEIs may conduct this function. Tentatively, it is proposed for NIPMO to have a team of technical expects to evaluate technical viability and the novelty of the disclosures. The proposed measure is envisioned to control confidentiality and ensure that due diligence is conducted by a team of technical experts. An added advantage of using the peer review for disclosures is that it will enhance collaboration among the researchers. However one should guard against personal conflicts which may affect the IP pipeline.

The government needs to adopt a system that monitors the allocation of research grants and research development funds to avoid repetitive research with no strategic intent. This is envisioned to utilise the limited resources adequately hence research focused strategy is required to enhance TT effectiveness. Allocating funds based on the regional economic developments is envisioned to minimise duplication of research and the value propositions by the TTOs will differentiate the niche areas where research needs to be focused. This will be boosted by the organisation structures of the TTOs, where the research is integrated with TTOs structure to form a synergy among the various stakeholder within the HEIs ecosystem. This may also enhance the effectiveness of the IPR_Act (2008) disclosures publication will be controlled.

It is recommended that a study be conducted to evaluate the effect revising the HEIs in SA to have "Speciality University" focusing on enhancing the competencies within the sectors and taking advantage of the regional economic development. The study to focus on how the proposed strategy will impact the education mandate and overcrowding at the higher education institutions. The study to also explore sectors that could be merged among the regions. This is envision to minimise duplication of research and enhance effective use of the limited GERD (0.77% GDP).

- It is recommended for a study to be conducted to evaluate the relevance of the IPR_Act (2008) in meeting the socio-economic needs and preparing the country for the 4th industrial revolution. This is based on that the technologies are evolving at a faster rate and TT process is lengthy, taking approximately 5 years for patents to be accepted.
- It is recommended that the NIPMO training programmes be reviewed, and form platforms that the various TTOs can cross-pollinate and leverage on their various strengths. Post oversees training and development programmes, the professionals to share learnings with various TTOs.

6.4. Technology Transfer Ecosystem

The TT ecosystem is intertwined with the various actors within the ecosystem interdependent; therefore alignment among the various actors is important.

An alignment workshop between the government stakeholders (i.e. DST, DHET including TTOs and HEIs executives, TIA, IDC, The dti, department of economic development) is proposed for the various stakeholders to align their mandates and develop TT roadmap which details TT minimum requirements for the predecessor. The roadmap can be used as a guideline by various stakeholder within the TT ecosystem. TT is not a linear process, however the roadmap will only be used to enhance synergy among the stakeholder.

An alignment workshop is recommended to enhance effectiveness among the government structures. TIA, IDC, SEDA and SPII provide funding for "innovative" projects aimed at technology development, there is a need for strategic alignment to structure and allocate the various funding from the various government departments. The outcomes of the proposed government stakeholder alignment workshops to be used for an alignment with the private sector. This will identify the sectors that need private sector input thus enhancing effectiveness within the ecosystem.

The business schools can integrate the TTOs in their teaching modules where the students of the business schools are assigned project tasks to build or develop models to take sustainable business to the market. This will leverage the resources as the work will be done by the students and also offer the students an experiential learning i.e. human capital effectiveness criteria.

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8. APPENDICES

Appendix 1: TTO structured interview questions

1. Kindly advise what are the core functions of the TTO?
2. What challenges are experienced in executing the core functions of the TTO?
   Follow up questions
   a. What are the outputs and metrics used to assess the effectiveness of the core functions?
   b. What are social impacts of technology transfer outputs conducted by the TTO and how are they quantified?
3. May you kindly advise what the strategy of the TTO and how is it executed? (mission and goals of how the TTO execute some of its functions
   a. What is the value proposition/competitive edge of the TTO? What is the differentiating factor relative to the other TTO's?

For TTO in operation prior to 2008, was the strategy changed since inception of the TTO?

   b. If yes, has the impact on technology transfer process been positive or negative?
4. In your view, who are the major stakeholders in technology transfer ecosystem?
   a. Are there programmes, platforms in place to enhance the linkages between TTO's? At what stage of the technology transfer are these linkages critical?
5. What influences/informs the choice of the mode of technology transfer?
   a. How are the technology recipients identified and what are is their involvement during the technology transfer process?
6. What support structure is received and required by TTO's to enhance the transfer effectiveness?
   a. From the university and externally?
7. What are the critical skills required and human capital development initiatives to improve technology transfer in South Africa?
8. What is your view on the technology transfer culture of the TTOs?

