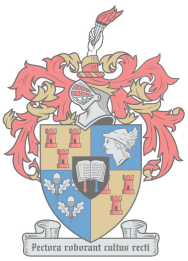
Improving the Efficiency of University Technology Transfer

Christle de Beer



Dissertation presented for the degree of Doctor of Philosophy in Industrial Engineering at the Faculty of Engineering at Stellenbosch University

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Supervisor: Prof. C S L Schutte

March 2018

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Abstract

The aim of this study is to improve the efficiency of university technology transfer. Research has shown that there are three primary ways of achieving this. First, determining how efficient technology transfer offices (TTOs) are at university technology transfer (internal). Secondly, determining best practices that can be shared between TTOs to improve university technology transfer (interoffice). Finally, through strategic intervention by university management (intra-organisation).

In developing countries, such as South Africa, there is a paucity of tangible data that can be used to determine the efficiency of TTOs using traditional benchmarking techniques. This study, therefore, addressed this gap by the creation of a novel self-assessment tool, using non-monetary and intangible indicators collectively known as intellectual capital (IC), to determine the efficiency of TTOs.

Furthermore, there are a myriad of challenges in sharing best practices between organisations, and these are exacerbated in the case of TTOs as university technology transfer is a complex process. In order to address these challenges this study created a maturity model, to be used in conjunction with the self-assessment tool, which can act as a mechanism for sharing best practices between TTOs.

Given that university technology transfer is a relatively new development in South Africa, university management often lack the background to understand how TTOs function, and therefore how to effectively intervene to improve the efficiency of TTOs. This study therefore visualised the data on the performance of the TTO (as per the self-assessment tool and maturity model) in a way that is relatable to all levels of university management.

Collectively, this study resulted in the creation of three novel tools that can be used to improve the efficiency of university technology transfer at the TTO level (both internal and interoffice) and at university level (intra-organisation). Furthermore, this study addressed three gaps identified in literature: the inability to determine the efficiency of technology transfer without tangible data, the lack of a mechanism to effectively share best practices between TTOs, and, the use of intellectual capital as a tool for university management to intervene and improve technology transfer.

Given that these are novel tools, each had to be verified and validated using a variety of techniques. The results of this study are given in article format moving from why and how the tools were created, to validation and verification, and finally to practical applications of the tools in real and theoretical case studies. This study concludes that, through this three-pronged approach the efficiency of technology transfer offices may be improved. Future work will see these tools tested in developing countries, and more detailed case studies will be developed.

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Opsomming

Die doel van hierdie studie is om die doeltreffendheid van tegnologie-oordrag in universiteite te verbeter. Navorsing het getoon dat daar drie primêre maniere is om dit te bereik. Eerstens, om die doeltreffendheid van tegnologie-oordragkantore (TOK'e) te bepaal en interne verbetering te bewerkstellig. Tweedens, deur beste praktyke tussen TOK'e met mekaar te deel om universiteitstegnologie-oordrag te verbeter (inter-kantoor). Laastens deur die strategiese ingryping deur universiteitsbestuur (intra-organisasie).

In ontwikkelende lande, soos Suid-Afrika, is daar 'n gebrek aan data wat gebruik kan word vir vergelykende studies om die doeltreffendheid van TOK'e te bepaal. Hierdie studie het dus die gaping aangespreek deur 'n nuwe self-assesseringsinstrument te skep wat nie-monetêre en ontasbare aanwysers vir intellektuele kapitaal gebruik om die doeltreffendheid van TOK'e te bepaal.

Verder is daar 'n magdom uitdagings om beste praktyke tussen organisasies te deel, en dit word vererger in die geval van TOK'e aangesien universiteitstegnologie-oordrag 'n komplekse proses is. Hierdie studie het dus 'n volwassenheidsmodel geskep wat saam met die selfassesseringsinstrument gebruik kan word, wat kan dien as 'n meganisme om beste praktyke tussen TOK'e te deel, en so doende die gaping aanspreek.

Aangesien universiteitstegnologie-oordrag 'n relatief nuwe ontwikkeling in Suid-Afrika is, het die universiteitsbestuur dikwels nie die agtergrond om te verstaan hoe TOK'e funksioneer nie, en weet dus nie hoe om effektief in te gryp om die doeltreffendheid van TOK'e te verbeter nie. Hierdie studie het dus die prestasie van die TOK (soos per die selfassesseringsinstrument en volwassenheidsmodel) voorgestel op 'n manier wat deur alle vlakke van universiteitsbestuur begryp kan word.

