THE UNIVERSITY OF QUEENSLAND
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# University Technology Transfer Performance in Australia

Rashed Sulaiman R Alhomayden

Bachelor of Science (Pharmacology); Master of Applied Science (Molecular Biotechnology)

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School of Chemistry and Molecular Biosciences

## **Abstract**

University technology transfer is considered to be an important driver of national innovation and regional economic development. However, previous studies on university technology transfer productivity and efficiency have not evaluated the relative efficiency of Australian universities in technology transfer. In the first study of this thesis, secondary data was used to conduct data envelopment analysis to measure the technical efficiency of Australian universities in producing four technology transfer related outputs, namely the number of invention disclosures, the number of licenses executed, the amount of licensing royalty income and the number of spin-offs created with university equity. Universities were then ranked according to the average technical efficiency scores for producing the four technology transfer related outputs. Subsequently, taking differences between universities in technology transfer efficiency into account; semi-structured interviews were conducted with 25 University Technology Transfer Office (UTTO) representatives to identify 12 antecedents of university technology transfer efficiency.

The literature on university technology transfer has proposed individual, organisational and environmental determinants to superior university technology transfer performance. However, most of the previous studies on university technology transfer productivity and efficiency have not made a theoretical contribution to the field which might have limited the generalisability of their findings. In the second study of this thesis, the Resource-Based Theory (RBT) was adopted to examine and explain performance differences between universities in technology transfer considering three resource factors, namely the number of ARC Linkage funded projects (financial capital), the number of UTTO staff holding a PhD (human capital) and the joining of a UTTO to a consortium (social capital). Using primary and secondary data, these resource factors were regressed against six university technology transfer performance measures, namely the number of invention disclosures, the number of filed patents, the number of executed licenses, the amount of licensing royalty income, the number of all spin-offs created and the number of spin-offs created with university equity. Empirical findings show that the application of financial, human and social capital matters for technology transfer performance. UTTOs that possess these tangible and intangible resources report higher performance on most of the performance measures applied.

Previous studies have not established a relationship between the organisational structure of UTTOs and their performance. In the third study of this thesis, the RBT was adopted to examine and explain performance differences between universities in technology transfer considering four resource factors in relation to the organisational structure of UTTOs; centralisation, specialisation, configurational autonomy and financial dependence. Using primary and secondary data, these resource factors were regressed against six university technology transfer performance measures, namely the number of invention disclosures, the number of filed patents, the number of executed licenses, the amount of licensing royalty income, the number of all spin-offs created and the number of spin-offs created with university equity. Empirical findings show that decentralised UTTOs are superior to centralised UTTOs by all technology transfer performance measures. In relation to specialisation, a positive association was not confirmed for any of the studied technology transfer performance measures. It was also found that highly autonomous UTTOs receive more invention disclosures, file more patents and execute more licenses than non-autonomous UTTOs. Interestingly, it was also found that financially independent UTTOs file fewer patents, execute fewer licenses but receive more licencing royalty income and create more spin-offs with or without university equity than financially dependent UTTOs. Universities' ability to effectively configure the organisational structures of their UTTOs is indeed valuable in ensuring comparatively higher technology commercialisation performance. It is advisable for universities to adopt autonomous UTTO structures since it would enhance the number of patent filings and licencing agreements whereas maintaining the UTTOs as decentralised and financially independent cost centres would ensure financial sustainability.

## Declaration by Author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my research higher degree candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

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Alhomayden, R., Barnard, R.T. & Gronum, S. (2016). *New insights into university technology transfer performance: the case of Australian universities.* Asia-Pacific University-Industry Engagement Conference. Adelaide, Australia, 15th-17th February, 2017.

**Publications Included in This Thesis**

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This publication is included in this thesis, Chapter four. The contributions of all authors to the publication as per the requirements in the UQ Authorship Policy (PPL 4.20.04 Authorship) are presented in the following table.

| Contributor | Statement of Contribution |
| --- | --- |
| Alhomayden, R. (Candidate) | Statistical Analysis (100%)<br><br>Wrote and edited the paper (80%) |
| Barnard, R.T. | Wrote and edited paper (10%) |
| Gronum, S. | Wrote and edited paper (10%) |

## Contributions by Others to the Thesis

No contributions by others.

## Statement of Parts of the Thesis Submitted to Qualify for the Award of Another Degree

None.

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**Keywords**

Australian Research Commercialisation Environment, University Technology Transfer, Entrepreneurial University, Resource-Based Theory, Organisational Legitimacy, Organisational Structure, Technical Efficiency, Data Envelopment Analysis, Regression Analysis.

**Australian and New Zealand Standard Research Classifications (ANZSRC)**

ANZSRC code: 150307, Innovation and Technology Management, 80%

ANZSRC code: 150304, Entrepreneurship, 20%

**Fields of Research (FoR) Classification**

FoR code: 1503, Business and Management, 100%

## Table of Contents

# List of Figures & Tables

# List of Abbreviations

| | |
|---|---|
| ARC | Australian Research Council |
| ARCNUM | Number of ARC Linkage Funded Projects |
| ASTP-Proton | Association of European Science and Technology Transfer Professionals |
| ATICCA | Australian Tertiary Institutions Commercial Companies Association |
| AUTM | Association of University Technology Managers |
| AUTO | Configurational Autonomy of Organisational Structure |
| AVCAL | Australian Private Equity and Venture Capital Association Limited |
| BITS | Building on Information Technology Strengths |
| CCST | Coordination Committee on Science and Technology |
| CONMEM | Consortium-member UTTOs |
| CRS | Constant Return to Scale |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| DEA | Data Envelopment Analysis |
| DECENT | Decentralisation of Organisational Structure |
| DMU | Decision Making Unit |
| ERA | Excellence in Research for Australia |
| EXCLIC | Number of Executed Licenses |
| FILPAT | Number of Filled Patents |
| FININD | Financial Independence of Organisational Structure |
| GDP | Gross Domestic Product |
| H-Form | holding Company Model of Organisational Structure |
| ICTIP | Information and Communications Technology Incubators Programme |
| IDs | Invention Disclosures |
| INVDIS | Number of Invention Disclosures |
| IP/IPRs | Intellectual Property Rights |
| KCA | Knowledge Commercialisation Australasia |

| | |
|---|---|
| LES | Licensing Executives Society |
| LESANZ | Licensing Executives Society of Australia and New Zealand |
| LICINC | Amount of Licensing Royalty Income |
| M-Form | Multidivisional Model of Organisational Structure |
| MoC | Metrics of Commercialisation |
| MRCF | Medical Research Commercialisation Fund |
| MX-Form | Matrix Model of Organisational Structure |
| NISA | National Innovation and Science Agenda |
| NSRC | National Survey of Research Commercialisation |
| OECD | Organisation for Economic Cooperation and Development |
| PhD | Doctor of Philosophy |
| PHDSTF | Number of PhD Staff at University Technology Transfer Office |
| R&D | Research and Development |
| RBT | Resource Based Theory |
| RQF | Research Quality Framework |
| SFE | Stochastic Frontier Estimation |
| SMEs | Small and Medium Enterprises |
| SPEC | Specialisation of Organisational Structure |
| SPICRE | Number of All Spin-offs Created |
| SPIEQU | Number of Spin-offs Created with University Equity |
| SPIRT | Strategic Partnership with Industry-Research and Training |
| STEM | Science, Technology, Engineering and Mathematics |
| U-Form | Functional or Unitary Model of Organisational Structure |
| UK | United Kingdom |
| UniQuest | Commercialisation Arm for the University of Queensland |
| US/USA | United States of America |
| UTTOs | University Technology Transfer Offices |

| | |
|---|---|
| VC | Venture Capital |
| VIFs | Variance Inflation Factors |
| VRS | Variable Return to Scale |
| WG | Working Group |

# Chapter One: Introduction

First world countries with advanced economies have recognised the importance of innovation for global competitiveness and can indeed be labelled as innovation-driven countries (Schwab & Sala-i-Martin, 2015). In order to foster national innovation and regional economic development, the United States of America (USA) has introduced the *Bayh-Dole* act in 1980 (Gerbin & Drnovsek, 2016). Prior to this act, ownership of intellectual property created at US universities and research centres belonged to the federal government. However, this act transferred the ownership of intellectual property to universities and research centres. Among other first world countries, especially in Europe, *Bayh-Dole*-like legalisation has been introduced (Mowery *et al.*, 2004). Following these acts, universities have faced continuous pressure to commercialise their research outcomes, and governments have tried to pave the way for universities to commercialise their intellectual property (Carlsson & Fridh, 2002).

Over the last three decades, this phenomenon, also known as "university technology transfer", "university research commercialisation" and "university's third mission" (Kim, 2013), has attracted the attention of scholars, policy makers and university management. Some scholars argue that university research commercialisation is a second academic revolution for universities, and the term *entrepreneurial university* has been coined (Etzkowitz, 2004). However, other scholars claimed that this phenomenon is only an institutionalisation of an activity that could be traced back 100 years, to the development of the chemical industry (Geuna & Muscio, 2009). Regardless of the debate about the initiation of this phenomenon, universities are expected to incorporate technology transfer as a new role in addition to their traditional teaching and research roles.

Knowledge exchange can be broadly defined as the transfer of knowledge between two entities. Figure 1.1 presents a model of the broad process of knowledge transfer in the university context (adapted by University of Glasgow, 2017).

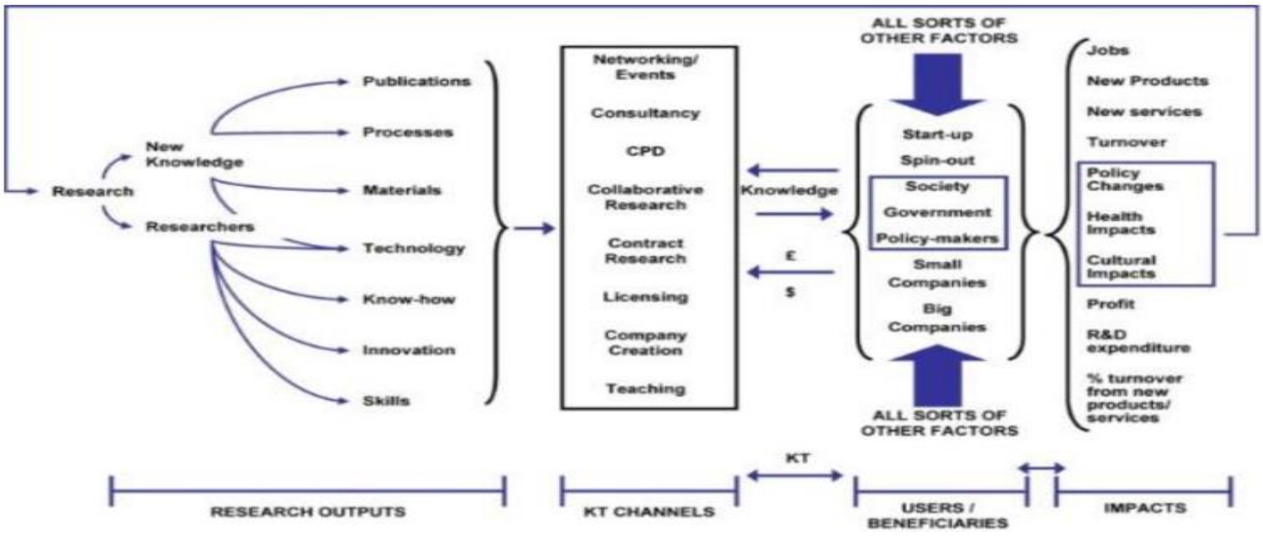


**Figure 1.1**: The process of knowledge transfer in the university context (adapted by University of Glasgow, 2017).

As shown in Figure 1.1, the university plays an important role as a research engine for end users or beneficiaries. The university utilises its resources and capabilities to establish connections and to generate wealth. The interactions of the university with beneficiaries such as the industry, the government and the community are critical to build the reputation of the university and to attract star scientists and outstanding students. These interactions carried out using multiple knowledge transfer (KT) channels ranging from teaching, continuing professional development (CPD) to contract research and consultancy agreements to licensing and spin-offs creation. Although all KT channels are critical to deliver research impact, only intellectual property (IP) commercialisation through technology licencing and spin-offs creation is considered for the scope of this thesis.

In more details, technology transfer can be broadly defined as the transfer of technology from a research-based organisation to a receptor organisation. University technology transfer has been linked to regional economic development. In fact, the Lisbon Strategy of the European Commission in 2000 emphasised the importance of research commercialisation and its positive effect on regional economic development (Schoen *et al.*, 2014). The simplified linear process of university technology transfer, adapted from Rogers *et al.* (2000), is presented in Figure 1.2.

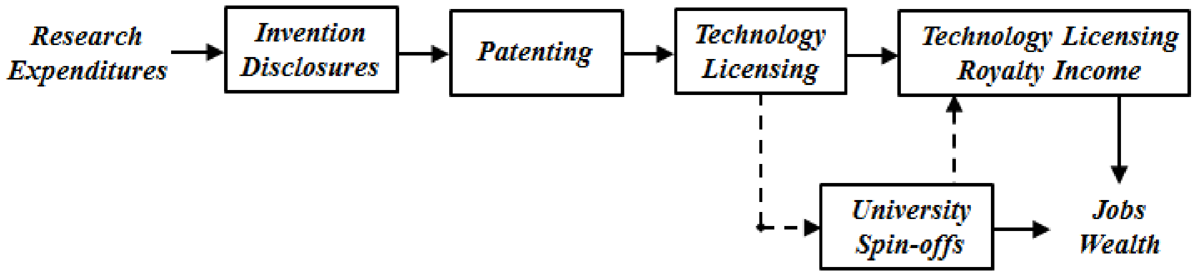

**Figure 1.2**: The simplified linear process of university technology transfer.

As shown in Figure 1.2, technology transfer involves transactions between the university and the private sector, and as a result institutional tensions between academic and commercial demands have emerged (Bercovitz & Feldman, 2006). These tensions are mainly due to the cultural differences between the academic and the commercial domains. With that in mind, universities have to manage entrepreneurial and traditional roles simultaneously. In other words, universities are expected to act as *ambidextrous organisations* (Tushman & O'Reilly, 1997).

The term 'organisational ambidexterity' was first coined by Duncan (1976); however, it was March (1991) who highlighted the term and launched the topic. According to March (1991), ambidextrous organisations should be able to exploit current capabilities and to explore new ones simultaneously and according to which they allocate resources and set objectives and targets. Organisations have to set up structures and to develop strategies in profoundly different contexts. Therefore, universities have developed organisational structures mainly responsible for technology transfer. These structures are referred to in the literature by different names such as university technology transfer offices (UTTOs) (Ambos *et al.*, 2008). In addition to technology transfer offices, other research commercialisation facilitators have been established by universities and government agencies such as business incubators, science parks and regional clusters (Phan & Siegel, 2006). Also, technology transfer office networks have been formed in order to enhance skills and to minimise expenses (Litan *et al.*, 2008).

Technology transfer offices are considered as intermediaries between scientists (innovation suppliers) and the commercial sector (innovation developers) (Siegel *et al.*, 2007). As per Figure 1.1, technology transfer officers normally receive invention disclosures, test the commercial viability and patentability of the invention and then decide on the best commercialisation strategy (Van Looy *et al.*, 2011). Strategies for research commercialisation are diverse and include contract research, academic consultancy, cooperative research and development, technology licensing and academic spin-offs (Perkmann *et al.*, 2013). These strategies differ by the degree of relational intensity, formalisation and knowledge finalisation as well as significance for industry (Ponomariov & Boardman, 2012).

With the increasing trend in technology transfer office establishment at universities, policy-makers have placed emphasis on technology transfer efficiency. The main dilemma faced by UTTO professionals is due to performance measurement. The root of such a dilemma is that the impact of research outputs rely mainly on the further development by recipient organisation, the licensee of university technologies (Friedman & Silberman, 2003). Additionally, even if the recipient organisation has the resources and the capability to further develop the licensed technology, the commercialisation process normally takes a period of 6-8 years and successful inventions disclosed seven years ago would be almost ready to be commercialised today (Kim & Daim, 2014). Also, non-science, technology, engineering, and mathematics (STEM) university research outputs are rarely associated with IP commercialisation. Therefore, the impact of non-STEM university research outputs is not captured by current metrics used to measure the performance of UTTOs (Siegel *et al.*, 2007). Those metrics fails to capture the impact of non-patentable research outputs and research outputs that result in policy change. Hence, the metrics used in this thesis are not to be generalised for all university research outputs rather it is only a reflection of the performance of UTTO's in the commercialisation of university's IP. The limitations of using these commonly used metrics are included throughout this thesis.

Hence, previous studies have evaluated technology transfer efficiency by using a diverse set of performance measures as inputs and outputs (Siegel *et al*., 2004; Thursby *et al*., 2001). Other studies developed this line of analysis further, to highlight determinants of efficient technology transfer (e.g. Macho-Stadler *et al*., 1996; Jensen & Thursby, 2001; Lach & Schankerman, 2004; Link & Siegel, 2005; Di Gregorio & Shane, 2003; O'Shea *et al*., 2005). Aims of the thesis are discussed next.

## 1.1 Aims of this Thesis

Australia is lagging behind other first world countries in terms of university research commercialisation with comparatively limited governmental initiatives to encourage interactions and collaborations between universities and the private sector (Harman, 2010). In fact, according to the Organisation for Economic Cooperation and Development (OECD)

(2015a), less than 5% of Australian SMEs and large businesses collaborate in innovation with higher education providers which is significantly below the OECD average of 13% for SMEs and 35% for large businesses. This is also reflected in that only 3% of Australian businesses obtained their innovative ideas from higher education providers in 2014-2015 (Australian Government, 2016).

With that in mind, it is important to point out that the absorptive capacity of firms plays a critical role in the interactions between the university and the private sector. According to Cohen and Levinthal (1990), absorptive capacity of firms is defined as "*an ability to recognise the value of new information, assimilate it, and apply it to commercial ends*" (p.128). The main factor for enhancing absorptive capacity of firms is through research and development (R&D) (Cohen & Levinthal, 1990). In fact, as shown in Figure 1.3 (adapted by OECD, 2015b), R&D active firms are more likely to produce innovative products than non-R&D firms (80% compared to 35% for Australian firms). However, less than 15% of Australian manufacturing and services firms, and less than 10% of SMEs and large companies introduced new products to the market in 2010-12.

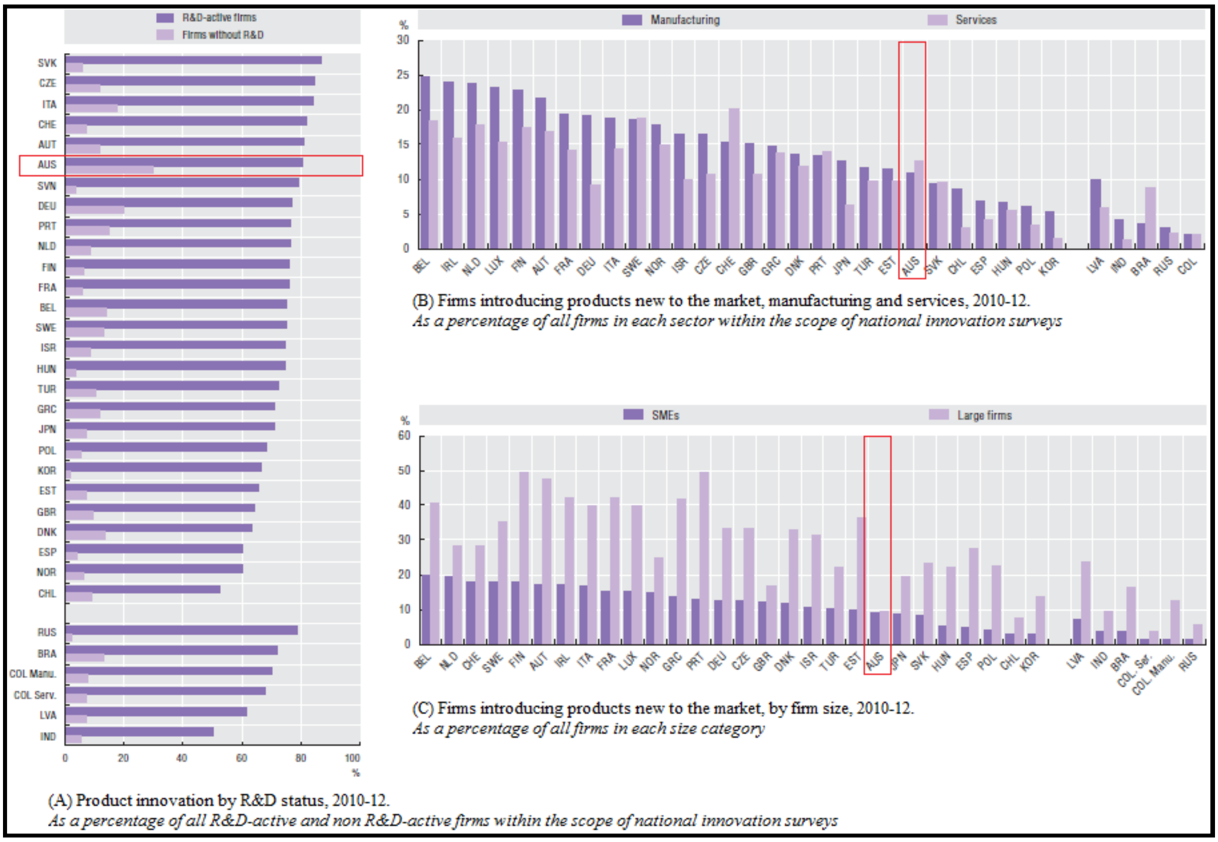


**Figure 1.3:** R&D activities of firms in OECD countries, Australian firms are highlighted in red rectangles (adapted by OECD, 2015b).

Consequently, the Australian Commonwealth government has recently recognised this shortcoming and shifted policy towards greater enhancement of university research commercialisation and technology transfer (Department of the Prime Minister and Cabinet, 2015). With this positive shift in public policy, it is also important to ensure that such policy imperatives and subsequent resource expenditure are delivering effective technology transfer and commercialisation outcomes. Therefore, to enhance Australian university research commercialisation, this thesis sets out to evaluate the relative efficiency of UTTOs in Australia and to identify antecedents of efficient university technology transfer.

Previous studies have examined the performance of UTTOs and established determinants of superior UTTO performance. However, most of these studies have adopted inductive approaches to examine UTTO performance which yielded theory-lacking conclusions and unjustified *ad hoc* recommendations (Johnson, 2011). These inductive approaches will hinder the development of the field towards being a valid scientific paradigm (Kuhn & Hawkins, 1963). Therefore, in hopes to enhance the development of the field, this study follows the lead of recent theory-based studies that have adopted theories such as agency and transaction cost (Kenney & Patton, 2009), path dependency theory (Mustar & Wright, 2010), dynamic capabilities as extension of the RBT (Rasmussen & Borch, 2010), population ecology (Cardozo *et al.*, 2011), and organisational control (Johnson, 2011). This thesis applies RBT as primary theoretical lens (Wernerfelt, 1984) in exploring three critical resource factors that are hypothesised to explain performance differences between universities in technology transfer. These resource factors are directly related to financial, human and network capital as measured respectively by the number of Australian Research Council (ARC) Linkage projects, the number of UTTO staff holding a PhD and the joining of a UTTO to a consortium.

With the increasing trends in establishment of UTTOs and development of university-industry innovation ecosystems, universities are concerned with the performance of technology transfer (Siegel *et al.*, 2004; Thursby *et al.*, 2001). Previous studies have attempted to evaluate performance of UTTOs, and have broadly categorised the determinants of UTTOs efficiency as *individual, environmental* and *organisational* (Siegel *et al.*, 2003a, 2008; Chapple *et al.*, 2005; Anderson *et al.*, 2007). In fact, most empirical research only focuses on the individual and environmental levels, whereas organisational structure is neglected at the organisational level. Although the way organisations are designed explains how people interact and how activities are carried out (Drucker, 1973), researchers who investigated organisational structures of UTTOs as a performance determinant address it as a "secondary subject" (Brescia *et al.*, 2016). In fact, Schoen *et al.* (2014) concluded that "*future studies might analyse the quantitative impact of different TTO types on the efficiency and effectiveness of technology transfer activities*". More recently, Brescia *et al.* (2016) concluded that "*it could be a matter for further studies to verify the efficiency and the productivity of the different models and configurations* [of UTTOs]". To my knowledge, previous studies have not provided empirical evidence bearing on the possible relationship between organisational structure features of UTTOs and their performance by quantitative impact analysis. One of this thesis aims is to apply the RBT (Wernerfelt, 1984) to explore the organisational structure of UTTOs as a resource factor that might explain performance differences between universities in technology transfer. The research design for the thesis is discussed in the following section.

## 1.2 Research Methodology for this Thesis

The methods adopted within this thesis are consistent with the research onion proposed by Saunders (2011). The theory defines research methodology in terms of "layers of an onion". The first layer, when viewed from outside, defines the research philosophy to be a positivist, an interpretivist, or a realist. The second layer is concerned with the research reasoning approach which could be either deductive or inductive. The third layer is associated with strategies of research such as case studies or questionnaires. The fourth layer is related to time horizon for the research which could be conducted as cross-sectional or longitudinal (Saunders, 2011).

In research, deductive and inductive approaches are mainly used. The deductive approach is concerned with reasoning initiated from a general theory and ending with specific hypotheses. While, the inductive approach is based on observations and pattern analysis in order to establish a general theory. When deductive approach is mainly associated with confirming hypotheses, inductive approach is exploratory, especially at the beginning (Fereday & Muir-Cochrane, 2006).