Appendix 2: NIPMO interview questions

Objective of the IPR Act was to enhance utilisation of the IP and TTO's were the conduits to enhance effectiveness and NIPMO was to have a statutory role on technology transfer in SA. I have interacted with the TTOs to establish their core functions, barriers and look at what they use to measure effectiveness.

1. What are the core function of the NIPMO?
    a. What support do you offer to the TTOs?
    b. What are the developmental programmes offered to TT professionals and how do you measure objectives of these programmes
2. What are the barriers that inhibit the NIPMO from achieving their core functions?
3. How do measure the effectiveness of your core functions?
4. In your view, who are the major stakeholders in technology transfer ecosystem?
5. In your view, why is SA still adopting technology from far and what can be done counteract the innovation chasm?
6. The current IP portfolio will it help the country leap frog for economic growth?
7. Has the IPR Act improved tech transfer in SA? What can be enhanced

Appendix 3: TIA interview questions

1. What is the role or the involvement TIA in the technology transfer space?
2. What are the barriers that affecting TIA from achieving the aforementioned roles?
3. What is the strategy that TIA employs to overcome the barriers and achieve their strategic mandate?
4. What assessment criteria is used to select the technologies for funding?
5. What is used to measure the effectiveness of TIA's core functions?
6. In your view, who are the major stakeholder in technology transfer and why?

Appendix 4: VCs interview questions

1. Kindly advise the type of VC and the types of projects that you fund? (Mandate, assessment criteria, stage of involvement)
2. How do you identify the portfolio of companies?
3. What are the barriers and challenges experienced with technologies that you fund?
4. What is the strategy used to overcome the barriers and execute the mandate of the VC?
5. In your opinion, do you think that there is role that venture capital can play in the technology transfer space i.e. management and commercialisation? What do you think your involvement should be?
6. What is your view on who are the active stakeholder? (the role of an ecosystem technology transfer)
7. What support (excluding financial) can be provided in the technology transfer space to enhance effectiveness
    a. What can be enhanced to improve the technology transfer effectiveness in SA?

Appendix 5: Introduction and consent letter to the interviewee

Letter of Introduction and Informed Consent

Investigating the role of South African Technology Transfer Offices and assess the barriers that affect technology transfer effectiveness.

Research conducted by: Mante H.S Kgaria

Date: 12 January 2018

Dear Technology Transfer Professional

You are invited to participate in an academic research study conducted by Mante Kgaria, a Masters student in Innovation Studies from the WITS Business School. The purpose of the study is to investigate the role of South African Technology Transfer Offices (TTOs) and assess the barriers that affect technology transfer effectiveness.

Please note the following:

- My studies are undertaken in my private capacity and are undertaken as part of the minimum requirement to qualify for a Master's degree.
- This is an anonymous study survey, your name will not be disclosed. The answers you give will be treated as strictly confidential as you cannot be identified in person based on the answers you give.
- The name of the TTO that participated in the study will only be mentioned in the sample frame and the discussion of the results will be anonymous.
- Your participation in this study is highly valued. You may, however, choose not to participate and you may also stop participating at any time without any negative consequences.
- An interview will be scheduled at a date and time suitable for both parties. This should not take more than 60 minutes of your time. Also a questionnaire will be sent and is anticipated to take less than 15 minutes of your time.
- The results of the study will be used for academic purposes only and may be published in an academic journal. We will provide you with a summary of our findings on request.
- Please contact my study leader, Prof Thembela Hillie on +27 12 841 3874 or thillie@csir.co.za or the course director Dr Diran Soumonni on +27 11 717 3646 or diran.soumonni@wits.ac.za if you have any questions or comments regarding the study.

Please indicate that:

☐☐You have read and understand the information provided above.

☐☐You give your consent to participate in the study on a voluntary basis. (Please tick). YES / NO

Signature: _____ **Date of consent:** _____

Appendix 6: List of the programmes offered by the HEIs at the different regions post the proposed 2005 merger (Ministry_of_Education, 2002)

Eastern Cape	Free state	Gauteng	Kwa-Zulu Natal	North West	Western Cape
Visual and performing arts	Agriculture and natural resources	Agriculture and natural resources	Architecture and environmental design	Visual and Performing Arts	Architecture and environmental design
Journalism, media and communication studies	Architecture and environmental design	Architecture and environmental design	Engineering	Business and management	Visual and performing arts
Languages and literary studies	Home economics	Visual and performing Arts	Health sciences	Education	Health sciences
Geological sciences	Public administration.	Business and management	Home economics	Health Sciences	Home economics
Public administration and social work.		Engineering	Languages and literary studies	Law	Languages and literary studies
		Health sciences	Public administration and social work.	Public administration	Library and museum studies
		Home economics			Public administration and social work
		Languages and literary studies			Gender studies.
		Geological sciences			
		Public administration and social work.			