Hierdie studie het dus gelei tot die skepping van drie nuwe tegnieke wat gebruik kan word om die doeltreffendheid van universiteitstegnologie-oordrag op die TOK-vlak (intern en interkantoor) en op universiteitsvlak (intra-organisasie) te verbeter. Diensooreenkomstig, is die drie gapings in die navorsing aangespreek, naamlik: die gebrek aan 'n manier om die doeltreffendheid van universiteitstegnologie-oordrag te bepaal sonder tasbare aanwysers, die gebrek aan 'n meganisme om beste praktyke effektief tussen TOK'e te deel, en, die gebruik van intellektuele kapitaal as 'n instrument wat universiteitsbestuur kan gebruik om strategies in te gryp om tegnologie-oordrag te verbeter.

Aangesien dit nuwe tegnieke is, moet elkeen deur 'n verskeidenheid metodologieë geverifieer en gevalideer word. Die resultate van hierdie studie word gegee in artikelformaat wat begin met hoekom en hoe die tegnieke geskep is, na verifikasie en validasie, en uiteindelik tot praktiese toepassings van die instrumente in werklike en teoretiese gevallestudies. Hierdie studie het tot die gevolgtrekking gekom dat die doeltreffendheid van tegnologie-oordragkantore deur middel van hierdie drieledige benadering verbeter kan word. Toekomstige navorsing sal die tegnieke toets in ontwikkelende lande, en breedvoerige gevallestudies sal opgeskryf word.

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Acknowledgements

The author wishes to acknowledge the AESOP programme for funding the mobility to the University of Salento, Lecce, Italy. At UniSalento the author was supervised by Prof.ssa Passiante and Dr.ssa Secundo, whom she would like to thank for their guidance, supervision, and motivation. The author further wishes to thank the Department of Innovation Engineering for hosting her in this period.

The author wishes to acknowledge the Future Research Leaders Incubation Programme for supporting the exchange to the University of Bath, England. There the author was supervised by Dr Fai, whom she would like to thank for her insight, supervision and inspiration. The author further wishes to thank the School of Management for hosting her in this period.

The author wishes to acknowledge the Journal of Measuring Business Excellence, the Journal of Intellectual Capital, the Journal of Knowledge Management Research and Practice, and Springer Books for granting permission to use the published works included in this portfolio.

Finally, the author wishes to acknowledge the Faculty of Engineering at Stellenbosch University for their willingness to accommodate her and granting her various special permissions throughout this research project which allowed this work to be completed within two years. Without the kind assistance of the Department of Engineering, and Prof. Schutte, this would not have been possible.

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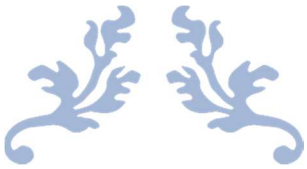

CHAPTER 1: THE STATUS QUO OF UNIVERSITY TECHNOLOGY TRANSFER IN SOUTH AFRICA

An Introduction to University Technology Transfer and the Aim of this Study

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The status quo of University Technology Transfer in South Africa

Introduction: Chapter 1

1.1 What is technology transfer?

Oliveira & Teixeira (2010) state that technology transfer is still in its infancy as a discipline and as such, there is little consensus on the definition of technology transfer. It is, however, generally agreed that technology transfer is a process. During this process, technology (science, knowledge or capabilities) is transferred or moved from one entity (person, group, organisation) to another for further development or commercialisation (Lane, 1999; Lundquist, 2003; Swamidass & Vulasa, 2008).

Anderson et al. (2007) define efficiency in technology transfer as a function of converting inputs to outputs by the involvement of one or more agents or stakeholders, namely researchers, technology transfer offices, entrepreneurs and private industries. These inputs often consist of research and development expenditure, either originated from private or public sources (Oliveira & Teixeira, 2010), and research results in the form of invention disclosures (Chapple et al., 2005). As for outputs, most authors (Anderson et al., 2007; Chapple et al., 2005) utilise tangible indicators such as licensing income, the number of and income from industry-sponsored research contracts, the number of patents granted and the number of spin-offs created. The conversion rate of these inputs to outputs is generally regarded as an indicator of the efficiency of technology transfer. Technology transfer is, however, influenced by determinants of effectiveness (also referred to as non-monetary indicators or intangibles). Oliveira & Teixeira (2010) define the aforementioned in two categories.