Studies can be classified as exploratory, descriptive or explanatory. Exploratory studies allow the researcher to pursue new information and to formulate new questions. Descriptive studies formulate a descriptive picture of a person, a situation or an event. Explanatory studies are concerned with studying the causal nature of a relationship (Creswell & Clark, 2007). A summary of the proposed research design of this thesis is presented in Table 1.1.

| Research Design | | | |
|---|---|---|---|
| **Studies** | One | Two | Three |
| **Purpose of Research** | 1. Evaluate the relative efficiency of UTTOs in Australia.<br>2. Identify antecedents of efficient university technology transfer. | Compare the relative efficiency of UTTOs in Australia to their counterparts in the UK | Examine the relationship between the structure of the UTTO and its efficiency |
| **Research Approach** | Inductive | Deductive | Deductive |
| **Research Type** | Descriptive & Exploratory | Explanatory | Explanatory |
| **Theoretical Lens** | N/A | RBT | RBT |
| **Unit of Analysis** | Australian universities | Australian universities | Australian universities |
| **Data Type** | Quantitative & Qualitative | Quantitative | Quantitative |
| **Time Horizon** | Longitudinal | Longitudinal | Longitudinal |
| **Main Data Source(s)** | Semi-structured interviews (Primary) and NSRC (Secondary) | Semi-structured interviews (Primary) and NSRC (Secondary) | Semi-structured interviews (Primary) and NSRC (Secondary) |
| **Statistical Approach** | Data Envelopment Analysis (DEA) | Regression Analysis | Regression Analysis |

**Table 1.1:** Summary of the proposed research design for this thesis.

### 1.2.1 Data and Sample

Data for this thesis were mainly obtained from primary and secondary sources. Primary data were collected by conducting semi-structured phone interviews with technology transfer officers at Australian universities. Telephone interviews have the advantage of allowing the researcher to control the process of the research. However, preparing, piloting and conducting the interviews as well as analysing responses can be time consuming (Brinkmann, 2014).

A cover letter, explaining the purpose of the study, was emailed to the interviewees prior to conducting the interviews. As recommended by Dillman (2000), a clear unbiased title and subtitle of the research topic were included. Also, the letter was addressed personally, as means for increasing response rate (Brinkmann, 2014). Furthermore, Gummesson (2000) stated that participation in a study is hindered by the limited sources and time of an organisation or an entity. Hence, participants were given the chance to choose the time to conduct the interview. Also, clear, precise language was used for communication to raise interest and to minimise participation barriers (Easterby-Smith *et al.*, 2002). The cover letter is presented in Appendix 1.

Indeed, asking the right questions in relation to the objectives of the research will result in appropriate, usable data (Cooper & Schindler, 2001). Moreover, as highlighted by Foddy (1994), questions should be understood by respondents and findings should be interpreted by the researcher in light of the research objectives. Bell (1999) noted that "piloting" of a research instrument is essential to ensure clarity of questions and to seek comments and recommendations, and to allow modifications based on feedback. Hence, the interview questions script was piloted prior to its administration to interviewees.

The interview was designed to collect quantitative and qualitative data in relation to different themes, and included questions requesting, a brief background about the university, information about the structure of the technology transfer office, the innovation-ecosystem of the university and the availability of venture capital. Interview questions script is presented in Appendix 2.

The secondary data were collected from multiple sources; however, most of the secondary data were obtained from the National Survey of Research Commercialisation (NSRC) for Australia. A comprehensive list of data and their sources are outlined for each of the three studies of this thesis.

The unit of analysis for this thesis is Australian UTTOs and 39 UTTOs participated in the NSRC. The researcher contacted all 39 universities prior to conducting the interviews. Interviews were conducted in October and November of 2016, and representatives from 25 Australian universities participated.

### 1.2.2 Validity, Reliability and Credibility Assessments

In relation to validation of methods and data, *credibility* concerns are usually associated with qualitative data whereas *validity* and *reliability* concerns are most relevant to quantitative data. Among other requirements, credibility requires the understanding of the theoretical backgrounds to achieve trustworthy findings (Glaser & Strauss, 1967). In relation to quantitative data, validity can be either internal or external. Internal validity is to do with the causal relationship between two variables within a research study, where external validity is the extent to which a research can be generalised. Internal validity is essential to external validity and vice versa (Last, 2001). Assessment of reliability is critical when research is conducted by different researchers or when interpretations are highly subjective. Lack of a proper reliability assessment is a risk for internal validity (Golafshani, 2003).

According to the definition of Joppe (2000:1), *reliability* is seen as “the extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable”. Joppe (2000) concluded that a research instrument is considered reliable if the same results can be reproduced by independent researchers. With that in mind, Charles (1995) proposed re-testing for determining consistency. Joppe (2000) argued that this approach is ‘unreliable’ if the same sample is re-tested. This argument is supported by Crocker and Algina (1986) as they concluded that re-testing leads to measurement errors.

Winter (2000) argued that validity within the positivist context is associated with objectivity, evidence and reasoning. Joppe (2000) described *validity* as the ability of a research instrument to achieve research objectives utilising trustworthy results. Moreover, Wainer and Braun (1988) proposed the concept of ‘construct validity’, which is associated with data gathering. They believe that construct validity is concerned with the ability of a test to be measuring what it is supposed to measure, and construct validity is reduced when researchers influence the interaction between the construct and the data.

Reliability of qualitative methods is a topic of controversy as many researchers argue that reliability is not applicable to qualitative methods. Stenbacka (1998) stated that qualitative studies are ‘no good’ with respect to reliability, because reliability is associated with measurements. On the other hand, Patton (2002) asserted that qualitative studies should be concerned with reliability and validity. To sum up, Healy and Perry (2000) stated that terms such as credibility, neutrality, consistency, dependability and transferability work as a substitute for reliability and validity in qualitative methods. However, Maxwell (1992) made the important point that generalisability is tested differently when conducting quantitative and qualitative research.

To achieve validity of qualitative research, Patton (2002) proposed the use of triangulation. Triangulation is means of collecting more than one independent source of data with consistency in order to minimise bias and increase trustworthiness. Using triangulation is highly dependent on research questions and design (Denzin, 1978). However, Babour (1998) argued that using triangulation for quantitative studies may lead to non-conclusive findings.

Moreover, Johnson (1995) highlighted that constructivism is essential for qualitative research. Constructivism is mainly concerned with the use of experiences and ideas to construct a valid and reliable reality through the use of multiple methods. Constructivism is usually associated with qualitative, open-ended research strategy (Johnson, 1997).

In order to ensure reliability and validity for quantitative methods, statistical validity was taken into account. In relation to credibility and trustworthiness for qualitative methods, triangulation and constructivist strategies were used in the present thesis.

## 1.3 Structure of this Thesis

The thesis is divided into five chapters. The first chapter is introductory. The following three chapters are designed as separate studies with abstract, introduction, literature review, methodology, results, discussions and conclusions. The final chapter is conclusory, and it highlights the main theoretical and practical contributions of this thesis, future implications of this thesis, limitations of this thesis and recommendations for future research.

# Chapter Two (Study One): University Research Commercialisation in Australia: Efficiency Evaluation and Analysis of Antecedents


## Abstract

University technology transfer is considered to be an important driver of national innovation and regional economic development. However, previous studies on university technology transfer productivity and efficiency have not evaluated the relative efficiency of Australian universities in technology transfer. Secondary data was used to conduct data envelopment analysis (DEA) to measure the technical efficiency of Australian universities in producing four technology transfer related outputs, namely the number of invention disclosures, the number of licenses executed, the amount of licensing royalty income and the number of spin-offs established with university equity. Universities were then ranked according to the average technical efficiency scores of the four outputs. Subsequently, semi-structured interviews were conducted with 25 UTTO representatives to identify 12 antecedents of university technology transfer efficiency, taking differences between universities in technology transfer efficiency into account.



## Keywords

University Technology Transfer, Australian Research Commercialisation Environment, Technical Efficiency, Data Envelopment Analysis.

## 2.1 Introduction

Before the introduction of technology transfer to universities, patenting and licensing were practised by less than 20 universities, clearly indicating that university-industry interactions were undervalued by most universities in the USA (Kim, 2013). In fact, university inventions were rarely used or developed by either government or industry (Mowery *et al.*, 2004). As a result, UTTOs were established to commercialise university inventions.

UTTOs are seen as intermediaries between innovation suppliers (university scientists) and innovation developers (recipient organisation or business) (Siegel *et al.*, 2007). UTTOs are usually owned by a parent university; however, some universities outsource their research commercialisation to external technology transfer corporations. Outsourcing technology transfer practises is encouraged to help some UTTOs overcome learning and skills limitations (Markman *et al.*, 2008a).

According to Brescia *et al.* (2016), the support activities that UTTOs provide various stakeholders can be classified in three main areas; intellectual property and licensing, sponsored-research and consultancy and spin-off creation. Although not all UTTOs simultaneously engage in all three types of activities, the interrelatedness of these activities is emphasised (Mathieu, 2011). In this regard, Van Looy *et al.* (2011) argue that these activities interact with each other since technologies are licensed for sponsored research and spin-offs are mainly created by technology licensing. Therefore, UTTOs use technology licencing and spin-offs creation as primary commercialisation strategies for transferring technologies to industrial partners (Perkmann *et al.*, 2013).

- **Technology Licensing**

  Universities license their intellectual property rights to the industry in exchange for cash, sponsored research or equity in a company (Markman *et al.*, 2005). Such licensing agreements can either be exclusive or non-exclusive, with exclusivity based on a specific scope or field, such as market, context, territory or time (Thursby & Thursby, 2007). Licensing at the university level has been investigated thoroughly and licensing agreements have been mainly used for examining the productivity of technology transfer offices (Thursby *et al.*, 2001). Licensing agreements are greatly affected by the stage of development of the research, where higher risk is usually associated with underdeveloped technologies (Meseri & Maital, 2001). Traditionally, most UTTOs used technology licensing as their dominant research commercialisation strategy (Thursby & Thursby, 2007).

- **Spin-offs Creation**

Previous studies have confirmed that spin-offs creation is linked to regional rather than national economic development (Clarysse *et al.*, 2005). The formation of academic spin-offs is dependent on the assignment or licensing of university intellectual property. Therefore, university strategy and policy play a critical role in the creation of academic spin-offs along with UTTO's business capabilities (O'Shea *et al.*, 2005). Also, spin-off creation is highly dependent on scientist's involvement in the process of technology transfer (Markman *et al.*, 2005). Currently, many academic scientists are in favour of spin-off creation as a technology transfer strategy (Siegel *et al.*, 2007). In spin-offs creation, academic scientists play a critical role in the development process of the technology to the market and they are usually assigned a share in equity (Wright *et al.*, 2004a). However, the actual processes, underlying economic growth of academic spin-offs, are still understudied (Mustar *et al.*, 2006).

Moreover, non-university joint venture spin-offs are found to be more successful than university spin-offs as industrial partners contribute heavily in the development and marketing of developed technologies. However, joint venture spin-offs are associated with concerns in relation to intellectual property and company ownership (Wright *et al.*, 2004b).

Since the introduction of the *Bayh-Dole* act in 1980 in USA, there was a marked increase in the establishment of UTTOs in the USA and Europe. Following this phenomenon, many technology transfer associations have been established such as the Association of European Science and Technology Transfer Professionals (ASTP-Proton) in Europe, and the Association of University Technology Managers (AUTM) in USA and Canada (Kim, 2013). Additionally, governments of first world countries have introduced initiatives to enhance university research commercialisation and technology transfer (Mowery *et al.*, 2004).

Australia is lagging behind other first world countries in terms of university research commercialisation with comparatively small governmental initiatives to encourage interactions and collaborations between universities and the private sector (Harman, 2010). In fact, according to the OECD (2015), less than five percent of Australian SMEs and large businesses collaborate in innovation with higher education providers which is substantially lower than the OECD average of 13% for SMEs and 35% for large businesses. This is also reflected in that only three percent of Australian businesses obtained their innovative ideas from higher education providers in 2014-2015 (Australian Government, 2016). However, the Australian Commonwealth government recognised this shortcoming and shifted policy towards greater enhancement of university research commercialisation and technology transfer (Department of the Prime Minister and Cabinet, 2015). With this positive shift in public policy, it is also important to ensure that such policy imperatives and subsequent resource expenditure are delivering effective technology transfer and commercialisation outcomes. Therefore, this study sets out to evaluate the relative efficiency of UTTOs in Australia and to identify antecedents of efficient university technology transfer.

This study is divided into several sections. The following section reviews the literature on efficiency evaluation of UTTOs. Subsequently, a review of the environment of university research commercialisation in Australia is presented, followed by a description of the theoretical approach of the study. Then study methods are explained, followed by a discussion of the study findings. Being mindful of the limitations of the present study, recommendations for future work are proposed.

## 2.2 Efficiency Evaluation of UTTOs

For evaluation purposes, it is necessary to define efficiency of university technology transfer. Although the literature in relation to efficiency of university technology transfer is abundant, different definitions and meanings have emerged. According to Bozeman (2000), technology transfer efficiency can have different proxy measures such as impacts on market, impacts on politics and impacts on personnel and available resources. In fact, his review identifies several inconsistence definitions of technology transfer efficiency, and some of which are contradictory. Therefore, the actual definition of technology transfer efficiency may vary according to research objectives. Warren *et al.* (2008) argue that a 'one size fits all' approach cannot be achieved which points out to the multifarious nature of UTTOs efficiency. However, the study did not precisely define technology transfer efficiency. Therefore, technology transfer efficiency is defined for this study as the level of successful transfer of technological innovations from one organisation to another (Rogers *et al.*, 2000).

Rogers *et al.* (1999) examined technology transfer efficiency of research centres at the University of New Mexico. Their study proposed an eight indicators framework for assessing technology transfer effectiveness on a four point Likert scale using mainly interview data obtained from representatives of research centres. The overall score for technology transfer effectiveness is obtained by summing the scores of each indicator, with 32 being the highest score.

Berman (1990) evaluated university technology transfer efficiency by economic impact. Trune and Goslin (1998) attempted to economically evaluate technology transfer efficiency by conducting a profit/loss analysis of technology transfer programs at some universities in the USA. The study found that more than 50% of technology transfer programs operate at a profit.

In 2006, the Milken Institute published a report on technology transfer efficiency in the field of biotechnology. The report proposed three indices: publication, patenting and technology commercialisation. The publication index is dependent on number of publications along with their activity and impact. The patent index is mainly dependant on absolute number of patents followed by current impact index, science linkages and technology life-cycle. The technology commercialisation index was reliant on issued patents, technology licenses executed, technology licensing income and spin-offs. The study then ranked universities according to the three indices (DeVol *et al.*, 2006). A review of university research commercialisation in Australia is discussed next.

## 2.3 University Research Commercialisation in Australia

In order to review the university research commercialisation environment in Australia, the study will build on the theoretical approach developed by Tornatzky *et al.* (2002) to examine the business-government-university relationship in the southern part of the USA. The authors proposed three domains to review university research commercialisation. The first domain is “mechanisms and facilitators” that are developed to enhance university research commercialisation. The second domain is “institutional enablers” that have an effect on the organisational culture and rewards. The third domain is concerned with “boundary spanning” structures and networks.

### 2.3.1 Mechanisms and Facilitators

In Australia, mechanisms and facilitators are the initiatives of the Commonwealth government, the state and territory governments, and universities to enhance university research commercialisation. Most of these initiatives have been made in responses to reports commissioned by Australian governmental departments and they are reviewed in this section. However, this section highlights only direct Commonwealth governmental initiatives to enhance university-industry interactions (refer to Appendix 3 for a detailed review of initiatives).

- *Information and Communications Technology Incubators Programme (ICTIP)*.
  This programme was introduced in 1999 to establish 11 specialised incubators across Australia. It was formally known as *Building on Information Technology Strengths (BITS) Incubator Programme* up till 2004 (Department of the Prime Minister and Cabinet, 2007).
- *Pre-Seed Fund Scheme*.
  This scheme was established in 2001 to provide funding to higher research institutes in order to take research to venture capital-ready stage. (Department of the Prime Minister and Cabinet, 2007).
- *Commercialisation Australia*
  This initiative was established in 2009 to help researchers and entrepreneurs to take their intellectual property to market. It provides grants in hopes to obtain skills and knowledge, to attract experienced executives, to support proof of concept projects and to support early stage commercialisation (Department of the Prime Minister and Cabinet, 2009).
- *Commonwealth Scientific and Industrial Research Organisation (CSIRO) Innovation Fund Scheme*
  This scheme was introduced in 2015 to enhance research commercialisation and business engagement at universities and higher research institutes (Department of the Prime Minister and Cabinet, 2015).
- *Biomedical Transition Fund Scheme*.
  This scheme was launched in 2015 to enhance biomedical research commercialisation at universities and higher research institutes (Department of the Prime Minister and Cabinet, 2015).

Commonwealth government initiatives in cooperation with other governmental entities include:

- *Industry-linked Postgraduate Awards*
  This initiative was introduced in 1991 to encourage businesses to train postgraduate students and familiarise them with the business needs (Harman & Harman, 2004).
- *Strategic Partnership with Industry-Research and Training (SPIRT) Programme*
  This initiative was also launched in 1991 to familiarise researchers with business needs and to provide incentives for graduate industry training (Harman & Harman, 2004).
- *Australian Research Council (ARC) Linkage Projects Scheme*
  This initiative was introduced in 2004 to provide funding for the collaboration of universities and higher research institutes with other industrial partners to enhance innovation and university research commercialisation (Allen Consulting Group, 2003a).
- *Medical Research Commercialisation Fund (MRCF)*
  This initiative was introduced in 2007 to provide funding for the commercialisation of medical research at universities and higher research institutes (MRCF, 2017).

A review of the institutional enablers that endorse on university research commercialisation is represented next.

### 2.3.2 Institutional Enablers

Australian universities were not always active in university research commercialisation, with the institutionalisation of research commercialisation by many Australian universities only witnessed over the past two decades. This is mainly due to the fact that *Bayh-Dole*-like legislation has not been enacted in Australia and ownership of intellectual property produced by publicly funded research is governed by the general law of Australia, which entitles employers the rights to the benefits of the employee's inventions (Collier, 2007).

In relation to management of Intellectual Property (IP) in Australian universities, there are two guidelines to help universities and other higher research institutes with IP management. The first document is the "National Principles of Intellectual Property Management for Publicly Funded Research" (aka the National Principles). The National Principles guide was developed in 2001 by a working party of the main stakeholders of university research commercialisation in Australia (ARC *et al*., 2001). The second document is the "Ownership of Intellectual Property in Universities Policy and Good Practice Guide” (aka the Policy Guide) (Australian Vice-Chancellors' Committee, 2002). The Policy Guide was introduced in 2002 to help with questions in relation to ownership of IP. However, Collier (2007) concluded that IP policies and procedures are diverse among Australian universities. The Australian Government’s Coordinating Committee on Innovation (2013) updated the National Principles and it is referred to as the 2013 National Principles.

In 2001, the Australian government published an action plan titled “Backing Australia’s Ability: An Innovation Action Plan for the Future” and it introduced the *Research Quality Framework* (RQF) (Zhao, 2004). The RQF evaluated research quality for research funding purposes, and it was renamed in 2007 to the *Excellence in Research for Australia* (ERA) (Hicks, 2012). The National Innovation and Science Agenda (NISA) was announced in 2015 and it highlighted the importance of university research commercialisation by introducing measures for non-academic impact and industry engagement (Department of the Prime Minister and Cabinet, 2015). These measures will be piloted by the ARC in 2017 and they will be included in the next ERA of 2018.

The National Survey of Research Commercialisation (NSRC) was introduced in 2000 and it aimd to capture technology transfer activity at universities and higher research institutes (Working Group on Metrics of Commercialisation, 2005). The survey mainly collected data in relation to the commercialisation of intellectual property; however, the Coordination Committee on Science and Technology (CCST) established a Working Group (WG) on Metrics of Commercialisation (MoC) in 2003, and the WG recommended to extend the metrics to include consultancy and research contracts (Working Group on Metrics of Commercialisation, 2005). Currently, the NSRC is conducted by the Department of Industry, Innovation and Science and it has been recently reviewed to ensure that metrics used are internationally comparable (Department of Industry, Innovation and Science, 2017).

Australian universities have developed mechanisms to incentivise researchers to commercialise their research findings, notably the most common mechanism is a share of licensing royalties. A web-based search for the royalty distribution formulae of Australian universities has been performed and the data obtained are presented in Appendix 4. Boundary-spanning structures and networks of university research commercialisation in Australia are discussed next.

### 2.3.3 Boundary-Spanning Structures and Networks

There are many boundary-spanning structures and networks that play a critical role in university research commercialisation in Australia. The Australian Institute for Commercialisation, an initiative of the Queensland government, helps businesses and universities to commercialise their Research and Development (R&D) outcomes (Collier, 2007).

Another network is the Australian Tertiary Institutions Commercial Companies Association (ATICCA) which was established in 1978 by seven universities and it had 46 member universities by 1988. The ATICCA was renamed to the Knowledge Commercialisation Australasia (KCA). KCA is the peak body representing knowledge transfer professionals in the public sector (Allen Consulting Group, 2003b). The Licensing Executives Society of Australia and New Zealand (LESANZ) is part of the global Licensing Executives Society (LES) and it represents technology transfer professionals in the public and the private sectors (LESANZ, 2017). Also, IP Australia launched *Source IP* which is an advertisement platform of IP available for licensing, and established the *Patent Analytics Hub* which is an analysis tool that can help patent holders with national and international patents data (IP Australia, 2016). Technology Parks and Incubators Association aims to help these organisations to promote the entrepreneurial culture (Collier, 2007). Another network is known as the Australian Private Equity and Venture Capital Association Limited (AVCAL) which is the peak body representing venture capital companies in Australia (AVCAL, 2017). The theoretical approach of this study is presented next.

## 2.4 Conceptual Framework

To establish a conceptual framework for this study, seven influential evaluation studies of UTTOs efficiency have been examined and summarised (Table 2.1). Previous evaluation studies of UTTO efficiency have utilised production functions and they have included essential financial inputs for university technology transfer such as federal, industrial and total research income as well as research expenditure and IPR protection costs. Additionally, they have included core human capital inputs such as faculty's staff and quality as well as UTTO staff. All of the selected studies have evaluated efficiency in relation to tangible, IP-related outputs. Consistent with Thursby and Thursby (2002), I have developed a two-stage production function model for this study (Figure 2.1).

| Authors (Year) | Unit of Analysis | Production Function Inputs | Production Function Outputs |
|---|---|---|---|
| **Thursby & Thursby (2002)** | 64 UTTOs (USA) | 1. Federal Research Income<br>2. Industrial Research Income<br>3. UTTO Staff<br>4. Faculty Staff | Invention Disclosures |
| | | 1. Invention Disclosures<br>2. Faculty Quality Rating<br>3. UTTO Staff | Patent Application |
| | | 1. Invention Disclosures<br>2. Faculty Quality Rating<br>3. UTTO Staff<br>4. Patent Application | Licenses Executed |
| **Thursby & Kemp (2002)** | 112 UTTOs (USA) | 1. Federal Research Income<br>2. UTTO Staff | 1. Invention disclosures<br>2. Patent applications<br>3. Licenses Executed<br>4. Amount of Industry-sponsored Research<br>5. Amount of Licensing Income |
| **Siegel *et al.* (2003a)** | 113 UTTOs (USA) | 1. Invention Disclosures<br>2. UTTO Staff<br>3. IPR Protection Costs | 1. Licenses Executed<br>2. Amount of Licensing Income |
| **Chapple *et al.* (2005)** | 50 UTTOs (UK) | 1. Total Research Income/ Invention Disclosures<br>2. UTTO Staff<br>3. IPR Protection Costs | 1. Licenses Executed<br>2. Amount of Licensing Income |
| **Anderson *et al.* (2007)** | 54 UTTOs (USA) | Research Expenditure | 1. Patents Filled<br>2. Patents Issued<br>3. Licenses Executed<br>4. Amount of Licensing Income<br>5. Spin-offs |
| **Siegel *et al.* (2008)** | 120 UTTOs (USA=83; UK=37) | 1. Total Research Income<br>2. UTTO Staff<br>3. IPR Protection Costs | 1. Licenses Executed<br>2. Amount of Licensing Income<br>3. Spin-offs with University Equity |
| **Curi *et al.* (2012)** | 96 UTTOs (France) | 1. Number of Publications<br>2. UTTO Staff | 1. Patent Applications<br>2. Software Applications<br>3. Patents with Submitted Extension Requests<br>4. Extensions Requested |

**Table 2.1:** Selected evaluation studies of UTTOs efficiency that used production functions.

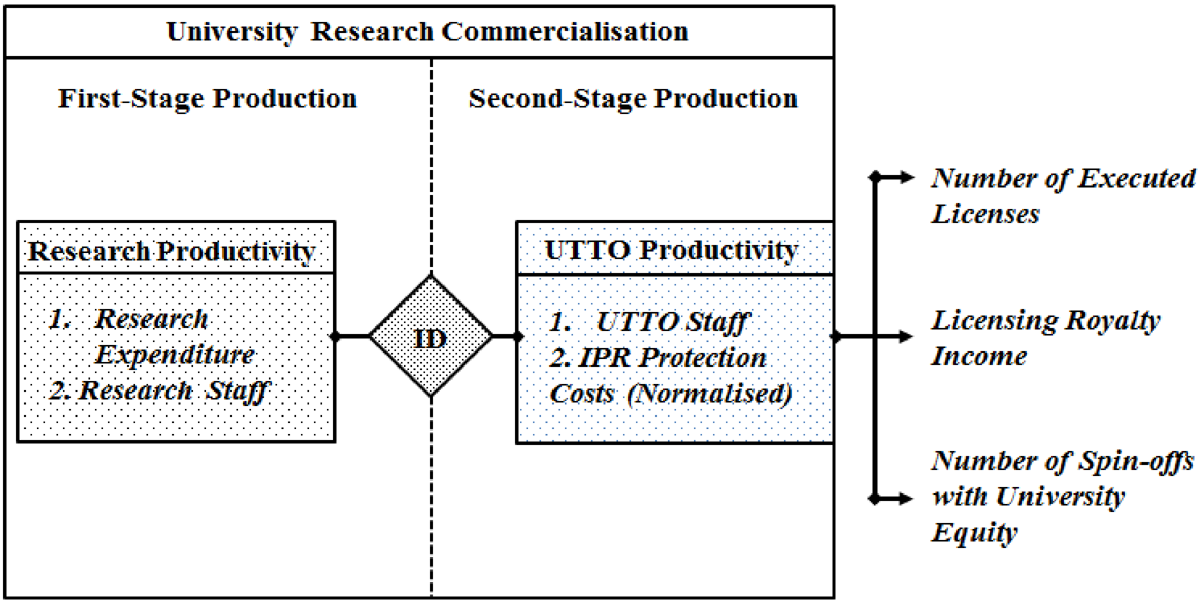


**Figure 2.1:** Two-stage production function model for this study.

The two-stage production model was developed because of the *ambidextrous* nature of universities. In other words, the first-stage production utilises core input factors for universities' traditional role of research, whereas the second production stage considers core input factors for the entrepreneurial role of technology transfer.