Appendix 7: Characteristic of the HEIs who participated in the study

HEI	Affected by Merger	Type of Institutions	Characteristics	Faculty office and the research focus areas	Year TTO established
UCT	No	University	Leading in teaching and research Africa. Research and Contracts & Innovation (RC&I) is an enterprise of the UCT responsible for managing, authorising and negotiating research contracts. The RC&I has a defined organogram with the TTO under the innovation umbrella. The functions entails IP management and IP commercialisation. http://www.uct.ac.za/main/research/groups/interdisciplinary-strengths	Commerce, Engineering & the Built Environment, Law, Health Sciences, Humanities and Science. **Some of the research focus areas;** Astrophysics, Cosmology and Gravity Centre (ACGC) African Climate and Development Initiative (ACDI) Drug Discovery and Development Centre (H3-D) Institute of Infectious Disease and Molecular Medicine (IDM)	1999
SU	No	University	One of SA leading HEIs based on research output, second rated scientists (NRF), and recognised internationally for academic excellence. The TT activities are carried out by an enterprise of the SU, Innovus. The Innovus website has a comprehensive IP portfolio, the number of spin-outs and the a roadmap for TT value chain with time lines. The Innovus reports to a board of directors, some who have an elaborate profile in the technology space. Launch lab as an incubator.	AgriSciences, Economic and Management Sciences, Medicine and Health Sciences, Engineering, Military Sciences, Arts and Social Sciences, Science, Education, Law and Theology.	1999

WITS	No	University	Top rated university nationally and has A-rated professors. The TT activities are conducted by TTO reporting to the WITS enterprise. There is comprehensive list of IP portfolio and the various stages of development along the TT value chain.	Commerce, Law & management, Engineering & the Built Environment, Health Sciences, Humanities and Science -	2002
UP	Yes (Merged with Vista Mamelodi campus)	University	One of the top research universities in SA. The TTO is housed at the Research and Contract and Innovation support office. There is TTO news featuring the technologies that have been transferred to the market and technology profile for technologies available for licensing	Economic and Management Sciences Education, Engineering, Built Environment and Information Technology, Health Sciences Humanities, Law, Natural and Agricultural Sciences, Theology Veterinary Science and the Gordon Institute of Business Science (GIBS).	
UWC	Yes (Merged with SU Dental school)	University	UWC seeks to be a roles player in the knowledge economy through strengthening its research outputs. UWC is in the process of establishing an enterprise and the TTO will be moved. This structure is anticipated to enhance commercialisation of the R&D outputs. The objectives and key activities are outlined on the TTO website and the IP portfolio for the flagship projects		
UFS	Yes (Bloemfontein and QwaQwa campus)	University	The TTO operates from the contract and research unit. Commercialisation is done via spin-outs and licensing (however not limited to)		2009

UJ	Yes (Merger of RAU and Wits tech)	Comprehensive Institute	Commercialisation and TT office (C&TTO) is responsible for conducting the TTO functions. This unit reports to the Cooperate services .The research at UJ is said to be primarily focused on the African continent. The university has various research centres.		2005
NMMU	Yes(Merger of PE university and Technikons)	Comprehensive Institute	The TTO is operated within the innovations office. The website has IP portfolio highlighting the projects at advanced research stage and commercialisation.	NMMU has identifies 13 research themes where the university will focuses its research, including the coastal marine and shallow water ecosystem	2007
TUT	Yes (merger of Pretoria Technikons)	Technikons (UoT)	The TTO is part of the innovation support unit which reports to the Director of Research and Innovation. Institute centres and Technology Station incubators (ICTSI) also report to the Research and Innovation directorate The ICTSI are in the following disciplines, economics and finance, Engineering and Built environment, ICT, management science and science		2005, merged into the research unit in 2007
CPUT	Yes (merger of cape Technikons)	Technikons (UoT)	The TTO reports to the research directorate. There are three technology stations at CPUT, namely Agri-food, textiles and advanced manufacturing.	CPUT has over 20 research centres and units in the various disciplines/sectors	
VUT	Yes	Technikons (UoT)	TT Innovation (TTI) comprises of seven units which work together to transfer technology to the public. The TTI is also a home of the Southern Gauteng Science and Technology park. VUT is established around the major petro-chemical, steel, engineering, telecommunications and manufacturing companies.	The major research focus areas are Sustainable livelihoods, Innovative product development, materials and metals, plant molecular genesis, renewable energy and water	