The first is internal conditions such as:

- organisational structure and status (Anderson et al., 2007; Bercovitz et al., 2001; Thursby & Kemp, 2002),
- size (Anderson et al., 2007; Macho-Stadler et al., 2007),
- rewards or incentives (Anderson et al., 2007; Friedman & Silberman, 2003; Siegel et al., 2003a),
- age or experience (Carlsson & Frith, 2002; Swamidass & Vulasa, 2008),
- nature and stage of technology (Jung et al., 2014),
- culture and norms of behaviour (Anderson et al., 2007; Bercovitz et al., 2001),
- links to industrial partners (Granieri & Frederick, 2015; Jung et al., 2014).

The second is external or framework conditions including:

- location (Chapple et al., 2005; Friedman & Silberman, 2003),
- context (Debackere & Veugelers, 2005; Siegel et al., 2003b),
- specific legislation and regulation (Granieri & Frederick, 2015),
- public policies (Bozeman, 2000).

An in-depth literature review has revealed very few studies that measure the efficiency of technology transfer in developing countries (de Falco, 2015). Moreover, literature has only taken account of the tangible indicators for measuring efficiency of technology transfer (Anderson et al., 2007; Siegel et al., 2007; Kim et al., 2008; Curi et al., 2012) and not the intangible indicators, which research shows have

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an influence on technology transfer. The research gap, therefore, lies not only in measuring the efficiency of technology transfer in developing countries such as South Africa but also in making use of non-monetary indicators.

1.2 Why are universities engaging in technology transfer?

The traditional roles of universities are being reconsidered to take account of new responsibilities in helping transform knowledge generated by university researchers. Seen as particularly important are reaping the benefits from research by:

- turning ideas and inventions into jobs and wealth,
- creating better career opportunities,
- transforming knowledge and technology into commercially usable forms (Harman & Harman, 2004).

The role of transferring knowledge from one organisation to another, is generally played by intermediaries, and technology transfer offices (TTOs) are an example of such an intermediary. Universities are increasingly being viewed by policymakers as engines of economic growth through technology transfer (Libecap et al., 2005). Indeed, it would appear that universities, through their TTOs have a role to play in increasing the efficiency of innovation in their respective innovation ecosystems by improving their efficiency at technology transfer. An innovation ecosystem can be seen as a framework of interconnected and interdependent public and private structural elements (policies, organisations, funds and people) and relationships (WIPO, 2013).

In South Africa TTOs are governed by the Intellectual Property Rights from Publicly Funded Research and Development Act[1] (the IPR Act) which states the functions of an office of technology transfer must:

(1) be performed by appropriately qualified personnel whom, when considered collectively, has interdisciplinary knowledge, qualifications and expertise in the identification, protection, management and commercialization of intellectual property and in intellectual property transactions.

(2) An office of technology transfer must, in respect of publicly financed research and development:

> *(a) develop and implement, on behalf of the institution or region, policies for disclosure, identification, protection, development, commercialization and benefit-sharing arrangements;*
> *(b) receive disclosures of potential intellectual property emanating from publicly financed research and development;*
> *(c) analyse the disclosures for any commercial potential, the likely success of such commercialization, the existence and form of the intellectual property rights, the stage of development thereof and the appropriate form for protecting those rights;*
> *(d) attend to all aspects of statutory protection of the intellectual property;*
> *(e) refer disclosures to the National Intellectual Property Management Office (NIPMO) on behalf of an institution.*

The main objective of the IPR Act is, together with the other acts and the supporting governmental organisations, to make provision for the development of intellectual property (IP) from publicly

[1] The National Intellectual Property Management Office. [Accessed 15 December 2015] *Legislation.* Available at: http://www.nipmo.org.za/legislation

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funded organisations. In addition, the IPR Act aims to ensure that IP from publicly funded research and development is utilised and commercialised for the benefit of South Africa. This poses new challenges and opportunities to publicly funded universities in South Africa. It is also clear that the IPR Act makes provisions only for tangible outputs from technology transfer, and therefore the performance of TTOs are measured in this way.