For the first production stage, a core financial input factor (research expenditure) and a core human capital input factor (research staff) have been proposed to evaluate relative efficiency of UTTOs in producing Invention Disclosures (IDs). The second-stage production involves a core financial input factor (Intellectual Property Rights (IPRs) protection costs normalised by the number of IDs) and a core human capital input factor (UTTO staff) to evaluate efficiency of UTTOs in producing three tangible performance outputs, namely number of executed licenses, licensing royalty income and number of spin-offs with university equity. Although invention disclosures are considered as the raw material for tangible outputs of UTTOs, it was not considered as a direct input for the second production stage since there is no formal contract for scientists at Australian universities to disclose inventions (Collier, 2007).

The use of production functions to evaluate the relative efficiency of UTTOs is powerful since the results of the production function will differentiate efficient UTTOs from inefficient UTTOs. However, production functions do not completely explain which factors influence UTTO efficiency, mainly because production functions are context-dependent (Curi *et al.*, 2012). Therefore, a qualitative approach is used in this study to identify antecedents of efficient university technology transfer. Research methodology of this study is discussed next.

## 2.5 Methodology

A mixed methods approach using quantitative and qualitative data was utilised because in this inductive study. A quantitative approach was used to evaluate the relative efficiency of UTTOs and a qualitative approach was used to identify antecedents of efficient university technology transfer.

### 2.5.1 Choice of Production Function for Efficiency Evaluation of UTTOs

According to Siegel and Phan (2005), the most commonly used production functions to evaluate UTTOs efficiency are Data Envelopment Analysis (DEA) and Stochastic Frontier Estimation (SFE). Chapple *et al.* (2005) applied DEA and SFE to evaluate UTTOs efficiency and they concluded that both techniques have provided similar efficiency scores. Anderson *et al.* (2007) hypothesised that DEA is a good evaluation technique for UTTOs efficiency and they confirmed their hypothesis. Consistent with Anderson *et al.* (2007) finding, this study will utilise DEA to evaluate UTTOs efficiency.

DEA is a non-parametric procedure that does not require any distributional assumptions (see Seiford & Thrall, 1990; Charnes *et al.*, 1994; Fare *et al.*, 1994). DEA operates as a linear program that finds the best practise by determining a virtual, technical inefficiency. In order to understand DEA, consider a Decision Making Unit (DMU) that has a certain amount of inputs and outputs. The DMU is considered relatively inefficient if another DMU achieves more outputs with the same inputs (output orientation) or produces the same outputs with fewer inputs (input orientation). DEA considers two models in relation to returns to scale; Constant Return to Scale (CRS) or Variable Return to Scale (VRS). When a proportional change of all inputs results in the same change in the outputs, the DMU is experiencing constant returns to scale. The most commonly used model is variable returns to scale as it allows for any mathematical form of scale effect and the possibility of diminishing returns.

For the scope of this study, DMUs are universities. The DEA will allow identification of the "best practice" universities, and then the efficiency of other universities will be determined in relation to their levels of outputs and inputs as compared to best practice universities. Simply put, efficient universities will form the production frontier and the efficiency of other universities is measured by the distance from the frontier (refer to Figure 2.2).

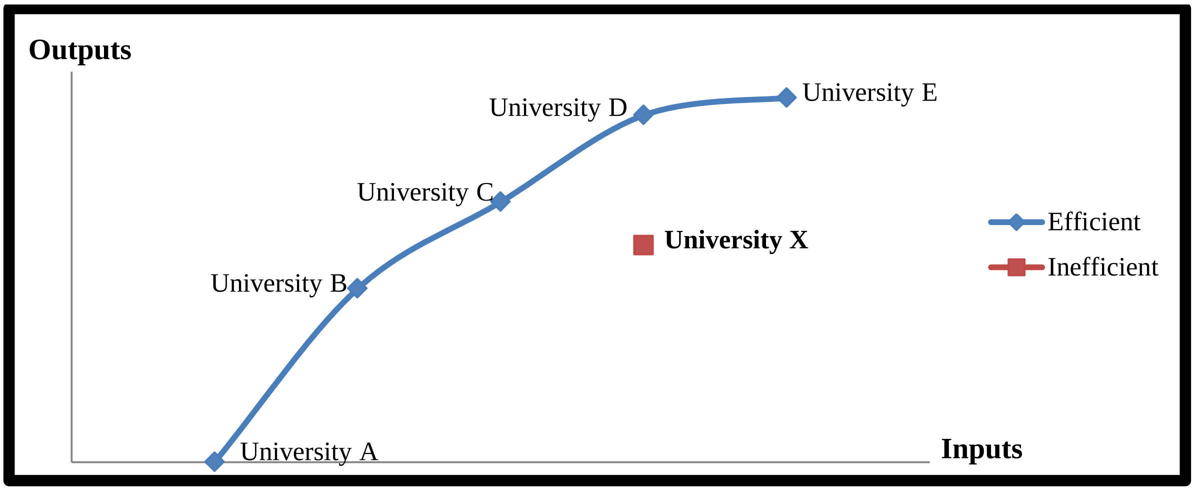


**Figure 2.2:** One input and one output DEA production frontier for six universities.

By considering Figure 2.2 as a simple production frontier, universities A to E are considered to be efficient achieving efficiency score of 100% whereas university X is considered to be inefficient and would be represented by an efficiency score between 0% and 100%. By considering an output orientation of DEA, university X will be compared to a virtual university on the frontier between universities B and C. However, when considering an input orientation of DEA, university X will be compared to university D on the production frontier.

Curi *et al.* (2012) examined the effect of returns to scale and they concluded that VRS is more representative than CRS for evaluating UTTOs efficiency. Other studies have found that most UTTOs are experiencing either CRS or decreasing returns to scale (Siegel *et al.*, 2003a, 2008; Chapple *et al.*, 2005). Therefore, the proposed DEA model will be conducted with the assumption of VRS, and consistent with Anderson *et al.* (2007), the proposed DEA model will be output-oriented mainly because this study is concerned with how to maximise outputs rather than how to minimise inputs.

University technology transfer input and output data were obtained from the National Survey of Research Commercialisation (NSRC) conducted annually by the Australian Department of Industry, Innovation and Science. Data are available for 39 Australian universities recorded for the years from 2000 to 2014. University technology transfer input and output data averages over the 15 year period were used.

### 2.5.2 Qualitative Approach for Analysis of Antecedents of Efficient University Technology Transfer

For the purpose of this study, a semi-structured telephone interview was used as a survey instrument (refer to Appendix 1 and 2 for interview invitation cover letter and interview questions script, respectively). Interviews were conducted in October and November of 2016, and representatives from 25 Australian UTTOs participated.

For qualitative data analysis, interviews were tape recorded and transcription of responses was conducted by a neutral third party. Then, multiple assessors identified themes from transcripts. Following that, themes were coded and frequency tables were formulated.

## 2.6 DEA Findings and Discussions

Output-oriented DEA results with the assumption of VRS are presented in Table 2.2 and the key findings were as follows:

- ***Number of Invention Disclosures DEA***

The average CRS technical efficiency score of UTTOs was 36% and the average VRS technical efficiency score of UTTOs was 44%. The average scale efficiency (CRS/ VRS) score of UTTOs was 85%. In relation to returns to scale, 19 UTTOs have achieved increasing returns to scale and 14 UTTOs have achieved decreasing returns to scale, while the remaining 6 UTTOs exhibited CRS. In fact, 3 UTTOs were CRS technically efficient, 7 UTTOs were VRS technically efficient, and 3 UTTOs achieved 100% scale efficiency.

- ***Number of Licenses Executed DEA***

The average CRS technical efficiency score of UTTOs was 0% and the average VRS technical efficiency score of UTTOs was 43%. The average scale efficiency score of UTTOs was 0%. In relation to returns to scale, 36 UTTOs have achieved increasing returns to scale, while the remaining 3 UTTOs exhibited CRS. In fact, 5 UTTOs were VRS technically efficient, and none of the UTTOs have achieved 100% CRS technical efficiency or scale efficiency.

- ***Licensing Royalty Income DEA***

The average CRS technical efficiency score of UTTOs was 0% and the average VRS technical efficiency score of UTTOs was 25%. The average scale efficiency score of UTTOs was 0%. In relation to returns to scale, 33 UTTOs have achieved increasing returns to scale, while the remaining 6 UTTOs exhibited CRS. In fact, 3 UTTOs were VRS technically efficient, and none of the UTTOs have achieved 100% CRS technical efficiency or scale efficiency.

- ***Number of Equity Spin-offs DEA***

The average CRS technical efficiency score of UTTOs was 33% and the average VRS technical efficiency score of UTTOs was 41%. The average scale efficiency score of UTTOs was 81%. In relation to returns to scale, 22 UTTOs have achieved decreasing returns to scale, while the remaining 17 UTTOs exhibited CRS. In fact, 4 UTTOs were CRS technically efficient, 7 UTTOs were VRS technically efficient, and 10 UTTOs achieved 100% scale efficiency.

| DMU | Number of Invention Disclosures DEA | Number of Licenses Executed DEA | Licensing Royalty Income DEA | Number of Equity Spin-offs DEA | Average of DEA Scores | Overall Ranking |
|---|---|---|---|---|---|---|
| The University of Queensland | 100% | 100% | 100% | 100% | **100%** | **1** |
| The University of Melbourne | 29% | 70% | 91% | 68% | **65%** | **2** |
| Swinburne University of Technology | 100% | 30% | 19% | 100% | **62%** | **3** |
| Macquarie University | 30% | 100% | 55% | 60% | **61%** | **4** |
| The University of Sydney | 57% | 100% | 18% | 61% | **59%** | **5** |
| The University of Adelaide | 100% | 39% | 61% | 35% | **59%** | **6** |
| The University of New South Wales | 50% | 100% | 33% | 42% | **56%** | **7** |
| The University of Western Australia | 32% | 63% | 26% | 100% | **55%** | **8** |
| Curtin University of Technology | 52% | 37% | 27% | 94% | **53%** | **9** |
| University of South Australia | 100% | 51% | 6% | 54% | **53%** | **10** |
| The Australian National University | 15% | 49% | 49% | 95% | **52%** | **11** |
| Charles Darwin University | 3% | 43% | 60% | 100% | **52%** | **12** |
| Monash University | 28% | 25% | 100% | 51% | **51%** | **13** |
| Australian Catholic University | 0% | 100% | 100% | 0% | **50%** | **14** |
| Central Queensland University | 15% | 46% | 30% | 100% | **48%** | **15** |
| The University of Newcastle | 100% | 24% | 32% | 20% | **44%** | **16** |
| University of Technology, Sydney | 100% | 25% | 10% | 22% | **39%** | **17** |
| James Cook University | 56% | 19% | 10% | 69% | **38%** | **18** |
| Southern Cross University | 49% | 100% | 0% | 0% | **37%** | **19** |
| University of Tasmania | 54% | 74% | 4% | 9% | **35%** | **20** |
| Bond University | 35% | 0% | 0% | 100% | **34%** | **21** |
| University of Wollongong | 62% | 39% | 22% | 8% | **33%** | **22** |
| Flinders University | 45% | 37% | 13% | 31% | **32%** | **23** |
| University of Canberra | 100% | 9% | 0% | 0% | **27%** | **24** |
| Murdoch University | 45% | 13% | 3% | 47% | **27%** | **25** |
| University of Western Sydney | 64% | 26% | 10% | 7% | **27%** | **26** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Federation University of Australia | 0% | 0% | 0% | 100% | **25%** | **27** |
| Queensland University of Technology | 58% | 18% | 5% | 18% | **25%** | **28** |
| Charles Sturt University | 10% | 40% | 47% | 0% | **24%** | **29** |
| RMIT University | 17% | 40% | 7% | 23% | **22%** | **30** |
| University of Southern Queensland | 56% | 20% | 1% | 0% | **19%** | **31** |
| University of the Sunshine Coast | 30% | 48% | 0% | 0% | **19%** | **32** |
| Griffith University | 15% | 16% | 10% | 36% | **19%** | **33** |
| La Trobe University | 14% | 33% | 2% | 27% | **19%** | **34** |
| Deakin University | 15% | 51% | 1% | 6% | **18%** | **35** |
| Victoria University | 20% | 42% | 2% | 5% | **17%** | **36** |
| The University of New England | 6% | 31% | 29% | 3% | **17%** | **37** |
| Edith Cowan University | 41% | 8% | 2% | 6% | **14%** | **38** |
| The University of Notre Dame Australia | 0% | 0% | 0% | 0% | **0%** | **39** |
| **Average** | **44%** | **43%** | **25%** | **41%** | **38%** | |

**Table 2.2:** Output-oriented DEA results with the assumption of VRS.

Based on the average VRS technical efficiency scores from each of the four DEA in this study, Australian UTTOs could increase their outputs on average by 56% for invention disclosures, 57% for licenses executed, 75% for licensing royalty income and 59% for spin-offs created with university equity.

Chapple *et al.* (2005) conducted output-oriented DEA with the assumption of VRS for UK UTTOs and the average technical efficiency was 19% for number of licenses and 14% for licensing royalty income. The authors also conducted another DEA with outliers omitted and the average technical efficiency was 35% for number of licenses and 16% for licensing royalty. Therefore, Australian UTTOs perform better than UK UTTOs, taking into account that different inputs and outputs were used to measure technical efficiency.

Siegel *et al.* (2008) conducted a joint output-oriented DEA with the assumption of VRS for US and UK UTTOs and the average technical efficiency was 71% for multiple-output models. When compared to the average VRS technical efficiency score of the four DEAs (38%), Australian UTTOs are outperformed by a joint sample of US and UK UTTOs, taking into account that different inputs and outputs were used to measure technical efficiency.

Additionally, Curi *et al.* (2012) conducted output-oriented DEA with the assumption of VRS for French UTTOs and the average technical efficiency was 49% for multiple-output model. When compared to the average VRS technical efficiency score of the four DEAs (38%), Australian UTTOs perform worse than French UTTOs, taking into account that different inputs and outputs were used to measure technical efficiency.

## 2.7 Qualitative Findings and Discussions

To identify antecedents of efficient university technology transfer, interviews were conducted with 25 Australian UTTOs representatives. Codes for interviewees are presented in Table 2.3. For interpretation of the qualitative data, universities were ranked and then classified into four categories according to the average VRS technical efficiency score of the four DEAs. Tier 1 classification for universities with overall ranking from 1 to 10, tier 2 classification for universities with overall ranking from 11 to 20, tier 3 classification for universities with overall ranking from 21 to 30, and tier 4 classification for universities with overall ranking from 31 to 39. Nine out of 10 tier 1 universities participated in this study, along with six tier 2 universities, six tier 3 universities and four tier 4 universities.

| University Tier | Interviewee Codes |
|---|---|
| 1 | B; C; E; J; O; Q; S; U; V |
| 2 | D; F; I; M; W; X |
| 3 | A; G; K; N; T; Y |
| 4 | H; L; P; R |

**Table 2.3:** Codes of interviewees.

After analysing interview data, it emerged that findings were mainly in relation to university research commercialisation environment, and antecedents of efficient university technology transfer.

### 2.7.1 University Research Commercialisation Environment

Interview findings in relation to the university research commercialisation environment can be classified into three themes, namely university mission, university internal research commercialisation funding and commercialisation support structures.

#### 2.7.1.1 University Mission

When interviewees were asked if research commercialisation is part of their university's mission, three responses were given as presented in Figure 2.3. Interview findings indicate that 7 universities have a traditional mission for research, and 18 universities included knowledge translation and research commercialisation in their mission statement.

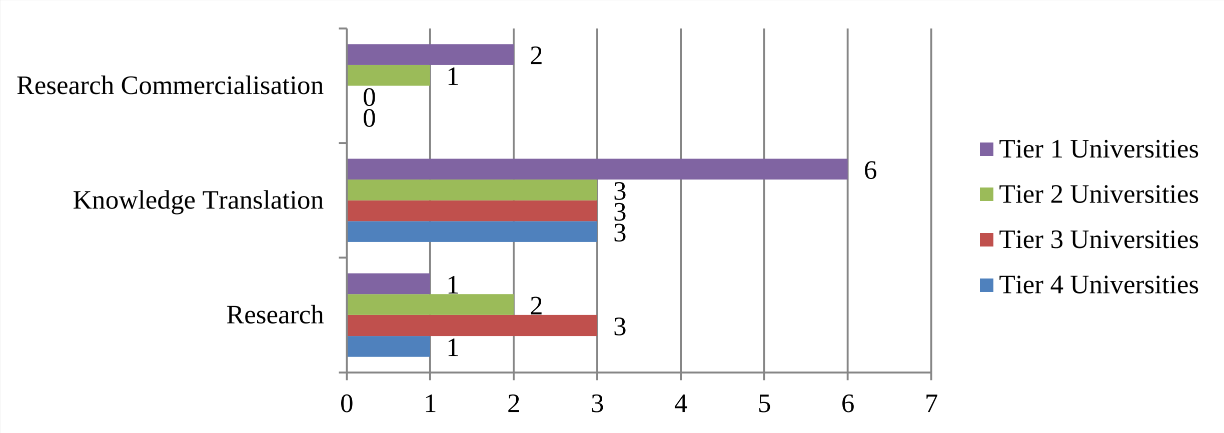


**Figure 2.3:** Interviewee responses for research commercialisation as part of university mission.

Knowledge translation is defined as "*the methods for closing the gaps from knowledge to practice*" (Straus *et al.*, 2009: 165). On the other hand, research commercialisation is defined as "*a process of developing new ideas and/or research output into commercial products or services and putting them on the market*" (Zhao, 2004: 225). Hence, one of the many ways to translate knowledge is through research commercialisation. An interesting finding is that universities which include research commercialisation in their mission are classified as tier 1 or 2. This finding is not surprising since Nelson (2014) asserted that university's mission shapes individual perceptions and behaviours towards university research commercialisation.

#### 2.7.1.2 Internal Research Commercialisation Funding

Interview findings indicate that four [one (tier 2), two (tier 3) and one (tier 4)] universities do not provide internal research commercialisation funding, whereas all tier 1 universities do. Three universities [two(tier 1) and one (tier 2)] provided internal research commercialisation funding as part of their UTTO's budget. Figure 2.4 present interview responses in relation to the purpose of internal research commercialisation funding categorised according to university tiers.

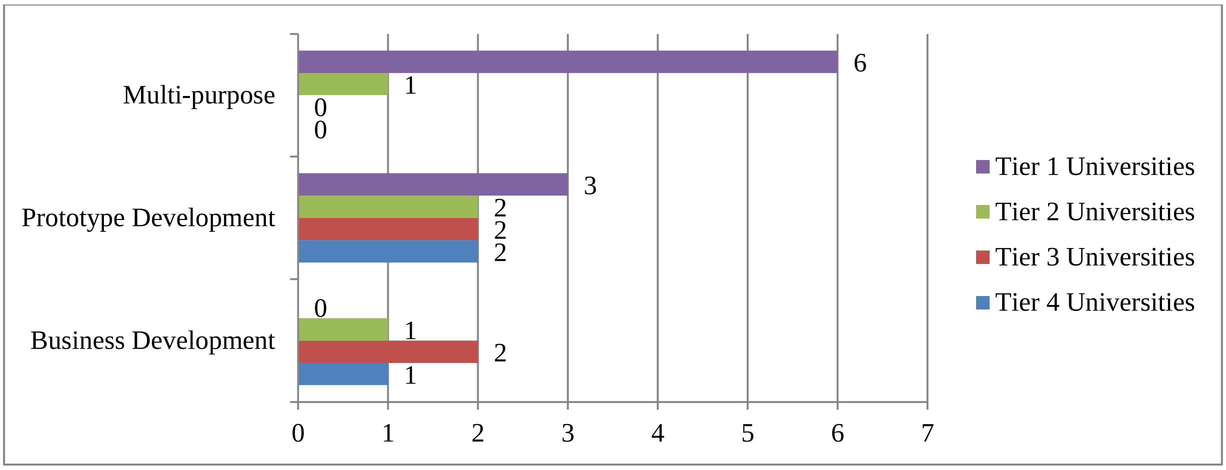


**Figure 2.4:** Interviewee responses for purpose of internal research commercialisation funding.

An interesting finding is that universities that offer internal research commercialisation funding as part of their UTTO's budget are in the tier 1 or 2 classification. Turning towards the purpose of the internal research commercialisation funding, an interesting finding is that tier 1 universities tend to offer multi-purpose research commercialisation funding to cover prototype *and* business development. On the other hand, tier 3 and 4 universities tend to offer internal research commercialisation funding for business development purposes only.

Although previous studies confirmed a positive association between the availability of early stage commercialisation funding and university technology transfer efficiency (Warren *et al.*, 2008; Palmintera, 2005), previous studies have not examined the association between the source and purpose of internal research commercialisation funding and university technology transfer efficiency. This finding underscores the importance of taking a holistic approach to the innovation value chain.

#### 2.7.1.3 Commercialisation Support Structures

Interview findings indicate that twelve [four (tier 1), three (tier 2), three (tier 3) and two (tier 4)] universities are not affiliated to commercialisation support structures such as incubators and technology parks. In agreement with Di Gregorio and Shane (2003) and O'Shea *et al.* (2005), 15 respondents reported that commercialisation support structures are not important for research commercialisation and they perceive the importance of commercialisation support structures to be linked with space and mentorship, technology-specific support structures, and proximity and linkages. Figure 2.5 presents interview responses in relation to the importance of commercialisation support structures categorised according to university tiers.

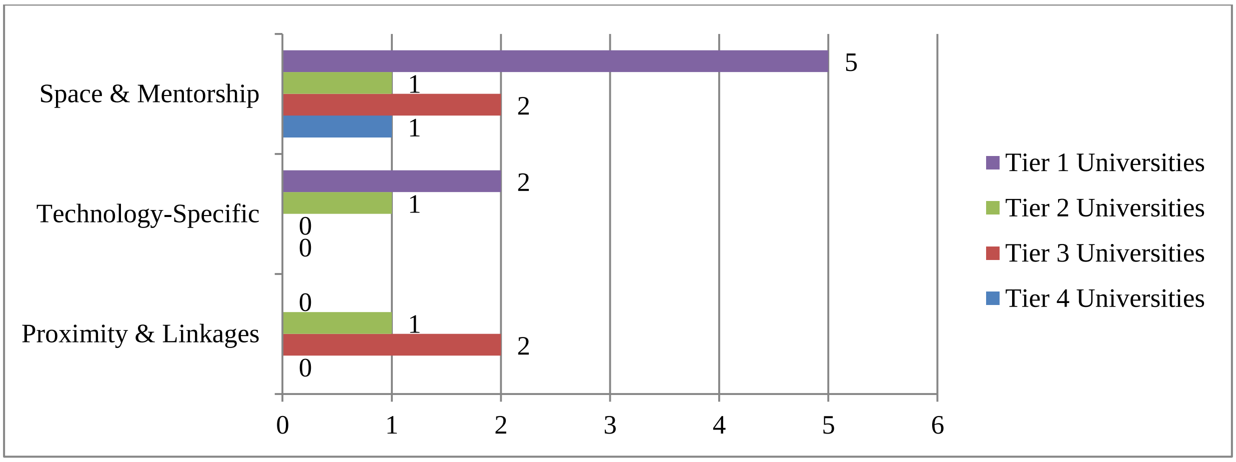


**Figure 2.5:** Conceptualisation of interviewee responses in relation to commercialisation support structures.

As shown in Figure 2.5, nine universities found commercialisation support structures helpful for only providing space and mentorship. In fact, interviewee "T" stated that:

> *We have not had a lot to do with them, they are probably not important. You can find the benefits they provide elsewhere. Most times the benefit that our businesses had is access to VC, access to mentorship. From our experience, they are not necessarily a key driver.*

Additionally, three universities found commercialisation support structures important if they are technology-specific. Interviewee "J" asserted that:

> *When they are a sector-specific technology park, they are quite important. So I would say that the university cannot be all things for all people, and if we are promoting entrepreneurship, we need to know where to recommend parties to go to for specific sectors, I mean IT or something. That's when technology parks can help them in translating their research.*

Also, another three universities acknowledge that commercialisation support structures are important if they are in proximity with the university and if the university has developed linkages with them. Interviewee "K" pointed out that:

> *We need to develop a model that has closer ties to the university…Our incubators and technology parks are not used by us. We have a challenge in identifying tenants who are interested in incubators and technology parks, and willing to invest in R&D.*

### 2.7.2 Antecedents of Efficient University Technology Transfer

When interviewees were asked about strengths and weaknesses of the commercialisation system at their university, twelve antecedents of university technology transfer emerged as presented in Figure 2.6.

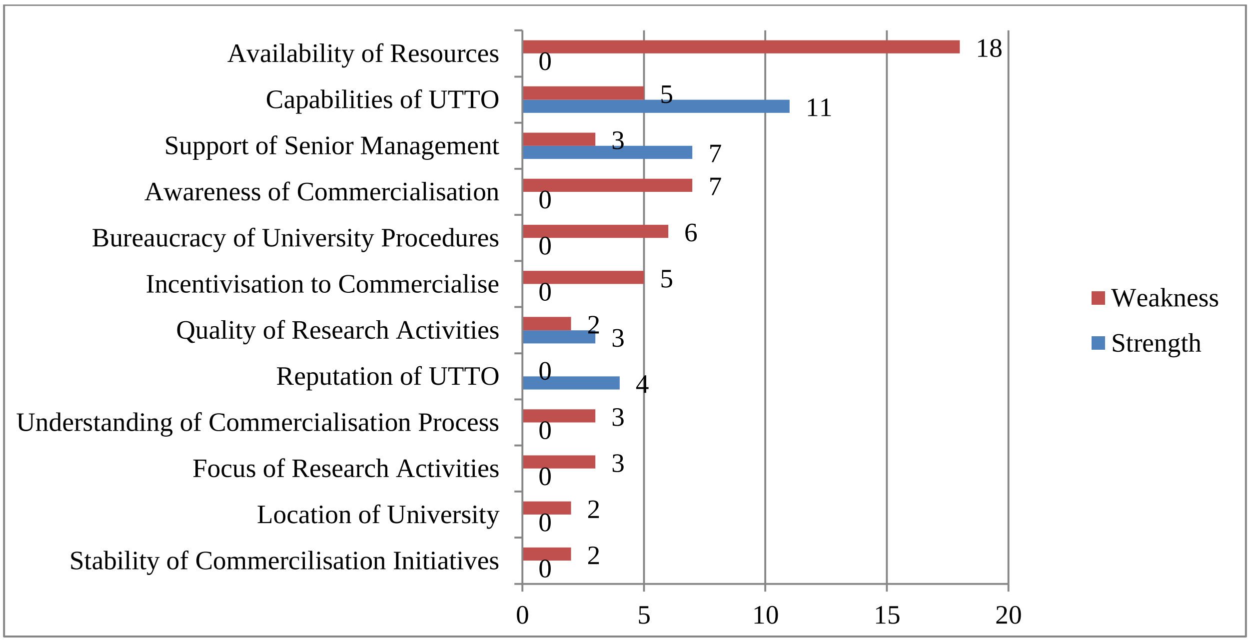


**Figure 2.6:** Interviewee perceptions of antecedents of university research commercialisation.

In this study, the most reported factor is *availability of resources*. Eighteen respondents stated that their UTTOs do not have enough human capital and financial resources to conduct their job efficiently and to educate academics about research commercialisation. In fact, interviewee "I" stated that:

> *We do not have enough resources. In fact, some of the academics do not even know that we are here helping them and because of resources.*

This finding has been widely mentioned in the literature and O'Shea *et al.* (2005) concluded that the amount of resources devoted to UTTOs is positively associated with efficient university technology transfer. However, Siegel *et al.* (2003a) found that most of UTTO staff tend to overestimate availability of resources as a weakness, compared to the estimation by university academics and industrial partners.

The second factor is *UTTO's unique capabilities*. Sixteen respondents mentioned UTTO capabilities; however, eleven respondents reported it as strength while five reported it as a weakness. Respondents reported factors such as the experience of UTTO staff, strength of relationship with industry, quality of program and business model, and flexibility when dealing with academics. In fact, there is a positive association between university technology transfer efficiency and experience of UTTO staff (Van Looy *et al.*, 2011), and strength of relationship with industry (Palmintera, 2005).

The third factor is *senior management support*. Ten respondents mentioned senior management support; however, seven respondents reported it as strength while three reported it as a weakness. An interesting finding is that universities which reported senior management support as a strength are classified as tier 1(four UTTOs) or tier 4 (three UTTOs). This is interesting since senior management support was not established as an antecedent of efficient university technology transfer, although previous studies found a positive association between university management support and university technology transfer efficiency (Heslop *et al.*, 2001; Rasmussen *et al.*, 2014). This could be due to the fact that some respondents have given their response as if the question was for financial support rather than strategic support. In fact, interviewee "S" stated that:

> *The DVCR is normally supportive of our ideas and strategies and agreements we are entering to. I am happy that we will get more resources next year so that is a good thing….. I think that visibility and the lack of support and interest from the high levels of the university is a weakness. We want the senior management to recognise our efforts and importance for IP commercialisation.*

The fourth factor is *commercialisation awareness*. Seven respondents mentioned that academics are not aware of the commercialisation process and industry-engagement. In fact, interviewee "E" stated that:

> *It is a big change to the way academics think; actually some of them have been working here for a long time and have never worked with industry and it is quite a different approach.*

This finding does not strike as surprising since previous research found that academics' commercialisation awareness is associated with efficient university technology transfer by IP-related measures (Abreu & Grinevich, 2013; Bercovitz &Feldman, 2008) and other commercialisation measures such as contract research (Abreu & Grinevich, 2013; Louis *et al.*, 1989).

The fifth factor is *bureaucratic procedures at universities*. Six respondents indicated that bureaucratic systems hinder their performance mainly by slow information processing and limited decision-making autonomy. In fact, interviewee "G" stated that:

> *There is a lot of bureaucracy in terms of negotiating a deal. We have to go to a legal unit to negotiate a deal, and we then need to go and seek approval from the finance team. All of that has to be done before a deal is signed and it is a long process. If we need to spin-out a company, we need to go through council meetings to get their approval and they must have equity in the company, but the issue is that they hold those meeting quarterly.*

Once again, this finding has been repeatedly reported in the literature and Siegel *et al.* (2003b) found that some academics do not disclose their inventions and go through with the commercialisation process mainly because of university bureaucracy. Additionally, Friedman and Silberman (2003) attributed efficient university technology transfer at private universities to being less bureaucratic than public universities. In fact, Hülsbeck *et al.* (2013) examined performance antecedents of UTTOs in Germany and they attributed poor performance to UTTOs being part of university bureaucracy rather than 'proactive units'.

The sixth factor is *incentives to commercialise*. Five respondents pointed out that academics are not incentivised to commercialise their research. In fact, Interviewee "O" declared that:

> *It is not the primary objective to translate their research outcomes through commercialisation. The changes under NISA mean that universities will be rewarded by industry engagement, including commercialisation, and that will aid in a change in moving academics away from publications to engage with industry and commercialisation. So, that is a big change in the behaviour of which universities are being incentivised.*

This finding has been widely mentioned in the literature and Siegel *et al.* (2003a) found that UTTO staff and industrial partners do not have a common ground with academics in relation the value of publications. Additionally, interviewee "E" stated that:

*We are recognising that when academics have something which is patented for example, you know that is a publication in some regard, so should that be regarded with similar rights to publications? We actually went through an exercise to show academics that the quality of the journal that you publish in is completely independent from the funding source. So if we really want people to work with industry, we might need to adjust KPIs.*

In fact, the association between publications and research commercialisation is one of the most debated topics in the literature. However, the association was found to be positive by some (Sampat *et al.*, 2003; Breschi & Catalini, 2010), and negative by others (Murray & Stern, 2007; Rosell & Agrawal, 2009).

The seventh factor is the *quality of university research*. Five respondents mentioned research quality; however, three respondents reported it as strength while two reported it as a weakness. An interesting but a minor finding is that universities which reported research quality as a strength are classified as tier 1(two UTTOs) or tier 4 (one UTTOs). This is interesting since research quality was not established as an antecedent for efficient university technology transfer, although previous studies found a positive association between research quality and university technology transfer efficiency (Schuelke-Leech, 2013; Bercovitz & Feldman, 2008). This could be due to the fact that available commercialisation measures (such as the ones used in this study) do not capture commercial opportunities of humanities and social sciences research. In fact, interviewee "H" (representative of the tier 4 university which reported research quality as strength) stated that:

*We have strength in research for humanities fields, but we have a challenge in commercialising that research.*

The eighth factor is *UTTO's reputation*. Four respondents indicated that UTTO's reputation, shaped by previous success stories, is their UTTO's strength. In fact, interviewee "B" stated that:

*Because we do not have a cranky reputation, we find people to work and agree with us. Other universities that I have previously worked in have that woeful reputation and companies just do not want to deal with them. In a way, we have got a mutual reputation, so when I say to someone look what are your drivers? What are your needs? Let's work together to reach an agreement, we often can.*

This finding does not strike as surprising since previous studies found that previous success in technology transfer is associated with efficient university technology transfer by IP-related measures (Abreu & Grinevich, 2013; Bercovitz & Feldman, 2008) and industry collaborations measures (Abreu & Grinevich, 2013; Tartari *et al.*, 2014).

The ninth factor is related to *understanding of the commercialisation process*. Three respondents indicated that lack of understanding of the commercialisation process hinder their performance especially in devoting resources and measuring performance. In fact, interviewee "R" stated that:

> *It is pretty much the timeline, to take something from the bench to the market it could take about 12 years; it is about understanding that you are in for the long term. We also do not recognise value quickly enough, or as part of a strategy. You want people to put their ideas out there, and if they fail, we would be able to say that is Ok, cut our losses and move on to something else. Australia is not part of the innovation/ entrepreneurial journey.*

This finding has been widely mentioned in the literature and Siegel *et al.* (2003a) found that academics, UTTO staff and industrial partners are in agreement that lack of understanding of the commercialisation process is the most profound barrier to efficient university technology transfer.

The tenth factor is the *focus of university research*. Three respondents distributed among tier 2, 3 and 4 universities mentioned research focus as a weakness. In fact, interviewee "K" stated that:

> *We are trying to know what our capability is in research, it is very scattered. We are not necessarily recognised for our research activities. It is difficult to highlight what is our key capability in research.*

This finding does not strike as surprising since previous research found that focus of research, especially applied research, is associated with efficient university technology transfer by IP-related measures (Abreu & Grinevich, 2013; Prodan & Drnovsek, 2010) and industry collaborations measures (Abreu & Grinevich, 2013; Tartari *et al.*, 2014).

The eleventh factor is related to the *location of the university*. Two respondents mentioned regional university location as a weakness, mainly because it is hard to attract human capital and R&D investments. In fact, interviewee “B” stated that:

> *Our challenge, being based in a regional area, is finding research dollars, finding industry that have the budget to invest in our research and create meaningful work. A lot of businesses in regional areas are small and are not in position to invest in R&D.*

In fact, previous studies concluded that regional characteristics such as R&D, VC intensity and GDP are associated with university technology transfer efficiency. The association was found to be positive by some (Siegel *et al.*, 2003a; Friedman & Silberman, 2003), but negative by others (Hülsbeck *et al.*, 2013; Lach & Schankerman, 2004). This discrepancy in the literature could be explained by the causality dilemma of which came first “the chicken or the egg?” This argument is supported by O'Shea *et al.* (2004) finding that pharmaceutical companies such as Novartis and Wyeth have established R&D facilities nearby entrepreneurial universities to benefit from knowledge spillovers. Therefore, the main question would be “are the entrepreneurial activities of universities a cause of regional characteristics (e.g. are they attractors of innovative companies) or do they benefit from pre-existing regional characteristics?” Considerable additional research, beyond the scope of the present thesis, would be needed to tease out these interactions and their time-course. It is reasonable to suggest that the interaction is a complex, and that both factors are important.

The twelfth factor is *stability of commercialisation initiatives*. Two respondents stated that commercialisation initiatives are not stable and that therefore impact UTTO’s long-term vision and strategic planning. In fact, interviewee “J” stated that:

> *We have different views about commercialisation and how it could be managed. It is important for the external world to see consistency within your commercialisation offices and they should have that history. If they are changing every year, then that will be a disadvantage for the sector.*

In fact, Bercovitz and Feldman (2008) found that academics tend to disclose their inventions if they belong to a university which has stable initiatives in relation to technology transfer and research commercialisation.

### 2.7.3 Impact Measurement: UTTO Concerns and Recommendations

When interviewees were asked about impact measurement, respondents acknowledged that measuring impact effectively is difficult and they feared that the ARC will introduce metrics which fail to capture all aspects of industry engagement and research commercialisation. Interviewee concerns are conceptualised along 7 identified themes as presented in Figure 2.7.

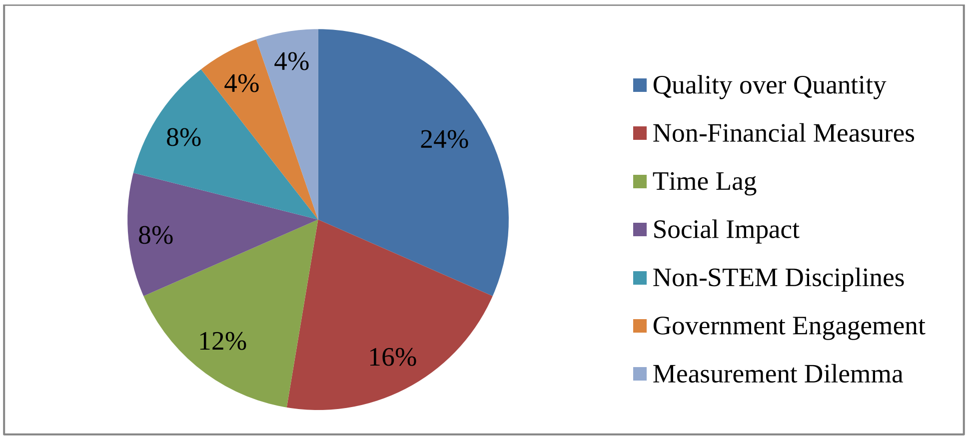


**Figure 2.7:** Conceptualisation of interviewee concerns in relation to impact measurement.

The most commonly reported concern in relation to impact measurement is quality over quantity. Six respondents expressed their concern that it is about measuring the quality of the impact, rather than the quantity. Interviewee "F" asserted that:

> *Some people have suggested filed patents to be a measure of impact; we think that is a poor measure because it relies on how big is your patenting budget is? Another one is number of licenses but again it does not guarantee if the technology is being used. So, it is basically a measure of whether the technology is being used to improve businesses and people's life, but capturing that effectively is not easy.*

In fact, Gerbin and Drnovsek (2016) conducted a literature review about university technology transfer efficiency and they concluded that most previous studies should be considered with 'caution' as they are quantity-based, rather than quality-based.

Respondents also feared that the ARC will fail to capture impact by non-financial measures or to recognise time-lag between research and impact. Interviewee "U" stated that:

> *Licensing should be tied up with long-term strategic intent, such us repeat return of industry to university or contract research, because there could be not a financial return associated with licensing or there could easily be 10 years without a financial*

*component. It all translates back down to the fundamental relationship in the beginning and the research integrated from that.*

Additionally, respondents feared that the ARC will fail to capture social impact, to consider impact measures for non-STEM disciplines, and to differentiate between industry engagement and government engagement. Interviewee "C" shed the light on a critical concern in relation to impact measurement dilemma as expressed by his statement:

> *I believe impact is measurable but it has two major issues. The first issue is that impact is created by a research-user rather than by the university, and therefore what we are measuring is the performance of our partner rather than our performance. The second issue is that it typically takes 15 years to go from research to impact, and therefore if you start measuring performance based on impact of research then you are actually measuring research that was done 15 years ago. Therefore, these two issues are not to be controlled.*

Additionally, respondents recommended several measures for impact. Interviewee recommendations for impact measures are conceptualised in 4 themes as presented in Figure 2.8.

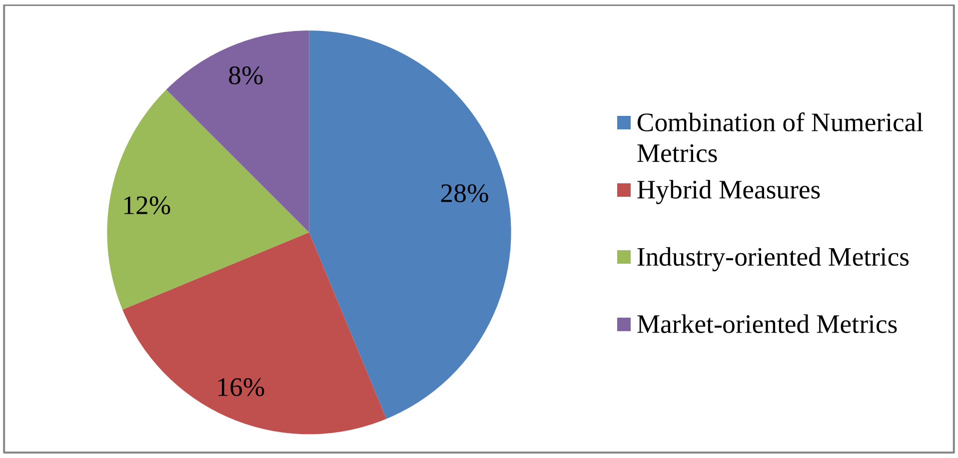


**Figure 2.8:** Conceptualisation of interviewee recommendations in relation to impact measurement.

Twenty-eight percent of interviewees recommended the use of a combination of numerical metrics to capture impact while 16% of respondents recommended the use of hybrid measures of data metrics and case-studies. Twenty percent recommended industry-oriented and market-oriented metrics to measure impact; however, recommended metrics are not to be easily captured. In fact, interviewee "V" asserted that:

> [UTTO Name] *is held up as being a benchmark standard for being a successful commercialisation office; you know that there are plenty of people who would disagree with that. But the reality of whether you think it works or does not, you cannot copy the model that was nicely brought by* [UTTO Name] *and over lay that to any other university because it just would not work as the culture is different, the critical mass of research excellence is different, the people are different, and that is why the idea of putting something in a container and treating every project or every patent through the same way or the same lens just does not work.*

## 2.8 Conclusions

University technology transfer is considered to be an important driver of national innovation and regional economic development. However, previous studies on university technology transfer productivity and efficiency have not evaluated the relative efficiency of Australian UTTOs. In this study, an inductive, mixed-methods approach was adopted to evaluate the relative efficiency of Australian UTTOs, and then to identify antecedents of efficient university technology transfer in Australia. Technical efficiency was evaluated and then universities were ranked according to their average technical efficiency score. Taking into account differences among universities in technology transfer efficiency, antecedents were established.

Based on the average VRS technical efficiency scores from each of the four DEAs in this study, Australian UTTOs achieved average technical efficiency of 44% for invention disclosures, 43% for number of licenses, 25% for licensing royalty income and 41% for number of spin-offs with university equity. The average VRS technical efficiency score of the four DEAs was 38% for the whole sample. The University of Queensland has the most efficient UTTO with 100% as an average VRS technical efficiency score of the four DEAs, followed by the University of Melbourne (65%) and Swinburne University of Technology (62%).

In relation to university‘s mission and internal research commercialisation funding, qualitative findings of this study suggest the following propositions:

***Proposition 1: Efficient universities in technology transfer are more likely to include research commercialisation in their mission statement.***

***Proposition 2: Efficient universities in technology transfer are more likely to provide internal research commercialisation funding as part of their UTTO's budget.***

***Proposition 3: Efficient universities in technology transfer are more likely to provide internal research commercialisation funding for multi-purpose commercialisation activities including prototype and business development.***

In relation to the importance of research commercialisation support structures, qualitative findings of this study suggest that research commercialisation support structures are considered not important by most UTTO's representatives and they can be useful only for space and mentorship if they are technology-specific. Therefore, I advise the Australian government to expand its ICTIP scheme to other technologies and to foster linkages between government-funded commercialisation support structures and universities.

In relation to antecedents of university technology transfer efficiency, qualitative findings of this study point out that high UTTO's capabilities, well-established UTTO's reputation and strong support from university's senior management are the main strengths of UTTOs. On the other hand, shortage in available resources, lack of commercialisation awareness among academics, highly bureaucratic university procedures and lack of incentivisation to commercialise are the main weakness of UTTOs. Hence, qualitative findings of this study suggest the following propositions:

***Proposition 4: Efficient universities in technology transfer are more likely to have unique UTTO's capabilities.***

***Proposition 5: Efficient universities in technology transfer are more likely to have well-established UTTO's reputation.***

***Proposition 6: Efficient universities in technology transfer are more likely to have strong senior management support.***

***Proposition 7: Efficient universities in technology transfer are more likely to have access to more resources.*** (By adopting the RBT, availability of financial, human and social resources is empirically tested in chapter 3 of this thesis)

***Proposition 8: Efficient universities in technology transfer are more likely to have commercially-aware academics.*** (The number of ARC Linkage Projects was chosen as a financial resource factor in chapter 3 of this thesis since it is a reflection of the number of commercialisation aware academic)

***Proposition 9: Efficient universities in technology transfer are more likely to have low bureaucratic orientation of technology transfer procedures.*** (By adopting the RBT, resource factors of organisational structure of UTTOs is empirically tested in chapter 4 of this thesis)

***Proposition 10: Efficient universities in technology transfer are more likely to provide high incentives for research commercialisation.***

In relation to impact measurement, UTTO representatives' main concerns were related to considering quality of impact rather than quantity, failure to capture impact by non-financial measures, and failure to recognise time-lag between research and impact. The majority of UTTO representatives recommended the use of a combination of numerical metrics or the use of hybrid measures of numerical metrics and case-studies.

This study has three limitations. The first limitation is related to the small sample size of 25 UTTOs that participated in the qualitative analyses. However, this study's sample was representative of Australian universities and accounted for 80% of invention disclosures, 85% of filled patents, 79% of executed licenses, 82% of licensing royalty income, 84% of spin-offs created and 83% of spin-offs created with university equity. The second limitation is that inputs takes time to produce outputs and therefore efficiency measurement can be limited by time-lag between inputs and actual outputs. To overcome this limitation, this study utilised 15 years average for university technology transfer input and output data. The last limitation is that our study considered Australian universities and therefore generalisability of the research findings to other types of research institute or to other countries may be limited.

Future studies could investigate the two propositions of this study. Additionally, this study could be extended to other countries to investigate whether antecedents of university research commercialisation are country-specific. This could yield particularly valuable information in the case of UK since the government has been active in supporting university technology transfer. A detailed review of initiatives to enhance university-industry interactions in the UK are outlined in Appendix 5.

# Chapter Three (Study Two): New Insights into University Technology Transfer Performance: The Case of Australian Universities

**Abstract**

The literature on university technology transfer has proposed individual, organisational and environmental determinants to superior university technology transfer performance. However, most of the previous studies on university technology transfer productivity and efficiency have not made a theoretical contribution to the field which might have limited the generalisability of their findings and hindered the progress of the field. In this study, the RBT was adopted to examine and explain performance differences between universities in technology transfer considering three resource factors, namely the number of ARC Linkage funded projects (financial capital), the number of UTTO staff holding a PhD (human capital) and the joining of a UTTO to a consortium (social capital). Using primary and secondary data, these resource factors were regressed against six university technology transfer performance measures, namely the number of invention disclosures, the number of filed patents, the number of executed licenses, the amount of licensing royalty income, the number of all spin-offs created and the number of spin-offs created with university equity. Empirical findings of this study show that the application of financial, human and social resource factors matters for technology transfer performance. UTTOs that possess these tangible and intangible resources report higher performance on most of the performance measures applied.

**Keywords**

University Technology Transfer, Organisational Legitimacy, Resource-Based Theory, Regression Analysis.

## 3.1 Introduction

Prior to 1980 in the United States of America (USA), intellectual property rights (IPRs) for inventions arising from federal funding were assigned to the federal government (Mowery *et al.*, 2004). In fact, most inventions were not subsequently utilised by the government nor transferred to other organisations (Bozeman, 2000). Therefore, with the view to remedying this situation, the USA adopted the *Stevenson-Wydler Technology Innovation* act of 1980 and the *Bayh-Dole* act of 1980 which allows assignment of IPRs for federally-funded research related inventions to universities and research centres (Colyvas *et al.*, 2002). Also, these acts obligate researchers to disclose their inventions to the parent organisation (Carlsson & Fridh, 2002). Subsequently, many first world countries have introduced similar statutes to formalise university technology transfer practises (Mowery *et al.*, 2004). The sole aim of these governmental actions is to encourage universities and research institutes to participate in innovation diffusion through technology transfer (Bercovitz *et al.*, 2001).

Technology transfer has been introduced to universities in order to stimulate regional growth and economic development (Thursby & Thursby, 2002). While the first academic revolution, in the 19$^{th}$ century, was to introduce research as a university's primary role based on ideas of Fichte and Schleiermacher (Kirby, 2006), Etzkowitz (2004) argued that universities are going through a 'second academic revolution' by adopting technology transfer. However, Geuna and Muscio (2009) argued that labelling the formal introduction of technology transfer to universities as a second academic revolution is ambiguous since interactions between university members and the industry sector can be traced back to the 19$^{th}$ century during the development of the chemical industry.

UTTOs are responsible for evaluating the commercial viability of inventions. If the invention is commercially viable or interest has been received from industry,  UTTOs then protect university intellectual property and initiate the process of technology transfer. Therefore, university technology transfer is describable by a linear flow model where the UTTO acts as primary agent in university-industry interactions (Siegel *et al.*, 2003a). This model can be seen from a simplified perspective as consisting of two steps. The first step involves technology evaluation while the second step includes protection of intellectual property and transfer of potential technologies from university to industry.

Ponomariov and Boardman (2012) classified several university-industry interactions according to four criteria; relational intensity, significance for industry, degree of formalisation and degree of knowledge finalisation. They have concluded that contract research, collaborative research, consultancy agreements, and professional conferences are highly significant to industry, while technology transfer is not considered to be so significant to industry. However, university-owned patents had contributed to 3.6% of US-owned patents by 2005 compared to only 1.1% in 1991(US Patent and Trademark Office, 2007). While the percentage of university-owned patents is relatively low, Siegel *et al.* (2003a) argue that university technology transfer plays a critical role in sustaining the global competitiveness of firms in the USA. In fact, from 1991 to 2005, the amount of licensing revenue generated by US universities has increased more than eight-fold (Kim, 2013). As a result, universities have given great attention to efficient technology transfer in order to boost research funding and to attract industry sponsorship (Carlsson & Fridh, 2002). Hence, researchers have examined the performance of UTTOs and established determinants of superior performance by UTTOs.

However, most of previous studies have conducted inductive approaches to examine UTTO performance which yielded theory-lacking conclusions and unjustified *ad hoc* recommendations (Johnson, 2011). These inductive approaches will hinder the development of the field towards being a valid scientific paradigm (Kuhn & Hawkins, 1963). Therefore, this study follows the lead of recent theory-based studies such as the use of agency and transaction cost theories (Kenney & Patton, 2009), path dependency theory (Mustar & Wright, 2010), dynamic capabilities perspective of the RBT (Rasmussen & Borch, 2010), population ecology (Cardozo *et al.*, 2011), and organisational control theory (Johnson, 2011). Hence, this study applies the theoretical lens of RBT (Wernerfelt, 1984) to explore three resource factors that might explain performance differences between universities in technology transfer. These resource factors are the number of ARC Linkage projects (financial capital), the number of UTTO staff holding a PhD (human capital) and the joining of a UTTO to a consortium (social capital).

This study is divided into several sections. The following section reviews the literature on determinants of university technology transfer performance. Subsequently, I argue that the RBT explains the importance of three resource factors in building competitive advantage for universities in technology transfer and hypotheses are formulated. Then methods are represented, followed by the study findings. Finally, findings are discussed, and being mindful of the limitations of the present study, recommendations for future work are proposed.

## 3.2 Determinants of University Technology Transfer Performance

Notwithstanding the importance of technological determinants of UTTO performance in relation to technological novelty of inventions (Nerkar & Shane, 2003), complexity of inventions (Crespi *et al.*, 2010; Nerkar & Shane, 2003) and technological stage of development of inventions (Thursby *et al.*, 2001; Jensen *et al.*, 2003), previous studies have classified determinants of UTTOs performance into three categories; *individual*, *environmental* and *organisational* (Siegel *et al.*, 2003a, 2008; Chapple *et al.*, 2005; Anderson *et al.*, 2007).

Although university scientists are required to disclose their inventions to the technology transfer office under the regulations of the *Bayh-Dole* Act (Mowery *et al.*, 2004), it has been found that faculty members are not disclosing their inventions to their UTTOs (Siegel *et al.*, 2004; Thursby *et al.*, 2001), and university inventions are 'going out the back door' (Markman *et al.*, 2008b). Jensen and Thursby (2001) concluded that licensing of university technologies is enhanced by the participation of scientists in the technology transfer process. In addition, it has been found that scientists have the leverage to choose the research commercialisation strategy when their involvement is essential (Lockett *et al.*, 2005). Therefore, scientist involvement is critical for successful technology transfer which encouraged researchers to examine individual determinants of UTTOs performance.

Previous researchers have examined individual determinants of UTTO performance in relation to scientist ethnicity (Krabel & Mueller, 2009; Schuelke-Leech, 2013), scientist age (Davis & Lotz, 2006; Haeussler & Colyvas, 2011), scientist gender (Landry *et al.*, 2007; Aldridge & Audretsch, 2010), scientist social capital (Oliver, 2004; Murray, 2004; Giuliani *et al.*, 2010), scientist alignment with Mertonian "open science" values (Renault, 2006; Haeussler & Colyvas, 2011), scientist reputation among scientific peers (Baldini *et al.*, 2007; Krabel & Mueller, 2009), scientist productivity and publication impact (Zucker & Darby, 1996; Davis & Lotz, 2006), professional status of scientist (Boardman & Ponomariov, 2009; Haeussler & Colyvas, 2011), scientist curiosity to validate research (Lee, 2000; Owen-Smith & Powell, 2001), scientist research type (Calderini *et al.*, 2007; Tartari *et al.*, 2014), scientist research resources (Landry *et al.*, 2007; Haeussler & Colyvas, 2011), previous interaction of scientist with industry (Bercovitz & Feldman, 2008; Tartari *et al.*, 2014), and entrepreneurship in scientist's family (Haeussler & Colyvas, 2011).

In addition to individual determinants, previous studies have examined environmental determinants of UTTOs performance (Friedman & Silberman, 2003; Lach & Schankerman, 2004; Chapple *et al.*, 2005; Siegel *et al.*, 2003a, 2008). However, these determinants could be analysed by the causality dilemma of which came first, the chicken or the egg? This argument is supported by O'Shea *et al.* (2004) finding that pharmaceutical companies such as Novartis and Wyeth have established R&D facilities nearby entrepreneurial universities to benefit from knowledge spillovers. Regardless of which came first, universities located in intensified R&D regions are found to be more efficient in technology transfer (Bercovitz & Feldman, 2006). The nature of the relationship between environmental determinants and UTTO performance was examined in relation to reliance of businesses on external R&D (Thursby & Thursby, 2002), regional Gross Domestic Product (GDP) per capita (Anderson *et al.*, 2007; Van Looy *et al.*, 2011), regional R&D intensity (Van Looy *et al.*, 2011; Curi *et al.*, 2012; Hülsbeck *et al.*, 2013), and regional Venture Capital (VC) intensity (Siegel *et al.*, 2008).

Organisational determinants of UTTO performance are inadequately studied in the literature (Sellenthin, 2009), notwithstanding they have recently attracted the attention of many researchers (e.g. Conti & Gaulé, 2009; Caldera & Debande, 2010; Hülsbeck *et al.*, 2013). Previous studies have examined multiple organisational determinants such as faculty size (Powers, 2004; Van Looy *et al.*, 2011), faculty quality (Stuart & Ding, 2006, Bercovitz & Feldman, 2008), university patent stock and quality (Powers & McDougall, 2005; Azoulay *et al.*, 2007), university policies (Kenny & Goe, 2004; Baldini *et al.*, 2007), university norms (Bercovitz & Feldman, 2008; Abreu & Grinevich, 2013), and university entrepreneurial culture (Owen-Smith & Powell, 2001; Palmintera, 2005). The theoretical framework of this study is discussed next and hypotheses are formulated.

## 3.3 Theoretical Framework and Hypotheses

The RBT has attracted the attention of management and organisational scholars in recent years (Connor, 1991). The theory was developed to compliment other theories in the field of management (Peteraf & Barney, 2003) and it is one of the most commonly used theories in the management and entrepreneurship literature (Barney *et al.*, 2011; Lipczynski *et al.*, 2013). The theory has been intensively used since Wernerfelt's (1984) proposition to analyse firms in terms of their resources. He supported his proposal by referring to the seminal work of Penrose (1959) that analysed the growth of firms as a dynamic process to achieve market opportunities by acquiring, building, and adapting resources. Some scholars are in agreement of Penrose's contribution to the RBT (Barney, 2001; Kor & Mahoney, 2004); whereas Foss (1999) argues that Penrose contributed towards the behavioural theory of the firm rather than the RBT.

The RBT is mainly utilised to examine differences between competing firms in terms of performance in using available resources (Madhok, 2002). In fact, the RBT is defined as "a factor-based, efficiency-oriented, and firm-level explanation of performance differences" (Peteraf & Barney, 2003: 315). Hence, differences in endowment between firms explain the performance of firms where differences are attributed to the availability of resources. Broadly speaking, resources are factors that contribute to the growth of firms whether they are sources of strengths or weaknesses (Wernerfelt, 1984). Firm resources include tangible and intangible assets ranging from physical assets to firm reputation. Therefore, according to the RBT, it is within the ability of firms' management to acquire, develop and utilise resources and capabilities to enhance performance (Barney, 1991).

Although the RBT has repeatedly been used to explain situations within the commercial sector, the present study applies the RBT to examine performance differences among universities in relation to technology transfer. Hence, the real problem is that universities are assumed to operate in a non-competitive environment (Kennedy, 1995), whereas the RBT is concerned with using available resources to build and sustain a competitive advantage for the firm (Wernerfelt, 1984). However, universities compete against other universities to obtain financial resources such as research funding, and to attract human capital such as "star scientists" and talented students (Powers & McDougall, 2005). Additionally, a competitive environment has emerged among universities to achieve high university ranking (McDonough *et al.*, 1998). Therefore, universities under current realities are operating in a competitive environment (Gumport, 1997) and specific resource factors contribute to the differences in performance of universities in relation to technology transfer.

The choice of appropriate resource factors is a challenge in the university context. According to the literature of the RBT, resource factors are classified into four themes, namely *financial*, *human capital*, *physical* and *organisational* (Busentitz & Barney, 1997). In the university context, entrepreneurial resources are fundamentally important for superior technology transfer performance (Powers & McDougall, 2005). Previous studies have proposed several entrepreneurial resource factors such as scientific capabilities of experts (Deeds *et al.*, 1997;

Finkle, 1998), and access to skilled personnel (Flynn, 1993) and support structures (Mansfield, 1995).

Consistent with the qualitative findings of study one of this thesis (refer to section 2.7.2), Siegel *et al.* (2003a) indicated that availability of financial, human and social capital are critical for efficient university technology transfer. Qualitative findings of study one of this thesis indicated that commercialisation-aware academics are strength for university technology transfer mainly because they tolerate interaction with industry. Therefore, as a reflection of the number of commercially-aware academics and the entrepreneurial culture at the university, the number of ARC Linkage projects is examined as a financial capital in the present study.

Additionally, previous studies indicated that developing an identity for the organisation is beneficial for building legitimacy (Brown & Toyoki, 2013; Navis & Glynn, 2011), especially if trying to shape identity with multiple stakeholders (Chermak & Weiss, 2005; Sillince & Brown, 2009). O'Kane *et al.* (2015) have conducted qualitative research to confirm that UTTOs shape a "dual identity" to build legitimacy with two principal stakeholders within the university, namely academics and university management. They concluded that holding a PhD degree is essential for UTTO staff to shape a scientific identity with university academics and to enhance UTTO legitimacy and hence the number of UTTO's staff holding a PhD is examined as a human resource factor in the present study as it is a reflection of organisational legitimacy of the UTTO.

Furthermore, by examining the effectiveness of networks of technology transfer offices, Park *et al.* (2010) argued that being part of a consortium enhances the productivity of technology transfer offices. Surprisingly, previous studies have not empirically examined the relationship between UTTO consortium membership and university technology transfer performance. Therefore, the joining of a UTTO to a consortium is examined as social capital since it is a reflection of the networking ability of UTTOs. The present study proceeds to test whether there is a significant association between each of these three resource factors and different performance indicators.

### 3.3.1 ARC Linkage Funding

*ARC Linkage Projects Scheme* is an initiative that was introduced in 2004 to provide funding for the collaboration of Australian universities and higher research institutes with other industrial partners to enhance innovation and university research commercialisation in

Australia (Allen Consulting Group, 2003a). Eligible organisations can submit proposals for project funding for an amount of 50,000 to 300,000 per annum. This project funding requires the availability of a financially-contributing partner organisation, and the project has to be of innovative nature in one of the priority areas of research for Australia. Consistent with the qualitative findings of study one of this thesis (refer to section 2.7.2), Siegel *et al.* (2003a) indicated that availability of financial, human and social capital are critical for efficient university technology transfer. Qualitative findings of study one of this thesis indicated that commercialisation-aware academics are strength for university technology transfer mainly because they tolerate interaction with industry. In fact, Australian universities compete against each other to obtain this financial resource factor and it can be assumed that universities approved to receive more funded projects would be superior in relation to technology transfer. Therefore, the following hypothesis is formulated.

> **Hypothesis 1: There is a statistically significant association between the number of ARC Linkage projects and different performance indicators including the number or amount of: H1a invention disclosures; H1b filed patents; H1c executed licenses; H1d licensing royalty income; H1e all spin-offs created; and H1f spin-offs created with university equity.**

### 3.3.2 Number of UTTO's Staff Holding a PhD

Legitimacy is defined as "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman, 1995: 574). Smith (2011) concluded that it is essential for organisations to build legitimacy to be profitable. Also, previous studies indicated that developing an identity for the organisation is beneficial for building legitimacy (Brown & Toyoki, 2013; Navis & Glynn, 2011), especially if trying to shape identity with multiple stakeholders (Chermak & Weiss, 2005; Sillince & Brown, 2009). O'Kane *et al.* (2015) have conducted qualitative research to confirm that UTTOs shape a "dual identity" to build legitimacy with two principal stakeholders within the university, namely academics and university management. They concluded that holding a PhD degree is essential for UTTO staff to shape a scientific identity with university academics and to enhance UTTO legitimacy. Therefore, it would be expected that UTTOs that employ staff with a PhD degree to have good relationships with university academics and therefore better academic involvement in the process of technology transfer. Surprisingly, UTTO legitimacy, as measured by the number of UTTO staff holding a PhD degree, has not been examined in the literature as a resource factor that might explain performance differences between universities in technology transfer. Therefore, this study will contribute to the literature by examining the following hypothesis.

> **Hypothesis 2: There is a statistically significant association between the number of UTTO staff holding a PhD and different performance indicators including the number or amount of: H2a invention disclosures; H2b filed patents; H2c executed licenses; H2d licensing royalty income; H2e all spin-offs created; and H2f spin-offs created with university equity.**

### 3.3.3 Member of UTTO Consortium

Technology transfer office networks (consortia) are a means for enhancing the skills and minimising the resources by economies of scale (Powell, 1990). The importance of establishing networks is well known in the organisational literature (Sala *et al.*, 2011)., According to Jones-Evans *et al.* (1999), UTTOs join networks to access expertise in diverse areas related to technology transfer. On a national level, technology transfer offices networks have been observed within some European countries (Geuna & Muscio, 2009).

On a regional level, some authors suggested the establishment of discipline-specialised networks of technology transfer offices especially in areas categorised with low levels of R&D (e.g. Chapple *et al.*, 2005). In relation to regional consortia, Litan *et al.* (2008) elaborated further that universities benefit from economies of scale as the cost of commercialisation is shared among participating universities. Other researchers have proposed models where technology transfer office networks are established both regionally and on a national level to boost communication and knowledge exchange between regions (e.g. Young, 2007). In fact, by examining the effectiveness of networks of technology transfer offices, Park *et al.* (2010) argued that being part of a consortium enhances the productivity of technology transfer offices. Surprisingly, previous studies have not empirically examined the relationship between UTTO consortium membership and university technology transfer performance. It is assumed that UTTOs that are members of a consortium of UTTOs would have higher social capital and would perform better in technology transfer compared to their non-member peers. Therefore, the joining of a UTTO to a consortium is examined as a social resource factor since it is a reflection of the networking ability of UTTOs:

**Hypothesis 3: There is a statistically significant association between joining a UTTO consortium and different performance indicators including the number or amount of: H3a invention disclosures; H3b filed patents; H3c executed licenses; H3d licensing royalty income; H3e all spin-offs created; and H3f spin-offs created with university equity.**

## 3.4 Methodology

Correlation and linear regression analysis are used to examine the association between three critical resource factors and different measures of university technology transfer performance.

University technology transfer performance data were obtained from the National Survey of Research Commercialisation (NSRC) conducted annually by the Australian Department of Industry, Innovation and Science. Performance data are available for 39 Australian universities recorded for the years 2000 to 2014. The average university technology transfer performance data for the recorded period were used. ARC Linkage data were obtained from ARC for approved projects for funding commencing by 2016.  UTTO's staff and consortium membership data were obtained by conducting structured telephone interviews with UTTO representatives from universities that responded to the NSRC. Interviews were conducted in October and November of 2016, and representatives from 25 Australian universities participated. Regression analysis variables, their abbreviations and their sources are summarised in Table 3.1.

| Variable Names | Variable Types | Source | Year |
|---|---|---|---|
| Number of Invention Disclosures (INVDIS) | Continuous | NSRC | 2000-14 |
| Number of Filled Patents (FILPAT) | Continuous | NSRC | 2000-13 |
| Number of Executed Licenses (EXCLIC) | Continuous | NSRC | 2000-14 |
| Licensing Royalty Income (LICINC) | Continuous | NSRC | 2000-14 |
| Number of All Spin-offs Created (SPICRE) | Continuous | NSRC | 2000-14 |
| Number of Spin-offs Created with University Equity (SPIEQU) | Continuous | NSRC | 2000-14 |
| Number of ARC Linkage Funded Projects (ARCNUM) | Continuous | ARC | 2016 |
| Number of UTTO staff holding a PhD (PHDSTF) | Continuous | Interview | 2016 |
| Consortium Membership (CONMEM) | Binary (No=0; Yes=1) | Interview | 2016 |

**Table 3.1:** Dependent and independent variables for regression analysis.

## 3.5 Empirical Findings

Descriptive and correlation statistics are presented in Table 3.2. For the recorded performance period (as shown in Table 3.1), the average number of inventions disclosed was 32.95 per annum and the average number of patents filled was 18.68/year. UTTOs had executed an average of 9.35 licenses per annum and received an average licensing royalty income of AUD$1.89 million/year. In addition, UTTOs had created an average of 5.21 spin-offs companies and 4.57 spin-offs companies with university equity holdings. On the other hand, the average number of ARC Linkage projects was 37.48 and the average number of UTTOs' staff holding a PhD was 3.

| | Minimum | Maximum | Mean | Standard Deviation |
|---|---|---|---|---|
| (1) INVDIS | 0 | 198.29 | 32.95 | 40.18 |
| (2) FILPAT | 0 | 87.77 | 18.68 | 25.25 |
| (3) EXCLIC | 0 | 41.47 | 9.35 | 12.55 |
| (4) LICINC | 0 | 23.97 | 1.89 | 4.91 |
| (5) SPICRE | 0 | 32.5 | 5.21 | 6.88 |
| (6) SPIEQU | 0 | 32.46 | 4.57 | 6.58 |
| (7) ARCNUM | 0 | 144 | 37.48 | 43.29 |
| (8) PHDSTF | 0 | 15 | 3 | 3.88 |
| (9) CONMEM | 0 | 1 | .16 | .374 |

**Correlation Coefficients**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| (1) INVDIS | 1 | | | | | | | | |
| (2) FILPAT | .856** | 1 | | | | | | | |
| (3) EXCLIC | .787** | .928** | 1 | | | | | | |
| (4) LICINC | .884** | .723** | .608** | 1 | | | | | |
| (5) SPICRE | .914** | .816** | .767** | .878** | 1 | | | | |
| (6) SPIEQU | .910** | .742** | .681** | .905** | .987** | 1 | | | |
| (7) ARCNUM | **.762**** | **.912**** | **.824**** | **.704**** | **.842**** | **.766**** | 1 | | |
| (8) PHDSTF | **.818**** | **.822**** | **.792**** | **.671**** | **.774**** | **.727**** | .721** | 1 | |
| (9) CONMEM | .497* | .280 | .173 | .399* | .421* | .472* | .183 | .315 | 1 |

**Table 3.2:** Descriptive statistics and correlation coefficients for dependent and independent variables.

*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.

Regression analysis was performed for the six performance variables (INVDIS, FILPAT, EXCLIC, LICINC, SPICRE and SPIEQU) and three independent variables (ARCNUM, PHDSTF and CONMEM). Results of the regression analyses are summarised in Table 3.3. Variance Inflation Factors (VIFs) were estimated to check for multicollinearity and VIFs were substantially below the problematic level of 10 (Von Eye & Schuster, 1998). Also, adjusted R-square values were relatively close to the actual R-square values which indicate that the regression model is not overfit (Leinweber, 2007).

| | INVDIS | FILPAT | EXCLIC | LICINC | SPICRE | SPIEQU |
|---|---|---|---|---|---|---|
| *Constant* | .692<br>(5.227) | -2.839<br>(2.448) | -.209<br>(1.791) | -1.599<br>(.912) | -.495<br>(.874) | -.566<br>(1.007) |
| **ARCNUM** | .357**<br>(.130) | .390***<br>(.061) | .151***<br>(.045) | .055**<br>(.023) | .097***<br>(.022) | .081***<br>(.025) |
| **PHDSTF** | 4.663***<br>(1.502) | 2.093***<br>(.703) | 1.406**<br>(.515) | .317<br>(.262) | .462*<br>(1.855) | .425<br>(.289) |
| **CONMEM** | 30.526**<br>(10.981) | 3.8<br>(5.143) | -2.005<br>(3.762) | 3.043<br>(1.916) | 4.179**<br>(1.836) | 5.207**<br>(2.115) |
| **Sample Size** | 25 | 25 | 25 | 25 | 25 | 25 |
| **R-Square** | .803*** | .891*** | .763*** | .599*** | .813*** | .728*** |
| **Adjusted R-Square** | .775 | .875 | .729 | .542 | .786 | .689 |

**Table 3.3:** Regression analysis results (standard errors in parentheses underneath estimated regression coefficients).

*. Statistically significant at the 0.1 level or better. **. Statistically significant at the 0.05 level or better. ***. Statistically significant at the 0.01 level or better.

All resource factors had varied effects on technology transfer performance indicators of universities with the number of ARCNUM as the most significant resource factor across six performance indicators. ARCNUM has a positive and significant association with the number or the amount of INVDIS (at the 0.05 level), FILPAT (at the 0.01 level), EXCLIC (at the 0.01 level), LICINC (at the 0.05 level), SPICRE (at the 0.01 level) and SPIEQU (at the 0.01 level). Also, the number of PHDSTF was positively and significantly associated with better university technology transfer performance in relation to the number of INVDIS (at the 0.01 level), FILPAT (at the 0.01 level), EXCLIC (at the 0.05 level) and SPICRE (at the 0.1 level). On the other hand, CONMEM was only associated with better performance in relation to the number of INVDIS (at the 0.05 level), SPICRE (at the 0.05 level) and SPIEQU (at the 0.05 level).

## 3.6 Discussion

This study aimed to investigate the impact of three resource factors of UTTOs on six university technology transfer performance measures. The hypothesised relationships and the results of the empirical tests are presented in Table 3.4.

| | A<br>Invention Disclosures | B<br>Filed Patents | C<br>Executed Licenses | D<br>Royalty Income | E<br>All Spin-offs Created | F<br>Spin-offs Created with University Equity |
|---|---|---|---|---|---|---|
| **Hypotheses set 1: ARC Linkage Projects** | **Confirmed**<br>(+) | **Confirmed**<br>(+) | **Confirmed**<br>(+) | **Confirmed**<br>(+) | **Confirmed**<br>(+) | **Confirmed**<br>(+) |
| **Hypotheses set 2: PhD Staff** | **Confirmed**<br>(+) | **Confirmed**<br>(+) | **Confirmed**<br>(+) | Rejected | **Confirmed**<br>(+) | Rejected |
| **Hypotheses set 3:** | **Confirmed** | Rejected | Rejected | Rejected | **Confirmed** | **Confirmed** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Consortium Membership** | (+) | | | | (+) | (+) |

**Table 3.4:** Summary of hypotheses testing results. Positive and negative signs in parentheses represent the nature of the association.

The number of ARC Linkage funded projects was positively associated with all six measures of performance. This is in line with the finding of Watanabe (2009) who found that highly collaborative universities filled more patenting and received higher licensing royalty income. The author attributed that to universities using patenting and technology licensing as strategic techniques to build long-term university-industry collaborations.

This finding supports *proposition 8* of study one of this thesis since it is confirmed that the number of commercially-aware academics is associated with better university technology transfer. Universities that have high levels of commercialisation awareness among their academics have a competitive advantage over other universities that help them to excel in technology transfer. In fact, Tartari *et al.* (2014) found that departmental colleagues of commercialisation-aware academics as well as co-authors are more likely to be involved in collaborative projects with industry. Also, previous studies have reached the same conclusion for patenting and technology licensing (Azoulay *et al.* 2007; Bercovitz & Feldman, 2008), and spin-offs creation (Sturat & Ding, 2006). Universities with higher number of commercially-aware academics will obtain higher number of ARC Linkage funded-projects and they will develop an entrepreneurial culture. Entrepreneurial culture was found to be positively associated with patenting and technology licensing (Owen-Smith & Powell, 2001). Hence, the number of ARC Linkage funded projects can defiantly be considered as a good predictor of overall performance differences between universities in technology transfer.

The number of UTTO's staff holding a PhD was positively associated with the number of inventions disclosures, filed patents, executed licenses and all spin-offs created. In fact, it is argued that academic inventions are not being disclosed and one of the contributing factors was academics-UTTO relationship (Markman *et al*., 2008b), and this finding indicate that highly legitimate UTTOs have a competitive advantage in relation to building better relationships with university academics. This study supports the conjecture of Jensen and Thursby (2001) that involvement of academics in technology licensing is positively related to legitimacy of the UTTO. Lockett *et al.* (2005) hypothesised that academic involvement is crucial for spin-offs creation and this finding confirmed a positive association for the number of all created spin-offs.  Hence, the number of employed PhD staff can be considered as a good predictor of overall performance differences between universities in technology transfer and therefore has a strong explaining power as a human capital resource factor.

Most striking is the important difference in the impact that UTTO's consortium membership has on the various UTTO performance measures. UTTO's consortium membership is a neglected social resource factor in the empirical literature and this study therefore contributes to the literature on UTTO performance in providing clarity on its impact on performance at a granular level. It is clear from the results that UTTOs that are consortium members emphasise disclosure of inventions and creating spin-offs as their main technology commercialisation focus with less emphasis on increasing the number of licencing agreements and the amount of licensing royalty income. In contrast with findings of Park *et al.* (2010), a positive association was not confirmed between consortium membership and the number of filed patents, the number of executed licenses nor the amount of licensing royalty income. It was interesting to confirm that consortium member UTTOs establish more Spin-offs. This could be attributed to the assumed wide access to consortium-provided social capital; including venture capitalists and consulting firms (Lockett *et al.*, 2003; Siegel *et al.*, 2003a).

## 3.7 Conclusion

The literature on university technology transfer has proposed multiple determinants of performance. In this study, the RBT was adopted to analyse performance differences between universities in technology transfer considering three resource factors. These resource factors were the number of ARC Linkage funded projects, the number of UTTO staff holding a PhD and the joining of UTTO consortium.

Empirical findings of this study show that the number of ARC Linkage funded projects has an overall positive effect on universities' performance in technology transfer. Additionally, this study confirmed a positive association between the level of UTTO legitimacy and multiple numerical technology transfer performance measures. It was also found that consortium member UTTOs receive more invention disclosures and establish more spin-offs with or without university equity than non-member UTTOs. Hence, a university's ability to competitively obtain more financial resources is indeed valuable in ensuring comparatively higher technology commercialisation performance. It is advisable for UTTOs to join consortia, because this would enhance the number of invention disclosures and spin-offs created, both with and without university equity.

This study has three limitations. The first limitation is that this study has a small sample size of 25 UTTOs. However, the sample was representative of Australian universities and accounted for 80% of invention disclosures, 85% of filled patents, 79% of executed licenses, 82% of licensing royalty income, 84% of spin-offs created and 83% of spin-offs created with university equity. The second limitation is that interviews were conducted in 2016 to gather information about two critical resource factors for UTTOs' performance while performance data were obtained for a different period. To overcome this limitation, the study utilised average performance data for a 15 year period to take account for time-lags between research and impact. In relation to this limitation, further analysis could be conducted to estimate the effect of time-lag and that can be carried out as a qualitative study (field study or a series of case studies) followed by a quantitative study to empirically examine the estimated time-lag, taking into account differences related to the level of development of technologies and the strictness of IP laws. The last limitation is that this study considered Australian universities and therefore the generalisability of the research findings to other types of research institute or to other countries may be limited.

Future studies could investigate additional resource factors of UTTOs that could contribute to performance differences between universities in technology transfer. It would be particularly interesting for future studies to examine whether technology transfer is a dynamic capability that grants some universities a competitive advantage over others. Additionally, this study could be extended to other countries to investigate performance differences in relation to the studied resource factors. This could yield valuable information in the case of the UK, since the government is active in supporting collaboration between universities and industry, and most UTTOs in the UK are consortium members.

# Chapter Four (Study Three): Does Organisational Structure of University Technology Transfer Offices Matter?

**Abstract**

The literature on university technology transfer is abundant; however, previous studies have not established a relationship between the organisational structure of University Technology Transfer Offices (UTTOs) and their performance. In this study, the RBT was adopted to examine and explain performance differences between universities in technology transfer considering four resource factors in relation to the organisational structure of UTTOs. The resource factors chosen were centralisation, specialisation, configurational autonomy and financial dependence. Using primary and secondary data, these resource factors were regressed against six university technology transfer performance measures, namely the number of invention disclosures, the number of filed patents, the number of executed licenses, the amount of licensing royalty income, the number of all spin-offs created and the number of spin-offs created with university equity. Empirical findings of this study show that decentralised UTTOs are superior to centralised UTTOs by all technology transfer performance measures. In relation to specialisation, a positive association was not confirmed for any of the studied technology transfer performance measures. It was also found that highly autonomous UTTOs receive more invention disclosures, file more patents and execute more licenses than non-autonomous UTTOs. Interestingly, it was also found that financially independent UTTOs file fewer patents, execute fewer licenses but receive more licencing royalty income and create more spin-offs with or without university equity than financially dependent UTTOs. Universities' ability to effectively configure the organisational structures of their UTTOs is indeed a valuable resource in ensuring comparatively higher technology commercialisation performance. It is advisable for universities to adopt autonomous UTTO structures since it would enhance the number of patent filings and licencing agreements whereas maintaining the UTTOs as decentralised and financially independent cost centres would ensure financial sustainability.

**Keywords**

University Technology Transfer, Entrepreneurial University, Organisational Structure, Resource-Based Theory, Regression Analysis.

## 4.1 Introduction

Traditional academic universities are transforming into entrepreneurial universities, from primarily knowledge creators to also becoming technology commercialisation agents. To successfully manage the contradictory demands and skillsets characterising this transition, careful consideration needs to be given to the development of appropriate organisational structures to build and maintain competitiveness in rapidly changing commercial landscapes.

The term *entrepreneurial universities* was introduced by Etzkowitz (1983: 232) to label universities that are "*evolving from an institution dependent for its support on income from endowment, gifts, fees paid by students and grants from governments, into an enterprise capable of obtaining income from its research activities*". Jacob *et al*. (2003) highlighted that entrepreneurial universities are required to undergo organisational transformation and to adapt their culture and missions. Universities are required to play an entrepreneurial role of technology transfer in addition to their traditional roles of research and teaching (Etzkowitz *et al*., 2000; Grigg, 1994). Siegel *et al*. (2004) suggest that traditional academic and entrepreneurial roles strengthen and support each other, while Grigg (1994) recommends the use of an 'umbrella strategy' by universities to create an appropriate environment for innovation within its dimensions. Ambos *et al.* (2008) emphasised that university-industry interactions should be balanced by their respective assets, research as a university asset and commercialisation expertise as an industry asset. In fact, entrepreneurial universities are required to fulfil both academic and commercial research demands (West, 2008).

These demands are contradictory in nature for multiple reasons. The first reason is that research at universities is generally more curiosity-driven with long-term goals whereas industrial research is more commercially-driven with short-term goals (Di Gregorio & Shane, 2003). Although some researchers argue that the shift towards entrepreneurial activities may compromise academic freedom and lead to increased investments in applied research (Louis *et al*., 2001; Gulbrandsen & Smeby, 2005), empirical evidence for basic research being dominated by applied research remains elusive (Van Looy *et al*., 2004). Another reason proffered by some authors is that universities encourage an open science culture, while commercial research is surrounded with protection of IPRs for maintaining competitive advantage (Nelson, 1959). Additionally, researchers at universities are tenured for publishing their research outcomes, while it has been asserted that industry researchers tend to keep results hidden and are less motivated to publish their findings (Stern, 2004).

Although the dichotomies described above are simplifications, (because universities have become more sophisticated in their protection of IPRs, realising that it is not necessarily incompatible with publication), it remains true that universities were designed for certain roles (teaching and research) and are now required to do another completely different role (technology transfer). As a result, the balance of these contradictory roles has created institutional tensions when it comes to allocating resources, setting up incentive systems and designing appropriate organisational structures. At its heart, the challenge is not to switch from one role to another; it is to conduct and manage both roles simultaneously. *Organisational ambidexterity* presents a useful theoretical lens that provides insight into the transition of universities towards increased technology transfer roles and the difficulty of managing the dual roles simultaneously (Tushman & O'Reilly, 1997). Since universities are facing institutional tensions to balance contradictory traditional and entrepreneurial demands (Ambos *et al.*, 2008), they have responded by designing policies in favour of commercialising research outcomes (Lockett & Wright, 2005), and by establishing various organisational structures for technology transfer (Phan *et al.*, 2005). These organisational structures are commonly referred to in the literature as University Technology Transfer Offices (henceforth, UTTOs). University researchers disclose their inventions to UTTOs where IPRs to potential inventions are protected in order to license technologies and to create spin-offs companies.

With the increasing trends of establishing UTTOs and university-industry innovation ecosystems, universities are concerned with the performance of technology transfer (Siegel *et al*., 2004; Thursby *et al*., 2001). Previous studies have attempted to evaluate performance of UTTOs, and have broadly classified the determinants of UTTOs efficiency into *individual, environmental* and *organisational* (Siegel *et al.*, 2003a, 2008; Chapple *et al.*, 2005; Anderson *et al.*, 2007). In fact, most empirical research only focuses on the individual and environmental levels, whereas organisational structure is neglected at the organisational level. Although the way organisations are designed explains how people interact and how activities are carried out (Drucker, 1973), researchers who investigated organisational structures of UTTOs as a performance determinant address it as a "secondary subject" (Brescia *et al.*, 2016). In fact, Schoen *et al.* (2014) concluded that "*future studies might analyse the quantitative impact of different TTO types on the efficiency and effectiveness of technology transfer activities*". More recently, Brescia *et al.* (2016) concluded that "*it could be a matter for further studies to verify the efficiency and the productivity of the different models and* *configurations* [of UTTOs]". To my knowledge, previous studies have not provided empirical evidence bearing on the possible relationship between organisational structure features of UTTOs and their performance by quantitative impact analysis. This study applies the RBT (Wernerfelt, 1984) to explore the organisational structure of UTTOs as a resource factor that might explain performance differences between universities in technology transfer.

This study is divided into several sections. The following section reviews the literature on organisational structures of UTTOs. Subsequently, the author argues that the RBT explains the importance of UTTO organisational structure in building competitive advantage and hypotheses are formulated. Methods of this study are discussed next, followed by the findings. Finally, a discussion of findings is presented, and being mindful of the limitations of the present study, directions for future work are recommended.

## 4.2 Organisational Structure of UTTOs

Empirical literature describe different UTTO organisational structure typologies and provide evidence of how organisational structure choice impacts performance. Organisational structure of UTTOs was first studied by Bercovitz *et al.* (2001) who classified organisational forms as *functional/unitary*, *multidivisional*, *holding form* and *matrix* forms. Also, classifications were made based on certain qualities relevant to information processing capacity, coordination capability and incentive alignment.

- *The functional or unitary model (U-Form)* is characterised with high level of centralisation where decision-making and coordination responsibilities are assigned to a small group of top managerial people.
- *The multidivisional model (M-Form)* is characterised with moderate level of centralisation and semi-autonomous divisions.
- *The holding company (H-Form)* is similar to the multidivisional form; however, it is characterised with low level of centralisation.
- *The Matrix model (MX-Form)* is characterised with a combination of functional and divisional features.

According to these classifications, they have determined performance of three US universities. They concluded that the *matrix form* yielded the highest level of engagement with industry in terms of research contracts and licensing agreements; however, it was associated with a higher amount of research support and lower amounts of royalties. Also, the authors found that *multidivisional* and *holding* forms are characterised with higher information processing capacity than other forms as measured by the numbers of invention disclosures, patents and licenses per UTTO employee. In regards to coordination capability, they concluded that *functional/unitary* form has the highest coordination capability. To summarise, they found, by addressing three managerial qualities, that each organisational form has advantages and disadvantages.

Another study on the organisational structure of UTTOs was conducted by Debackere and Veugelers (2005). They used the technology transfer office of K.U. Leuven as a case study and compared it to 11 other European UTTOs. They found that the structure of the UTTO affects the process of technology transfer, and they have argued that a *matrix form* is essential for better technology transfer performance since research groups are closely involved in the technology transfer process. The study has also emphasised the importance of having a proper incentive management system with sufficient resources. The theoretical underpinnings of organisational structure classifications in empirical research as well as its performance consequences will be discussed next.

## 4.3 Theoretical Frameworks and Hypotheses

In order to understand the organisational structure of UTTOs and to determine the relevant structural dimensions, this study utilises the bureaucracy model theorised by Weber (1947). The model was introduced as a unidimensional concept; however, it was expanded by multiple researchers such as Pugh *et al.* (1968) and Child (1972) to five structural dimensions which are *centralisation*, *specialisation*, *configuration*, *standardisation* and *formalisation*. Because of the complexity of organisations and the importance to choose the relevant structural dimensions (Meyer *et al.*, 1993), the trade-off between complexity and precision has to be taken into account in order to achieve generalizable findings (Schoen *et al.*, 2014). Therefore, *standardisation* was not considered mainly because the process of university technology transfer is well established in the literature (Schoen *et al.*, 2014). Also, Tello *et al.* (2010) developed an integrated framework of rational choice and institutional theory. By conducting interviews with 11 UTTO staff at 6 universities, they examined their framework on five UTTO procedures in relation to market determination, competitive environment assessment, success-factor weighting, technology commercialisation and success measurement. They concluded that procedures of IPRs protection are highly formalised and procedures of IP commercialisation are highly informal. Therefore, *formalisation* could not be used quantitatively to explain performance differences between universities in technology transfer.

This study focuses on resource factors in relation to different dimensions of UTTOs organisational structure, namely *centralisation*, *specialisation* and configuration in terms of decision-making *autonomy* and *financial dependence*. To enable analysis of findings and to compare different organisational structures, it is important to precisely define these structural dimensions (Pugh *et al.*, 1968).

### 4.3.1 Centralisation/ Decentralisation

Centralisation is originally defined in terms of the locus of authority to make decisions (Pugh *et al.*, 1968). In the UTTO context, knowledge and technology transfer activities are distributed either within a single central unit or among several units within universities (Brescia et al., 2016). Accordingly, if technology transfer activities are carried out at a single location, the UTTO is labelled as centralised. On the other hand, the UTTO is considered decentralised when activities are conducted at multiple locations. The structural classification of UTTOs as centralised or decentralised, in terms of the number of units where knowledge transfer activities are undertaken, has been adopted in several empirical studies, briefly discussed here. Jones-Evans *et al.* (1999) concluded that most UTTOs in Sweden are decentralised whereas most of Ireland's UTTOs are centralised. Link and Siegel (2005) identified only one fully centralised UTTO in an American state. Huyghe *et al.* (2014) examined the structure of Ghent University's technology transfer office. They concluded that having a ''hybrid model'', with central management and decentralised divisions, is beneficial for spin-off creation. Carlsson *et al.* (2008) investigated centralisation of IP management units at US companies. They identified three orientations, namely centralised, compromise (semi-centralised) and decentralised. They concluded that centralised forms positively impact the speed of communication with divisional units, while decentralised forms impede interaction between divisional units. Therefore, they emphasised the benefits of the compromised form which correspond to the *matrix form* of Bercovitz *et al.* (2001). Litan *et al.* (2008) observed that, similarly to IP management units, most UTTOs in the USA are centralised. They argue that centralised UTTOs are more administrative-oriented and less facilitative-oriented. In other words, they believe that centralised UTTOs impede university technology transfer. Therefore, the following hypotheses were formulated to examine centralisation as a resource factor.

**Hypothesis 1: There is a statistically significant association between UTTO centralisation and different performance indicators including the number or amount of: H1a invention disclosures; H1b filed patents; H1c executed licenses; H1d licensing royalty income; H1e all spin-offs created; and H1f spin-offs created with university equity.**

### 4.3.2 Specialisation

Specialisation is considered according to tasks and disciplines. Task-specialisation is directly related to UTTO activities, which can be classified into three themes; IP-related support, research-related support and spin-offs creation support (Brescia *et al.*, 2016). UTTOs can be classified by the degree of specialisation they exercise in relation to tasks. However, since the essence of university technology transfer correlate with IP, task specialisation is linked to IP support (Schoen *et al.*, 2014). Therefore, task-specialised UTTOs provide IP and spin-offs support, whereas task-integrated UTTOs provide support related to IP, research and spin-off. Task specialisation of UTTOs has been directly linked to technology transfer efficiency (Phan & Siegel, 2006). In the case of the *matrix form* of UTTOs, prior research included task specialisation as an essential structural dimension (Bercovitz *et al.*, 2001; Debackere & Veugelers, 2005). Meyer and Tang (2007) examined the effect of task specialisation on patent value by undertaking a case study of the technology transfer office at U.K. University. Lockett and Wright (2005) highlighted a positive relationship between the level of spin-off creation support of the UTTO and the number of spin-offs created. However, Caldera and Debande (2010) found no relationship between task-specialised UTTOs and efficiency of UTTOs in relation to technology licensing and spin-off creation.

Additionally, specialisation by discipline is concerned with the degree of specialisation that UTTOs exhibit in relation to handling invention disclosures. A discipline-specialised UTTO has multiple commercialisation managers to process invention disclosures according to their discipline. On the other hand, discipline-integrated UTTOs handle all invention disclosures without any differentiation (Schoen *et al.*, 2014). In other words, discipline-specialised technology transfer is conducted at the departmental level while discipline-integrated technology transfer is carried out at the institutional level. Hülsbeck *et al.* (2013) concluded that low level of specialisation measured by task-per-employee is associated with lower numbers of invention disclosures. For the present work, I have developed a measure to capture both task and discipline specialisation. If the UTTO is task-specialised but discipline-integrated or *vice versa*, it is considered as semi-specialised. Specialised UTTOs provide IP and spin-offs support and they have specialised teams to handle invention disclosures. Integrated UTTOs provide IP, research and spin-offs support and they have an integrated team to handle all invention disclosures. The following hypotheses were formulated to examine the effects of specialisation on university technology transfer performance.

> **Hypothesis 2: There is a statistically significant association between the level of UTTO specialisation and different performance indicators including the number or amount of: H2a invention disclosures; H2b filed patents; H2c executed licenses; H2d licensing royalty income; H2e all spin-offs created; and H2f spin-offs created with university equity.**

### 4.3.3 Configurational Autonomy

Autonomy as a configurational dimension is concerned with the locus of decision-making power (Brescia *et al.*, 2016). In fact, the level of autonomy is included in the latest report for technology transfer by the European Commission (2009), which highlights its importance as a structural dimension. An example of an autonomous technology transfer office of the University of Wisconsin is one of the oldest in the USA and it was established in 1924 (Sampat, 2006). According to Litan *et al.* (2008), it operates as an independent entity with full decision-making power. Non-autonomous UTTOs usually report to the office of the provost or vice rector for research and therefore have limited decision-making power (Schoen *et al.*, 2014). Markman *et al.* (2005) interviewed 128 UTTO managers, and on that basis recognised three structures of UTTOs with different levels of configurational autonomy. Those structures are the traditional UTTO (non-autonomous), the non-profit foundation (autonomous) and the for-profit venture (autonomous). Young (2007) argued that successful technology transfer can be achieved by having a traditional UTTO as a filtration funnel for invention disclosures where promising inventions are then handled by a for-profit UTTO. Markman *et al.* (2005) elaborated further that non-profit UTTOs can be part of a research foundation that is affiliated to the university but has independent decision-making power. They concluded that traditional, non-autonomous UTTOs tend to license for sponsored research while for-profit UTTOs tend to license for equity. The effects of configurational autonomy, as measured by the level of administrative reporting in the organisational hierarchy, on university technology transfer performance are examined by testing the following hypotheses.

**Hypothesis 3: There is a statistically significant association between the level of UTTO configurational autonomy and different performance indicators including the number or amount of: H3a invention disclosures; H3b filed patents; H3c executed licenses; H3d licensing royalty income; H3e all spin-offs created; and H3f spin-offs created with university equity.**

### 4.3.4 Financial Dependence/ Independence

Financial dependence is defined according to the financial ability of the UTTO to cover its operational expenses. According to Fisher and Atkinson-Grosjean (2002), financially independent UTTOs act as for-profit or non-profit corporations which operate as a separate entity from the administrative hierarchy of the university. On the other hand, financially-dependent UTTOs are imbedded in the university's administrative hierarchy. It can be argued that financially independent UTTOs are more motivated and hence perform better than financially-dependent UTTOs. To my knowledge, previous studies have not examined the effects of financial dependence on university technology transfer performance; therefore, the following hypotheses were formulated.

**Hypothesis 4: There is a statistically significant association between UTTO financial dependence and different performance indicators including the number or amount of: H4a invention disclosures; H4b filed patents; H4c executed licenses; H4d licensing royalty income; H4e all spin-offs created; and H4f spin-offs created with university equity.**

## 4.4 Methodology

Correlation and linear regression analysis are used to examine the association between UTTO organisational structure and different measures of university technology transfer performance.

University technology transfer performance data were obtained from the National Survey of Research Commercialisation (NSRC) conducted annually by the Australian Department of Industry, Innovation and Science. Performance data are available for 39 Australian universities recorded for the years 2000 to 2014. The average university technology transfer performance data for the recorded period were used. UTTO's organisational structure data were obtained by conducting structured telephone interviews with UTTO representatives from universities that responded to the NSRC. Interviews were conducted in October and

November of 2016, and representatives from 25 Australian universities participated. Regression analysis variables, their abbreviations and their sources are summarised in Table 4.1.

| Variable Names | Variable Types | Source | Year |
|---|---|---|---|
| Number of Invention Disclosures (INVDIS) | Continuous | NSRC | 2000-14 |
| Number of Filled Patents (FILPAT) | Continuous | NSRC | 2000-13 |
| Number of Executed Licenses (EXCLIC) | Continuous | NSRC | 2000-14 |
| Licensing Royalty Income (LICINC) | Continuous | NSRC | 2000-14 |
| Number of All Spin-offs Created (SPICRE) | Continuous | NSRC | 2000-14 |
| Number of Spin-offs Created with University Equity (SPIEQU) | Continuous | NSRC | 2000-14 |
| Decentralisation (DECENT) | Binary (Centralised=0; Decentralised=1) | Interview | 2016 |
| Specialisation (SPEC) | Categorical (Integrated=0; Semi-Specialised=0.5; Fully-Specialised=1) | Interview | 2016 |
| Autonomy (AUTO) | Categorical (Director-level=1; Deputy Vice Chancellor-Level=2; Board-Level=3) | Interview | 2016 |
| Financial Independence (FININD) | Binary (Dependent=0; Independent=1) | Interview | 2016 |

**Table 4.1:** Dependent and independent variables for regression analysis.

## 4.5 Empirical Findings

Descriptive and correlation statistics are presented in Table 4.2. For the recorded performance period (as shown in Table 3.1), the average number of inventions disclosed was 32.95 per annum and the average number of patents filled was 18.68/year. UTTOs had executed an average of 9.35 licenses per annum and received an average licensing royalty income of AUD$1.89 million/year. In addition, UTTOs had created an average of 5.21 spin-offs companies and 4.57 spin-offs companies with university equity holdings.

| | Minimum | Maximum | Mean | Standard Deviation |
|---|---|---|---|---|
| (1) INVDIS | 0 | 198.29 | 32.95 | 40.18 |
| (2) FILPAT | 0 | 87.77 | 18.68 | 25.25 |
| (3) EXCLIC | 0 | 41.47 | 9.35 | 12.55 |
| (4) LICINC | 0 | 23.97 | 1.89 | 4.91 |
| (5) SPICRE | 0 | 32.5 | 5.21 | 6.88 |
| (6) SPIEQU | 0 | 32.46 | 4.57 | 6.58 |
| (7) DECENT | 0 | 1 | .16 | .37 |
| (8) SPEC | 0 | 1 | .48 | .42 |
| (9) AUTO | 1 | 3 | 1.92 | .7 |

| | | | | |
|---|---|---|---|---|
| (10) FININD | 0 | 1 | .08 | .28 |

**Correlation Coefficients**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) INVDIS | 1 | | | | | | | | | |
| (2) FILPAT | .856** | 1 | | | | | | | | |
| (3) EXCLIC | .787** | .928** | 1 | | | | | | | |
| (4) LICINC | .884** | .723** | .608** | 1 | | | | | | |
| (5) SPICRE | .914** | .816** | .767** | .878** | 1 | | | | | |
| (6) SPIEQU | .910** | .742** | .681** | .905** | .987** | 1 | | | | |
| (7) DECENT | **.712**** | **.766**** | **.791**** | .487* | **.592**** | **.526**** | 1 | | | |
| (8) SPEC | .172 | .121 | .010 | .092 | .207 | .205 | .021 | 1 | | |
| (9) AUTO | **.518**** | .483* | .471* | .375 | .491* | .467* | .209 | .418* | 1 | |
| (10) FININD | **.578**** | .331 | .328 | **.639**** | **.567**** | **.615**** | .273 | .193 | .463* | 1 |

**Table 4.2:** Descriptive statistics and correlation coefficients for dependent and independent variables.

*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.

Regression analysis was performed for the six performance variables (INVDIS, FILPAT, EXCLIC, LICINC, SPICRE and SPIEQU) and four independent variables (DECENT, SPEC, AUTO and FININD). Results of the regression analyses are summarised in Table 4.3. Variance inflation factors (VIFs) were estimated to check for multicollinearity and VIFs were substantially below the problematic level of 10 (Von Eye and Schuster, 1998). Also, *adjusted* R-square values were relatively close to the actual R-square values which indicate that the regression model is not overfit (Leinweber, 2007).

| | **INVDIS** | **FILPAT** | **EXCLIC** | **LICINC** | **SPICRE** | **SPIEQU** |
|---|---|---|---|---|---|---|
| ***Constant*** | -8.863<br>(14.835) | -12.615<br>(6.649) | -5.762<br>(4.382) | -.432<br>(2.366) | -1.358<br>(3.115) | -.754<br>(3.078) |
| **DECENT** | 61.722***<br>(13.370) | 46.979***<br>(8.696) | 24.044***<br>(3.949) | 4.301*<br>(2.133) | 8.341***<br>(2.807) | 6.563**<br>(2.774) |
| **SPEC** | -.804<br>(12.541) | -2.55<br>(8.157) | -5.024<br>(3.704) | -.612<br>(2) | .632<br>(2.633) | .652<br>(2.602) |
| **AUTO** | 15.018*<br>(8.341) | 13.098**<br>(5.425) | 7.161***<br>(2.464) | .618<br>(1.33) | 2.223<br>(1.751) | 1.642<br>(1.731) |
| **FININD** | 43.627**<br>(19.875) | -1.835<br>(12.927) | -.954<br>(5.871) | 9.211***<br>(3.17) | 8.227*<br>(4.173) | 10.074**<br>(4.124) |
| **Sample Size** | 25 | 25 | 25 | 25 | 25 | 25 |
| **R-Square** | .717*** | .697*** | .747*** | .520*** | .576*** | .547*** |
| ***Adjusted* R-Square** | .661 | .637 | .697 | .423 | .491 | .456 |

**Table 4.3:** Regression analysis results (standard errors in parentheses underneath estimated regression coefficients).

*. Statistically significant at the 0.1 level or better. **. Statistically significant at the 0.05 level or better. ***. Statistically significant at the 0.01 level or better.

All resource factors had varied effects on technology transfer performance indicators of universities with DECENT as the most significant resource factor across all of the performance indicators. FININD was found to be positively associated with better university technology transfer performance in relation to the number or the amount of INVDIS, LICINC, SPICRE and SPIEQU. Also, high level of AUTO was positively associated with three numerical technology transfer performance measures, INVDIS, FILPAT and EXCLIC. On the other hand, an association was not confirmed for SPEC with any of the performance measures.

## 4.6 Discussion

This study aimed to investigate the impact of four organisational structural resource factors of UTTOs on six university technology transfer performance measures. The hypothesised relationships and the results of the empirical tests are presented in Table 4.4.

| | **A Invention Disclosures** | **B Filed Patents** | **C Executed Licenses** | **D Royalty Income** | **E All Spin-offs Created** | **F Spin-offs Created with University Equity** |
|---|---|---|---|---|---|---|
| **Hypotheses set 1: Decentralisation** | **Confirmed** (+) | **Confirmed** (+) | **Confirmed** (+) | **Confirmed** (+) | **Confirmed** (+) | **Confirmed** (+) |
| **Hypotheses set 2: Specialisation** | Rejected | Rejected | Rejected | Rejected | Rejected | Rejected |
| **Hypotheses set 3: Autonomy** | **Confirmed** (+) | **Confirmed** (+) | **Confirmed** (+) | Rejected | Rejected | Rejected |
| **Hypotheses set 4: Financial Independence** | **Confirmed** (+) | Rejected | Rejected | **Confirmed** (+) | **Confirmed** (+) | **Confirmed** (+) |

**Table 4.4:** Summary of hypotheses testing results. Positive and negative signs in parentheses represent the nature of the association.

The first set of hypotheses was confirmed for all six measures of university technology transfer performance. These results indicated that decentralised UTTOs tended to receive more invention disclosures, file more patents, execute more licenses, receive more licensing royalty income and establish more spin-offs with or with university equity than centralised UTTOs. This is in line with the finding of Debackere and Veugelers (2005) who found that decentralised UTTOs operate close to research groups that enabled the university to overcome conflicts between the traditional and the entrepreneurial roles. this finding also support Litan *et al.* (2008) conjecture that decentralised UTTOs are more than just gatekeepers and that they have actually performed better than centralised UTTOs. Moreover, this finding agrees with the conclusion of Litan *et al.* (2008) that decentralised UTTOs find “synergies” between faculties and therefore receive more invention disclosures. In contrast, this finding disagree with the finding of Carlsson *et al.* (2008) that centralised UTTOs build better patent expertise and therefore they only choose commercially viable inventions to patent and eventually file more patents.

Therefore, based on this finding, it can be argued that the degree of UTTO centralisation can partly explain differences between universities in technology transfer performance, with decentralisation appearing to be advantageous. Hence, the level of UTTO centralisation is a differential resource factor for universities performance in technology transfer.

In relation to the second set of hypotheses, specialisation was not confirmed as a performance determinant for all six performance measures. In contrast with Hülsbeck *et al.* (2013), this finding does not confirm that highly specialised UTTOs receive more invention disclosures than integrated UTTOs. This finding does not support the conjecture of Debackere and Veugelers (2005) that highly Specialised UTTOs perform better than integrated UTTOs. This finding is in agreement with Caldera and Debande (2010) who found no relationship between UTTO Specialisation and technology transfer performance. Hence, the level of UTTO specialisation is not a good predictor of overall performance differences between universities in technology transfer and therefore has limited benefit as an organisational structural resource factor.

The third set of hypotheses was confirmed in three of the six measures of university technology transfer performance. Highly autonomous UTTOs received more invention disclosures, filed more patents and executed more licenses than non-autonomous UTTOs. This finding may indicate that autonomous UTTOs have a higher patenting budget than non-autonomous UTTOs which allow them to file more patents and eventually executed more licenses. However, a positive association was not confirmed for the level of UTTO's autonomy and the amount of licensing royalty income. Therefore, this finding does not support Markman *et al.* (2005) finding that non-autonomous UTTOs tend to license for sponsored research while for-profit UTTOs tend to license for equity. Hence, the level of UTTO configurational autonomy has a relatively strong explanatory power for performance differences between universities in technology transfer.

In relation to the fourth set of hypotheses, financial independence was found as a critical performance determinant in relation to four of the six performance measures. This finding indicates that financially dependent UTTOs file more patents and execute more licenses than financially independent UTTOs. On the other hand, financially independent UTTOs receive more invention disclosures, generate more licensing royalty income, and establish more spin-offs with or without university equity than financially dependent UTTOs. Additionally and more interestingly, this finding shows that financially independent UTTOs commercialise university research better than financially dependent UTTOs in relations to their financial performance. Parallel with Markman *et al.* (2005) finding, this could be due to the fact that financially dependent UTTOs tend to license technologies for sponsored research and they are less motivated to earn more commercialisation income. On the other hand, financially independent UTTOs are less motivated to increase the numbers of filed patents and executed licenses but rather focus their efforts on improving commercialisation matrices related to licensing income and creating more spin-offs. To remain viable, financially independent UTTOs are less interested in the quantity of potential technologies that they take on board (reflected in patent filing and licensing agreement numbers), but rather more interested in the financial quality of potential technologies that could successfully be commercialised to generate income. Hence, financial independence seems to be a critical indicator that explains differences between universities' technology transfer performance.

To sum up, of all tested organisational structure dimensions, task and discipline specialisation has the least impact on UTTO performance, in line with prior research by Caldera and Debande (2010). In contrast, decentralised organisational structures are associated with better technology transfer performance. In fact, the level of centralisation was tested as a binary variable which did not make provision for hybrid models, where for example, management is centralised and commercialisations teams are decentralised. Such hybrid models are expected to perform better than either purely centralised or decentralised organisational structures as confirmed in previous empirical studies (Carlsson *et al*, 2008; Huyghe *et al*., 2014).

UTTOs with autonomous organisational structures have advantages over other UTTOs in exhibiting significantly higher numbers of invention disclosures, and to a greater extent, higher numbers of patent filings and commercialisation licences. Nonetheless, autonomy as a structural dimension does not impact financial performance as measured by licencing income and the number of commercial spin-offs created. Most striking is the highly significant findings of differential impacts that financial independence has on the various UTTO performance measures. Financial dependency is a neglected structural dimension in the empirical literature and this study therefore contributes to the literature on UTTO performance in providing clarity of its impact on performance at a granular level. It is clear from the results that financially independent UTTOs emphasis the creation of spin-offs and increased licencing income as their main technology commercialisation focus with less emphasis on increasing the number of licencing agreements and filed patents. This does not imply that non-financial performance indicators are not important, but rather that financially independent UTTOs are less interested in the quantity of technology commercialisation opportunities and more interested in the financial quality of technology commercialisation opportunities which have the potential to become viable spin-offs or that would ensure monetary licensing returns.

## 4.7 Conclusions

The literature on university technology transfer is abundant; however, previous studies have not comprehensively established what the nature is of the relationships between different UTTO organisational structures and various indicators of performance. In this study, the RBT was adopted to analyse performance differences between universities in technology transfer considering four resource factors in relation to the organisational structure of UTTOs. These resource factors were centralisation, specialisation, configurational autonomy and financial dependence.

Empirical findings of this study show that decentralised UTTOs are superior to centralised UTTOs by all technology transfer performance measures. In relation to specialisation, a positive association was not confirmed for any of the studied technology transfer performance measures. It was also found that highly autonomous UTTOs receive more invention disclosures, file more patents and execute more licenses than non-autonomous UTTOs. Interestingly, it was also found that financially independent UTTOs file fewer patents, execute fewer licenses but receive more licencing royalty income and create more spin-offs with or without university equity than financially dependent UTTOs. Consistent with the Hawthorne effect studies (Gillespie, 1991), there is an issue with the independent use of numerical university technology transfer performance measures such as the numbers of invention disclosures, filed patents and executed licenses, in that highly non-autonomous UTTOs will eventually try to artificially inflate numbers in order to convince their superiors of their performance. Hence, they increase the quantity of invention disclosures, filled patents and executed licenses but fail to actually commercialise university research. Therefore, the use of the numbers of invention disclosures, filled patents or executed licenses independently as performance measures could lead to misleading conclusions.

Universities' ability to effectively configure the organisational structures of their UTTOs is indeed a valuable resource in ensuring comparatively higher technology commercialisation performance. It is advisable for universities to adopt autonomous UTTO structures since it would enhance the number of patent filings and licencing agreements whereas maintaining the UTTOs as decentralised and financially independent cost centres would ensure financial sustainability.

This study has three limitations. The first limitation is that interviews were conducted in 2016 to gather information about the organisational structure of UTTOs while performance data were obtained for a different period. To overcome this limitation, the study utilised average performance data for a 15 year period. Additionally, participant UTTOs were asked if their organisational structure was stable for the last 15 years and 92% of participant UTTOs indicated not being through a major organisational restructuring. The second limitation is that this study has a small sample size of 25 UTTOs. However, the sample was representative of Australian universities and accounted for 80% of invention disclosures, 85% of filled patents, 79% of executed licenses, 82% of licensing royalty income, 84% of spin-offs created and 83% of spin-offs created with university equity. The last limitation is that this study considered Australian universities and therefore generalisability of the research findings to other types of research institute or to other countries may be limited.

Future studies could investigate other organisational factors of UTTOs in order to explain performance differences between universities in technology transfer. This could include UTTO success measurement and employee satisfaction, as measured by employee turnover rate. Additionally, this study could be extended to other countries to investigate differences in relation to UTTOs organisational structure. This could yield valuable information in the case of USA since most universities have traditional UTTOs which are usually non-autonomous and financially-dependent.

# Chapter Five: Conclusions

This chapter briefly highlights the main theoretical and practical contributions of this thesis, future implications of this thesis, limitations of this thesis and recommendations for future research.

## 5.1 Main Theoretical and Practical Contributions of this Thesis

In the first study of thesis, an inductive, mixed-methods approach was adopted to evaluate the relative efficiency of Australian UTTOs, and then identify antecedents of efficient university technology transfer in Australia. Technical efficiency was evaluated and then universities were ranked according to their average technical efficiency score. Taking into account differences between universities in technology transfer efficiency, antecedents were established. This thesis made a contribution to the practice of university technology transfer in Australia and how it could be improved.

In the second study of this thesis, the RBT was adopted to examine and explain performance differences between universities in technology transfer considering three resource factors, namely the number of ARC Linkage funded projects (financial), the number of UTTO staff holding a PhD (human capital) and the joining of a UTTO to a consortium (organisational). This thesis made a theoretical contribution to the field of university technology transfer which advances the progress of the field towards being a scientific paradigm.

In the third study of this thesis, the RBT was adopted to analyse performance differences between universities in technology transfer considering four resource factors specifically in relation to the organisational structure of UTTOs. These resource factors were centralisation, specialisation, configurational autonomy and financial dependence. Organisational structure of UTTOs is neglected in the literature and this thesis therefore contributes to the literature on UTTO performance by providing clarity of its impact on performance at a granular level.

## 5.2 Future Implications of this Thesis

This thesis has the following implications for policy makers and university management. Firstly, the Australian government should invest more resources into university technology transfer and these resources should be addressed in universities' long term strategic plan for research commercialisation. Policy makers and university management should acknowledge the complexity of research commercialisation and maintain the stability of initiatives. The UK government has advanced over the last two decades in encouraging university technology transfer. Similarly, the Australian government would be well advised to expand its ICTIP scheme to other technologies and to foster linkages between government-funded commercialisation support structures and universities. Additionally, the Australian government represented by ARC should take attention of advantages and disadvantages of current performance measurement metrics revealed by the 25 UTTOs professionals interviewed in Study One of this thesis. Table 5.1 presents the main advantages and disadvantages of currently used performance metrics for Australian UTTOs.

| Advantages | Disadvantages |
|---|---|
| Convenient | Impact is measured as a quantity rather than a quality |
| Internationally comparable | Non-financial impact is not considered |
| Diverse set of metrics | Time-lag between research and impact is not considered |
| | Social impact is not considered |
| | Non-STEM research impact is not considered |
| | Government engagement is not considered |
| | Fails to recognise the difference between UTTOs performance measurement and industrial partner (licensee) performance |
| | Successful case studies are not included |

**Table 5.1:** The main advantages and disadvantages of currently used performance metrics for Australian UTTOs.

Secondly, it is advisable for universities to attract commercially-aware researchers to secure a higher number of ARC Linkage funded projects in order to ensure superiority in university technology transfer performance. Also, UTTOs are advised to join a consortium and to employ more PhD-holding staff. The former will enhance the entrepreneurial activities of the university, whereas the latter will encourage the development of a legitimate relationship between university academics and the UTTO.

Thirdly, universities' ability to effectively configure the organisational structures of their UTTOs is indeed a valuable resource factor in ensuring comparatively higher technology commercialisation performance. It is advisable for universities to adopt autonomous UTTO structures since it would increase the number of patent filings and licencing agreements, moreover, maintaining the UTTOs as decentralised and financially independent cost centres would ensure financial sustainability.

## 5.3 Limitations of this Thesis

This thesis has three limitations. The first limitation is that this study has a small sample size of 25 UTTOs. However, the sample was representative of Australian universities and accounted for 80% of invention disclosures, 85% of filled patents, 79% of executed licenses, 82% of licensing royalty income, 84% of spin-offs created and 83% of spin-offs created with university equity. The second limitation is that interviews were conducted in 2016 while performance data were obtained for a different period. To overcome this limitation, the study utilised average performance data for a 15 year period. The last limitation is that this study considered Australian universities and therefore the generalisability of the research findings to other types of research institute or to other countries may be limited.

## 5.4 Recommendations for Future Research

The first study of thesis recommended the following ten propositions for future studies.

> ***Proposition 1: Efficient universities in technology transfer are more likely to include research commercialisation in their mission statement.***

> ***Proposition 2: Efficient universities in technology transfer are more likely to provide internal research commercialisation funding as part of their UTTO's budget.***

> ***Proposition 3: Efficient universities in technology transfer are more likely to provide internal research commercialisation funding for multi-purpose commercialisation activities including prototype and business development.***

> ***Proposition 4: Efficient universities in technology transfer are more likely to have unique UTTO's capabilities.***

> ***Proposition 5: Efficient universities in technology transfer are more likely to have well-established UTTO's reputation.***

> ***Proposition 6: Efficient universities in technology transfer are more likely to have strong senior management support.***

> ***Proposition 7: Efficient universities in technology transfer are more likely to have access to more resources.***

***Proposition 8: Efficient universities in technology transfer are more likely to have commercially-aware academics.***

***Proposition 9: Efficient universities in technology transfer are more likely to have low bureaucratic orientation of technology transfer procedures.***

***Proposition 10: Efficient universities in technology transfer are more likely to provide high incentives for research commercialisation.***

Study two of this thesis adopted the RBT to test propositions 7 and 8. Study three of this thesis adopted the RBT to test propositions 7 and 9. However, future studies could further investigate the previous propositions of this thesis.

Future studies could investigate additional resource factors of UTTOs that could contribute to performance differences between universities in technology transfer. It would be particularly interesting for future studies to examine whether technology transfer is a dynamic capability that grants some universities a competitive advantage over others.

Future studies could investigate other organisational factors of UTTOs that could explain performance differences between universities in technology transfer. This could include UTTO success measurement and employee satisfaction, as measured by employee turnover rate.

Additionally, this thesis could be extended to other countries to investigate whether antecedents of efficient university research commercialisation are country-specific or not. This could yield particularly valuable information in the case of UK since the government has been active in supporting university technology transfer. This thesis could be also extended to other countries to investigate performance differences in relation to the three resource factors of study two. This could yield valuable information in the case of the UK, since the government is active in supporting collaboration between universities and industry, and most UTTOs in the UK are consortium members. Also, this thesis could be extended to other countries to investigate differences in relation to UTTOs organisational structure. This could yield valuable information in the case of USA since most universities have traditional UTTOs which are usually non-autonomous and financially-dependent.

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# Appendices

## Appendix 1: Interview Invitation Cover Letter

Email Title: Invitation to participate in a study in relation to university research commercialisation performance at Australian universities

Dear *Title*. *Participant name*,

My name is Rashed Alhomayden and I am a Doctor of Biotechnology candidate at the University of Queensland. My thesis is titled "University Technology Transfer Performance in Australia". The main outcome of the thesis is to identify resource factors of university technology transfer and to make recommendations on how these could be utilised for the purpose of enhancing university research commercialisation performance in Australia.

- I would like to conduct a telephone interview not exceeding twenty minutes with you or your nominee.
- I would like to record the interview.
- I will call you or your assistant to ascertain your availability.
- I will provide you with feedback if you wish.
- A script of the interview questions is attached.

I have attached a participant information sheet that describes the project and the steps that will be taken to ensure anonymity and data protection. Please read this sheet carefully and be confident that you understand its contents before deciding whether to participate. If you have any questions about the project, please contact the research investigator or the research project supervisor. Also, I have attached a participant consent form to be signed if you wish to participate in the study.

Thank you very much for your assistance and your time is highly appreciated.

Kind regards,

Rashed Alhomayden

Doctor of Biotechnology Candidate, School of Chemistry and Molecular Biosciences, the University of Queensland.

## Appendix 2: Interview Questions Script

| Topic/Theme | Closed-Ended Questions | Open-Ended Question |
|---|---|---|
| **General Background** | *Background about Interviewee:*<br>1. How long is your commercialisation experience?<br>*Background about university:*<br>2. Does your university have a medical school?<br>3. Cross-validate inventor royalty income share. | 4. Is commercialising research outcomes part of your university's mission and Why? |
| **Commercialisation Office** | *Background about the commercialisation office:*<br>1. When was your commercialisation office established?<br>2. How many staff does your office employ? What are their qualifications and commercialisation experience?<br>3. How many staff have left your office in the last financial year (i.e., turnover rate)? | 4. How essential is the commercialisation office for your university?<br>5. Is your office supported by senior university's administration? |
| | *Background about the structural dimensions of the commercialisation office:*<br><br>1. How does your office operate in relation to centralisation, i.e. how many offices does the university have to provide services to academics? (A. Highly centralized; C. Highly decentralized)<br>2. Is your office embedded into the administrative hierarchy of the university or does it act as an external structure, i.e. does the office operate as an internal department, an external corporation or both? (A. Highly internal; B. Both; C. Highly external)<br>3. If your office is internal, does it operate with full autonomy?<br>4. To whom does your office report?<br>5. What types of tasks are conducted at your office, i.e. how many of the following services does your office provide; IP management, consultancy and research contracts management, spin-offs management? (A. IP management only; B. IP, consultancy and research contracts management; C. IP and spin-offs management; D. All tasks/services)<br>6. How tasks are managed in relation to discipline, i.e. does your office classify tasks according to their discipline? (A. 1-2 scientific fields; B. +3 scientific fields)<br>7. How frequent does your office go through re-structuring? Was the office restructured over the past 15 years?<br>8. Are your office's services exclusive to the university?<br>9. Is your office dependent financially on the university?<br>10. Is your office part of a consortia or a network? | 10. How does your office make decisions regarding the following procedures? Is the process formal or rational?<br>• Determination and application of market factors<br>• Commercialization processes<br>• Measuring success<br>11. How does your office balance between the academic and the commercial needs?<br>12. Does the current structure of your office fulfil the commercialisation needs of the university? |
| **Commercialisation Funding** | 1. Is there any available funding for commercialisation at your university?<br>2. At what stage is the funding offered?<br>3. What is the cumulative value of that funding?<br>4. How many participants receive the funding? | 5. Does the current funding achieve the needs of your academics?<br>6. Is there any planned improvements?<br>7. How does the commercialisation office tackle this issue? |
| **Incubators and Technology Parks** | 1. Is your university affiliated to any incubators or technology parks?<br>2. If yes, how many incubators and/or science parks are affiliated to your university? | 3. How important are incubators and technology parks for research commercialisation? |
| **General Feedback** | | 1. What are the strengths and the weaknesses of |

| | | |
|---|---|---|
| | | the current commercialisation system at your university?<br>2. How could the current system be improved?<br>3. What would be the right metrics to measure impact? |

# Appendix 3: Detailed Review of Initiatives to Enhance University-Industry Interactions in Australia

Prior to starting this review, it is important to note that the rationale behind governmental actions might not be directly related to university research commercialisation. However, it is acknowledged that enhancing Business Expenditure on R&D (BERD) will result in more R&D activities being outsourced (Schuelke-Leech, 2013), and the main R&D organisations in Australia are universities and other higher research institutes (Collier, 2007). Therefore, university research commercialisation strategies such as research contracts, cooperative R&D projects, and consultancy contracts will be directly promoted, whereas other university research commercialisation strategies will be indirectly enhanced (Chapple *et al.*, 2005; Powers & McDougall, 2005).

***<u>Initiatives by the Commonwealth Government</u>***

This section highlights Commonwealth governmental initiatives to enhance the Australian innovative capacity. Most of these initiatives have been made as responses to reports such as the Australian Science, Technology and Engineering Council (ASTEC) report titled as "The Core Capacity of Australian Science and Technology" in 1989 (Ferris, 2001), the Block Report entitled as "Bringing the Market to Bear on Research" in 1991 (Allen Consulting Group, 2003a), the Commonwealth Chief Scientist report titled as "The Chance to Change" in 2000 (Batterham, 2000), the Allen Consulting Group report titled as "The Economic Impact of the Commercialisation of Publicly Funded Research and Development in Australia" in 2003 (Allen Consulting Group, 2003a), and the Allen Consulting Group report titled as "Building Effective Systems for the Commercialisation of University Research" in 2004 (Allen Consulting Group, 2004). As a result of these reviews, many governmental initiatives have been introduced and they are reviewed in this section.

- *Management and Investment Companies (MICs) Scheme*

The scheme was introduced in 1983 to provide financial support to a small number of MICs through means of tax concession in exchange of providing venture capital support for early stage technology-based companies (Allen Consulting Group, 2003a).

- *Grants for Industrial Research and Development (GIRD) Scheme*

This scheme aims to help businesses to conduct R&D projects by providing financial grants (Harman & Harman, 2004).

- *Cooperative Research Centres (CRCs) Programme*.

This programme was established in 1990 to provide a linkage between industry and researchers in means of competitive grants in addition to providing industry-sponsored education for university graduates (Collier, 2007).

- *Australian Technology Group (ATG)*

The ATG was launched in 1992 and it operates as a company that is fully owned by the Commonwealth government which aims to support early stage capital venture (Allen Consulting Group, 2003a).

- *Pooled Development Funds (PDFs) Act*

The PDFs act was introduced in 1992 to provide tax relief for registered investment companies in order to encourage long-term investment that is mainly targeting SMEs. The PDFs act was amended in 1994, 1998 and 1999 in hopes to make it more attractive for investment companies (Ferris, 2001).

- *AusIndustry*

This initiative was established in 1997 as the business unit for the Commonwealth government (Science and Innovation Mapping Taskforce, 2003).

- *125 percent R&D Taxation Concession Scheme*

This scheme was introduced in 1997 as a replacement for the *120 percent R&D Taxation Concession Scheme* and it aims to encourages businesses to conduct R&D activities by deducting 125% of R&D expenses from corporate tax returns. In other words, R&D expenses of 1 dollar will result in a tax relief of 1.25 dollars (Harman & Harman, 2004).

- *R&D Start Programme*

This programme was launched in 1997 to encourage businesses, especially SMEs, to undertake R&D activities by providing financial grants (Science and Innovation Mapping Taskforce, 2003).

- *Biotechnology Innovation Fund (BIF) Scheme*, This scheme was introduced in 2001 to enhance innovation in biotechnology businesses especially SMEs (Department of the Prime Minister and Cabinet, 2007).

- *Commercialisation of Emerging Technologies (COMET) Scheme*

This scheme was launched in 2001 to help high-tech businesses, especially SEMs, to become more innovative (Department of the Prime Minister and Cabinet, 2007).

***<u>Initiatives by State and Territory Governments</u>***

This section is a review of governmental initiatives of Australian states and territories with a focus on university research commercialisation. The state governments of Queensland and Victoria have been acknowledged for the introduction of direct support initiatives to enhance university research commercialisation (Harman & Harman, 2004).

- **Australian Capital Territory (ACT)**

The ACT government announced its "Innovation Framework" in 2001 and it introduced *Small Business Growth Programme* and *Business R&D Grants Scheme* (Allen Consulting Group, 2003b). These governmental initiatives were directed towards making businesses more innovative. Other governmental initiatives included the establishment of Canberra Biotechnology Business Accelerator and Epicorp Incubator.

- **New South Wales (NSW)**

NSW Innovation Council was established in 1996 by a Parliament act. In 1999, a report titled as "Growth through innovation-A Strategy for NSW" has proposed an innovation strategy for NSW (Allen Consulting Group, 2003b). In 2001, the NSW government launched its "BioFirst Strategy" and it introduced multiple initiatives (Science and Innovation Mapping Taskforce, 2003). The first initiative was *BioPlatform* and it aims to invest in research base. The second initiative is *BioBusiness* and it funds SMEs and commercialisation of research. The third initiative is *BioUnit* which is a coordination unit for biotechnology-related initiatives such as *BioEthics*. The fourth initiative is *BioHub* and it acts as a cluster of the *triple-helix* stakeholders. The final initiative is the *BioFirst Awards Programme* which includes *BioFirst Commercialisation Awards*.

- **Northern Territory (NT)**

The NT government announced its innovation strategy in 2002 which was titled as "Building a Better Territory: The Economic Development Strategy for the Northern Territory" (Allen Consulting Group, 2003b). However, the strategy was not directed to support business R&D or university research commercialisation.

- **Queensland (QLD)**

In 1999, the QLD government released its "Bioindustries Strategy" which was mainly supporting biotechnology R&D (Allen Consulting Group, 2003b). One initiative of this strategy was *BioStart* which provides proof of concept funding to SMEs.

The QLD government announced its "Smart State" strategy in 2000 which was followed by another strategy entitled as "Growing the Smart State" in 2002 (Harman & Harman, 2004). As a result of these strategies, the QLD government established the Australian Institute for Commercialisation (AIC) in 2002, which aims to enhance research commercialisation in Australia. Also, a *Smart State Facilities Fund* was introduced to support R&D infrastructure at QLD universities and research centres, along with a *Biodiscovery Fund*. Another initiative of the QLD government was *BioCapital Fund*, which provides venture capital funding for biotechnology firms. The QLD government supported early stage companies by its *Innovation Start Up Scheme*.

- **South Australia (SA)**

The SA government established *Playford Capital* in 1997 in order to provide venture capital funding for early stage ICT companies (Allen Consulting Group, 2003b). In 2001, the SA government established *Bio Innovation SA*, which is an incorporated body for biotechnology matters in SA (Allen Consulting Group, 2003a). Bio Innovation SA provided many initiatives targeting innovation and research commercialisation. One initiative was *Adelaide Integrated Biosciences (AIB) Laboratories Infrastructure Fund* which aims to establish shared laboratories for bioscience researchers. Another initiative was *BioCatalyst Programme* which aims to provide grants to start-up companies. Also, Bio Innovation SA introduced a *Pre-seed Fund*, an *IP Fund* to help with patent applications expenses, and a *Biotechnology Fellowship Fund* to attract well recognised researchers and scientists. A *Business Development* initiative was launched to help SMEs in preparing applications for COMET funding. In 2003, the SA government launched a *Venture Capital Fund* (Allen Consulting Group, 2003b).

- **Tasmania (TAS)**

In 1999, the TAS government established the Tasmanian Innovations Advisory Board in order to provide support for the government in relation to innovation policies and their implementation (Allen Consulting Group, 2003b). By 2001, the Tasmanian government launched its *Science and Technology Policy* backed with the *Tasmanian Innovations Programme* which provides direct support for research commercialisation, and the *Technology Industry Development Programme* which provides support for early stage companies (Allen Consulting Group, 2003b). Also, the Tasmanian government in partnership with the Commonwealth government introduced the *Intelligent Island Programme*, with initiatives such as the establishment of *In-tellinc* technology incubator and the launching of the *Investment Attraction* strategy (Allen Consulting Group, 2003b).

- **Victoria (VIC)**

In 2002, The Victorian government released a statement titled as "Victorians. Bright Ideas. Brilliant Future", accompanied with a 5 year *Science, Technology and Innovation (STI) Initiative* (Science and Innovation Mapping Taskforce, 2003). At the same year, the Victorian government established an Innovation Economy Advisory Board to provide guidance in relation to innovation policy (Allen Consulting Group, 2003b). One government initiative was the introduction of the *Technology Commercialisation Programme* (TCP), which aims to provide financial support for research commercialisation purposes. This programme was replaced with *Building Innovative Businesses* strategy as part of the second 5 year STI initiative (Allen Consulting Group, 2003b). Also, the Victorian government launched a "Biotechnology Strategic Development Plan", which led to co-investment with the University of Melbourne to establish the *Bio21* project. This project was a regional cluster for biomedical research (Allen Consulting Group, 2003b).

- **Western Australia (WA)**

The WA government introduced "Innovate WA" statement in 2001 which aims to enhance regional economic development and to support commercialisation of ideas (Allen Consulting Group, 2003b). The statement included initiatives such as the *Business Innovation Development Scheme* which provides support in early stages of commercialisation. Another government initiative was the *TRACKFAST Programme* which gives companies the opportunity to trial their technologies in Government agencies.

***Initiatives by Universities***

Many universities have introduced initiatives in order to enhance university research commercialisation and they include:

- *Uniseed*

Uniseed is a venture capital firm which has been established in 2000 by a joint investment between the University of Queensland and the University of Melbourne. The University of New South Wales has joined Uniseed in 2005 followed by the CSIRO, and the University of Sydney in 2015. Uniseed provides pre-seed funding to member universities only (Uniseed, 2016).

- *Trans Tasman Commercialisation Fund*

This initiative was established in cooperation between the University of Adelaide, Monash University, Flinders University, the University of South Australia and the University of Auckland to provide pre-seed funding to member universities (Mills, 2008).

- *Australian Technology Park Innovation (ATPi)*

This establishment was introduced in 2000 by a cooperation between the University of Sydney, the University of New South Wales, the University of Technology Sydney, and the Australian National University to provide space and support for university spin-offs (ATPi, 2016).

Other university initiatives have been carried out by individual universities in order to facilitate the process of university research commercialisation and they include:

- *IP Development Fund*

This initiative was introduced by Macquarie University to provide funding for researchers to conduct proof-of-concept projects (Macquarie University, 2016).

- *Invention Commercialisation Seed Fund*

This initiative was launched by the University of Technology Sydney to enhance research commercialisation by providing proof-of-concept funding (University of Technology Sydney, 2016).

## Appendix 4: Licensing Royalty Distribution Formulae of Australian Universities

Licensing royalty distribution formulae of Australian universities are presented in the following table as obtained from IP Policy of each university.

| ***University (Clause Number)*** | ***Royalty Distribution*** |
|---|---|
| Australian Catholic University (4.7) | **≤$25,000:** 70% to the Creators; 10% to the Faculty; 20% to the University.<br>**$25,001 to $100,000:** 50% to the Creators; 15% to the Faculty; 35% to the University.<br>**>$100,000:** 30% to the Creators; 20% to the Faculty; 50% to the University. |
| Charles Sturt University (36) | 50% to the Creators; 25% to the Faculty; 25% to the University. |
| Macquarie University (5.3) | 50% to the Creators; 50% to the University. |
| Southern Cross University (26) | 1/3 to the Creators; 1/3 to the Faculty; 1/3 to the University. |
| The University of New England (26) | 1/3 to the Creators; 2/3 to the University. |
| The University of New South Wales (9) | 1/3 to the Creators; 1/3 to NewSouth Innovations (NSi); 1/3 to the University. |
| The University of Newcastle (3.10) | **≤$50,000:** 100% to the Creators.<br>**$50,001 to $100,000:** 65% to the Creators; 35% to the University.<br>**>$100,000:** 50% to the Creators; 50% to the University. |
| The University of Sydney (13:1) | **≤$250,000:** 100% to the Creators.<br>**>$250,000:** 1/3 to the Creators; 1/3 to the Faculty; 1/3 to the Vice-Chancellor's Innovative Development Fund. |
| University of Technology Sydney (5.2.3) | 1/3 to the Creators; 1/3 to the Faculty; 1/3 to the University. |
| University of Western Sydney (65) | 40% to the Creators; 30% to the Faculty; 30% to Research Engagement, Development and Innovation |
| University of Wollongong (13:1) | 50% to the Creators; 50% to the University. |
| Deakin University (14) | 50% to the Creators; 50% to the University. |
| La Trobe University (132002P) | 30% to the Creators; 15% to the Creator's research [(1)]; 25% to the Faculty; 30% to the University. |
| Monash University (6.2.5.1) | 30% to the Creators; 33.33% to the Faculty; 36.67% to the University. |
| RMIT University | 50% to the Creators [(2)] |
| Swinburne University of Technology (8.1:b) | **≤$14,999:** 90% to the Creators; 10% to the Faculty.<br>**$15,000 to $49,999:** 70% to the Creators; 15% to the Faculty; 15% to the University.<br>**$50,000 to $99,999:** 50% to the Creators; 25% to the Faculty; 25% to the University.<br>**≥$100,000:** 50% to the Creators; 25% to the Faculty; 25% to the University. |
| The University of Melbourne (12.1:c) | 40% to the Creators; 40% to the Faculty; 20% to the University. |
| Federation University of Australia | Case-by-case [(3)] |
| Victoria University (16:3b) | 40% to the Creators; 30% to the Faculty; 30% to the University. |
| Bond University (7.3.1 & 7.5.3) | 40% to the Creators; 20% to the Faculty; 20% to the Division of Pro-Vice-Chancellor Research; 20% to the University. |
| Central Queensland University (5.32) | **≤$20,000:** 100% to the Creators.<br>**$20,001 to $90,000:** 50% to the Creators; 10% to the Research Division; 20% to the Faculty; 20% to the University.<br>**$90,001 to $150,000:** 40% to the Creators; 15% to the Research Division; 20% to the Faculty; 25% to the University.<br>**>$150,000:** 35% to the Creators; 20% to the Research Division; 15% to the Faculty; 30% to the University. |

| | |
|---|---|
| Griffith University (4.4.1) | 50% to the Creators; 12.5% to the School; 12.5% to the Faculty; 25% to the University. |
| James Cook University (12.2) | 40% to the Creators; 30% to the Faculty; 30% to the University. |
| Queensland University of Technology (3.1.9) | 1/3 to the Creators; 1/3 to the Faculty; 1/3 to QUTBlueBox. |
| The University of Queensland (9.1) | 1/3 to the Creators; 1/3 to the Faculty; 1/3 to UniQuest. |
| University of Southern Queensland (5.7) | 1/3 to the Creators; 1/3 to the Faculty; 1/3 to the University. |
| University of the Sunshine Coast (13.5.1) | 50% to the Creators; 25% to the Faculty; 25% to the University. |
| Curtin University of Technology (7.27.1) | 50% to the Creators |
| Edith Cowan University (7.1) | 50% to the Creators; 25% to the Faculty; 25% to the University. |
| Murdoch University (9.2) | 50% to the Creators; 50% to the University. |
| The University of Western Australia (11.2) | **≤$100,000:** 85% to the Creators; 15% to the University.<br>**>$100,000:** 50% to the Creators; 50% to the University. |
| The University of Notre Dame Australia (9.3) | **≤$50,000:** 85% to the Creators; 15% to the University.<br>**$50,001 to $150,000:** 65% to the Creators; 35% to the University.<br>**>$150,000:** 50% to the Creators; 50% to the University. |
| Flinders University (6.2) | **≤$15,000:** 100% to the Creators.<br>**$15,001 to $50,000:** 60% to the Creators; 20% to the Faculty; 20% to the University.<br>**$50,001 to $100,000:** 50% to the Creators; 25% to the Faculty; 25% to the University.<br>**>$100,000:** 40% to the Creators; 30% to the Faculty; 30% to the University (4). |
| The University of Adelaide (2:a) | 1/3 to the Creators; 1/3 to the Faculty; 1/3 to The Division of the Deputy Vice-Chancellor and Vice-President (Research). |
| University of South Australia | Not accessible |
| University of Tasmania (6.2) | 50% to the Creators; 20% to the Faculty; 30% to the University |
| Charles Darwin University | Not Available |
| The Australian National University (16) | 1/3 to the Creators; 1/3 to the Faculty; 1/3 to the University. |
| University of Canberra (13.1) | 40% to the Creators; 30% to the Faculty; 30% to the University. |

**Notes:**

(1) If the creator retires, he/she gets 45% of the licensing royalty income;
(2) The university does not have a numbering system for IP policies, and royalties are distributed according to the "Office of Pro Vice Chancellor (Research & Development) Practices: Research and Development Intellectual Property". This procedure manual does not include the distribution formula for the remaining 50% of the royalty income;
(3) Technology Transfer Office is entitled to determine the distribution formula;
(4) Licensing royalty distribution formula is based on annual earning.

## Appendix 5: Detailed Review of Initiatives to Enhance University-Industry Interactions in the UK

Initiatives introduced to enhance university research commercialisation are the main mechanisms and facilitators in the United Kingdom. The following sections review of initiatives by the European Union, the governmental departments of the UK, the governments of the member countries of the UK and universities in the UK.

***Initiatives by the European Union Commission***

Since the United Kingdom is part of the European Union (EU), it benefits from initiatives of the EU commission. Most of the initiatives by the EU are introduced by *Horizon 2020*, which is the EU main programme for funding research and innovation (Dowling, 2015). To name few, the *European Regional Development Fund (ERDF)* scheme and the *EU Structural and Investment Funds (ESIF)* scheme are both established to enhance regional economic development and to fund research infrastructure. Beyond the scope of Horizon 2020, *Eurostars Project* has been introduced to link UK high-technology companies with other businesses and higher education providers in Europe (Hughes, 2015). Also, another imitative of the European Union commission is the Enterprise Europe Network (EEN) which is a network of more than 600 organisations that support the economic growth of SMEs. In the United Kingdom, there are 11 EENs across the country and they are managed by Innovate UK (Dowling, 2015).

***Initiatives by the United Kingdom Government***

Most of the government initiatives come as a response to reviews in relation to university research commercialisation. Lambert (2003) conducted a review of business-university collaboration and concluded with many recommendations to enhance university research commercialisation. In 2004, the government responded with a statement titled as "Science and Innovation Investment Framework", which highlighted a 10 year plan for the United Kingdom. Following the lead of Lambert (2003), many review reports have been produced such as "The Race to the Top: A Review of Government's Science and Innovation Policies" by Sainsbury (2007), "The Current and Future Role of Technology and Innovation Centres in the UK" by Hauser (2010), "Review of Business-University Collaboration" by Wilson (2012), "Encouraging a British Invention Revolution" by Witty (2013), "Business-University Collaboration" by the House of Commons Business, Innovation and Skills (BIS) Committee (2014), and "Review of Business-University Collaboration" by Dowling (2015). As a result of these reviews, many governmental initiatives have been introduced and they are reviewed in the following section.

- **Governmental Departments**

Most of the initiatives in relation to enhancing BERD are originated from the Department of Business, Innovation and Skills (DBIS). One of these initiatives is the *R&D Tax Credits* scheme that was improved in 2012 in order to support SMEs and large companies with a tax relief of 225% and 130% of R&D expenditure, respectively (House of Commons Science and Technology Committee, 2013). Another initiative is *Above The Line (ATL) Credit* provision that was introduced in 2013 to support investment in R&D by large companies (Witty, 2013). Another innovative initiative is the *Patent Box* provision that was initiated in 2013 to enhance R&D activity by reducing corporate tax on patent-based income to 10% (Witty, 2013). In relation to venture capital funding, the DBIS introduced the *UK Innovation Investment Fund (UKIIF)* scheme (House of Commons Science and Technology Committee, 2013). The DIBS has also introduced the *UK Research Partnership Investment Fund (UKRPIF)* scheme to enhance university-business collaboration in R&D it is managed by the funding councils of the United Kingdom (Witty, 2013). In 1999, the Department of Trade and Industry (DTI) introduced the *University Challenge Funds (UCFs)* scheme which support university research commercialisation by providing proof of concept funding (Lambert, 2003). On the same year, the DTI launched the *Science Enterprise Challenge (SEC)* scheme which aims to enhance the entrepreneurial culture at universities (Sainsbury, 2007). Also, the DTI has launched the *Public Sector Research Exploitation Funds (PSREF)* scheme in 1999 to support university research commercialisation by providing infrastructure funding and early stage venture capital funding (Sainsbury, 2007).

Since the government of the UK has abolished Regional Development Agencies (RDAs) in 2010 (Hauser, 2010), *Local Enterprise Partnerships (LEPs)* programme has been introduced to enhance regional economic development (House of Commons Business, Innovation and Skills Committee, 2014). Currently, there are 39 LEPs which are funded by the government's *Growth Deals* and many of these LEPs have introduced local *Growth Hubs* as an entrepreneurial initiative (Dowling, 2015). In 2014, four *University Enterprise Zones (UEZs)* have been established in Bradford, Nottingham, Bristol and Liverpool to enhance business-university interactions (Dowling, 2015).

- **Innovate UK and Research Councils Initiatives**

Innovate UK was formed in 2007 and it was formally known as the Technology Strategy Board (TSB) until 2014 (Hughes, 2015). The main objective of Innovate UK is to enhance innovative activities of the public and the private sector. Innovate UK initiatives, in relation to the commercialisation of university research, include:

- *Catapults Centres*

This programme was established in 2011 to foster the innovative capacity of the UK in selected scientific fields. Currently, there are nine Catapults Centres with specialisation in high value manufacturing, energy systems, cell therapy, offshore renewable energy, precision medicine, satellite applications, connected digital economy, future cities and transport systems (Witty, 2013).

- *Small Business Research Initiative (SBRI)*

This scheme supports SMEs to be involved in providing innovative solutions for the public sector by providing grants for new product development that is mainly designed for the public sector (House of Commons Science and Technology Committee, 2013).

- *Innovation Vouchers*

This scheme was established in 2012 and it aims to provide grants to SMEs in order to enhance technology transfer from specific business sectors (Hughes, 2015).

- *SMART*

This scheme provides R&D grants for SMEs in three specific sectors which are technology, engineering and science (Witty, 2013).

- *Launchpad Fund*

This scheme supports R&D activities of high-technology businesses at specific geographical locations and this scheme has supported the establishment of the Materials and Manufacturing Launchpad in the North West, the Creative and Digital Launchpad in Greater Manchester, Cyber Security Launchpad in the Severn Valley, Tech City Launchpad in London, Motorsport Valley Launchpad in Oxfordshire, and Digital and Creative Clyde Launchpad in Glasgow (Dowling, 2015).

- *Knowledge Transfer Partnerships (KTPs)*

This scheme has been established to encourage collaboration in innovative projects between universities and businesses, especially SMEs (Sainsbury, 2007).

***Other initiatives have been introduced by UK Research Councils (RCs), they include:***

- *Gateway to Research*

This initiative was introduced in 2013 and it provides information about RCs-funded research to be used by interested innovation users (Witty, 2013).

- *Follow-on Fund*

This scheme provides proof of concept funding to facilitate commercialisation of RCs-funded research (Witty, 2013).

- *CASE Studentships*

The programme was formally known as to Collaborative Awards in Science and Engineering and it encourages placements of postgraduate students in businesses (Dowling, 2015).

- *Impact Acceleration Accounts (IIAs)*

This initiative enhances university research commercialisation by funding the early stages of the translation of research (Hughes, 2015).

Other initiatives have been introduced jointly by Innovate UK and the UK research councils, they include:

- *Innovation and Knowledge Centres (IKCs)*

This initiative was introduced in 2007 to foster research commercialisation and now there are seven IKCs located at universities (Dowling, 2015).

- *Catalysts*

This programme support the collaboration between businesses and researchers to develop solutions in certain areas, and the programme has supported the establishment of four catalysts which are the Biomedical Catalyst, the Agri-tech Catalyst, the Industrial Biotechnology Catalyst and the Energy Catalyst (Hughes, 2015).

- *Collaborative R&D Awards*

This programme enhances R&D collaboration in order to develop innovative solutions for certain technical or societal issues (Dowling, 2015).

- *Enterprise Research Centre (ERC)*

This initiative was also funded by the DBIS and it was established in 2013 to enhance productivity and growth of SMEs in the UK (ERC, 2016).

***<u>Initiatives by Countries of the United Kingdom</u>***

Since the United Kingdom is composed of four countries, this section reviews initiatives made by each country in relation to university research commercialisation. Regional Development Agencies (RDAs) were part of the innovative landscape of the UK up to 2010 and they have introduced many initiatives in relation to university research commercialisation.  Higher education funding councils are primarily responsible for providing block grants to higher education institutes; however, they have introduced many initiatives in relation to university research commercialisation and these initiatives will be reviewed as well.

- **England**

In England, there were nine RDAs and by 2008 they have already established more than 50 *Technology and Innovation Centres (TICs)* (Hauser, 2010). Other RDAs initiatives include:

- *NorthSTAR (NSTAR)*

This initiative was introduced by the North East England Development Agency to provide regional early stage venture capital funding (Lambert, 2003).

- *Enterprise Hubs*

This initiative was launched by the South East England Development Agency to provide support for start-up formation in the region (Lambert, 2003).

- *CONNECT Yorkshire*

This initiative was established by the Yorkshire and the Humber Development Agency to enhance entrepreneurial activities in the region (Sainsbury, 2007).

- *Mercia Spinner*

This initiative was established by the West Midlands England Development Agency to enhance entrepreneurial activities of universities in the region (Sainsbury, 2007).

- *Cambridge to Milton Keynes to Oxford (C-MK-O) Arc*

This initiative was established in 2003 as a high-technology entrepreneurial arc in collaboration by the Development Agencies of the East of England, the East Midlands of England, and the South East of England. This arc was formally known as the *Oxford to Cambridge (O2C) Arc* and later Milton Keynes joined the arc. This arc is located in one of the most economically influential regions in the UK and it enhances university research commercialisation in the region (Hauser, 2010).

Other initiatives have been introduced by the Higher Education Funding Council for England (HEFCE), they include:

- *Higher Education Reach Out to Business and the Community Fund (HEROBCF)*

This scheme was introduced in 1999 and it aims to enhance business-university interactions (Wilson, 2012).

- *HEFCE's Catalyst Fund*

This scheme was formally known as the *Strategic Development Fund* and it aims to enhance R&D collaboration between business and universities (Witty, 2013).

- *Higher Education Innovation Fund (HEIF)*

This scheme has been introduced by the DTI in 1999 and it aims to enhance university research commercialisation especially with SMEs. The HEIF scheme has supported the establishment of the London Technology Network (LTN) in 2002, the Knowledge House in the North East of England and I10 in the East of England. These initiatives aim to link regional university expertise with national and international companies (Lambert, 2003).

- **Northern Ireland**

Most of the Northern Ireland's initiatives in relation to university research commercialisation have been introduced by Northern Ireland Executive's Department for Employment and Learning, which include:

- *Connected*

This programme was established in 2007 and it acts as a platform for research commercialisation opportunities of Northern Ireland universities (House of Commons Business, Innovation and Skills Committee, 2014).

➢ *Northern Ireland Higher Education Innovation Fund (NI HEIF)*

This scheme was introduced in 1999 by the DTI and it aims to enhance regional economic development and SMEs-university interactions (Dowling, 2015).

- **Scotland**

In relation to university research commercialisation, most of the initiatives have been introduced by the Scottish government statement titled as "Scotland CAN DO" and the Scottish Funding Council (SFC). They include:

➢ *Interface*

This programme was introduced by the SFC in 2005 as a linkage tool between Scottish universities and businesses (Sainsbury, 2007).

➢ *Knowledge Transfer Grant (KTG)*

This scheme aims to support university research commercialisation and knowledge transfer (Hughes, 2015).

➢ *Innovation Centres (ICs)*

This programme was established in 2012 to support innovation and regional economic development in specific scientific areas and the programmes has supported the establishment of eight ICs with specialisation in Scottish aqua-culture, construction, digital health, informatics and computer sciences (Data Lap), sensor and imaging systems, industrial biotechnology, oil and gas, and stratified medicine (Dowling, 2015).

➢ *Scottish EU Funding Portal*

This platform provides information about funding opportunities by the EU (Dowling, 2015).

➢ *Scottish EDGE Fund*

This scheme aims to support the formation of start-ups and the growth of SMEs (Scottish Government, 2013).

➢ *Entrepreneurial SPARK (E-SPARK)*

This initiative aims to encourage students and university academics to create innovative ideas to solve technical or societal issues by providing a five month period of mentoring (Scottish Government, 2013).

- **Wales**

In relation to university research commercialisation, initiatives by the Welsh government and the Higher Education Funding Council for Wales (HEFCW) include:

➢ *HEFCW's Innovation and Engagement Fund*

This scheme was designed to enhance business-university interactions but unfortunately it has been recently abolished (Dowling, 2015).

➢ *Technium Centres*

This programme offers incubation services to university's spin-offs and it aims to enhance the regional economic development (Lambert, 2003).

***Initiatives by Universities***

In addition to governmental initiatives, initiatives by universities include:

➢ *Combined London Colleges University Challenge Seed Fund*

The initiative was launched by the London Business School, University College London, King's College London and Queen Mary University of London in order to fund their spin-offs (Lambert, 2003).

➢ *Science City York*

This science cluster was established by York University with local and regional support and it aims to enhance business-university interactions (Lambert, 2003).

➢ *The Southampton University Partnership*

This initiative was introduced by Southampton University to fund its spin-offs (Lambert, 2003).

➢ *SETsquared Partnership*

This initiative was established in collaboration between the universities of Bath, Bristol, Exeter, Southampton and Surrey. This initiative provides entrepreneurial support in many domains such as incubation of university spin-offs, entrepreneurship education for students and proof of concept funding (SETsquared Partnership, 2016).

- *REACT Hub*

This initiative was established in collaboration between the University of the West of England, and the Universities of Bath, Bristol, Cardiff and Exeter. The main aim of the initiative is to enhance business-university interactions in creative industries and economy (Dowling, 2015).