Several studies (Tahvanainen & Hermans, 2011; de Falco, 2015) have shown, using traditional benchmarking of tangibles, that a lot of TTOs operate inefficiently (Anderson et al., 2007). Therefore, this study aims to improve the efficiency of university technology transfer. Moving from the research gaps that have been identified, and the gaps in practice, this study will measure the efficiency of technology transfer using intangibles which can then be used to improve the efficiency of technology transfer in developing countries. The intention is to view the performance of TTOs holistically where both tangible and intangible data is available (developed countries) and to have an indication of performance using intangible data where that is the only source (developing countries).

1.3 How well do South African technology transfer offices perform?

Currently, South Africa ranks 57th globally out of 127 countries according to the Global Innovation Index *(GII)* (2017) (Cornell et al., 2017). The GII report uses a tool measuring 84 metrics to gauge the 'innovation index' per country. The GII (average) and Innovation Efficiency Ratio is the final function based on the two main sub-indexes, innovation input and innovation output as illustrated in Figure 1.1 below.

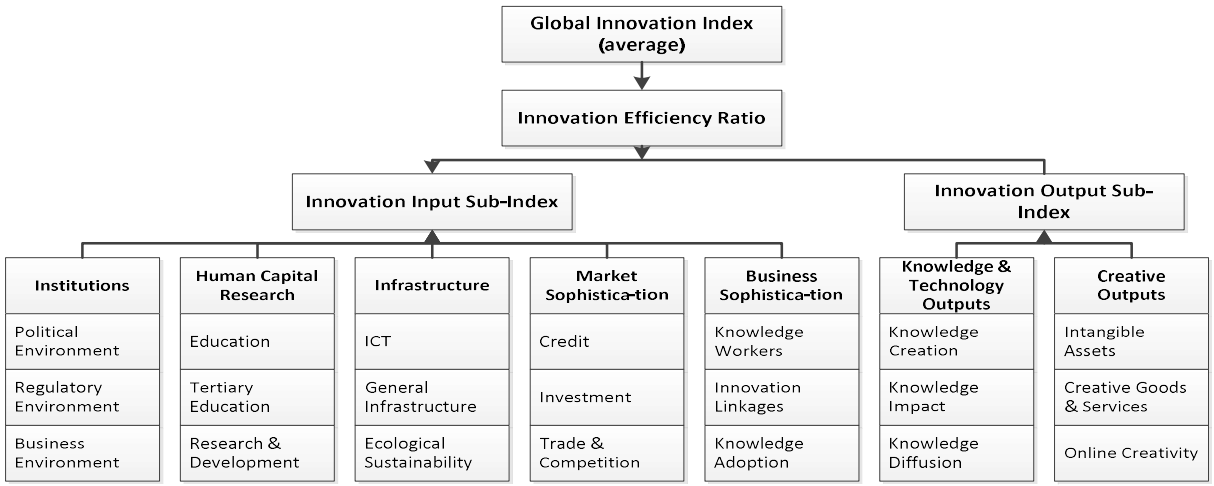

Figure 1.1: The innovation metric adopted framework of the Global Innovation Index (2017)

Considering then the strengths and weaknesses as cited by the GII 2017, South Africa's greatest strength is innovation input, and yet the greatest weakness is innovation output. The outputs measured are:

- Knowledge Creation
  - Domestic patent applications
  - PCT (Patent Cooperation Treaty) patent applications
  - Utility model applications
  - Scientific and technical articles
  - Citable documents

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- Knowledge Impact
    - Growth rate of GDP per person engaged
    - New business density
    - Total computer software spending
    - ISO 9001 quality certificates
    - High- and medium-high-tech outputs
- Knowledge Diffusion
    - IP (Royalty and licence fees) receipts
    - High-tech exports
    - ICT (Information and Communications Technology) services exports
    - FDI (Foreign Direct Investment) net outflows
- Intangible Assets
    - Trademark applications
    - Industrial design applications
    - ICTs and business model creation
    - ICTs and organisational model creation
- Creative Goods & Services
    - Cultural and creative services exports
    - National feature films produced
    - Global entertainment and media market
    - Printing and publishing output
    - Creative goods exports
- Online Creativity
    - Generic top-level domains (TLDs)
    - Country-code TLDs
    - Wikipedia edits
    - Video uploads on YouTube

Due to the low innovation outputs, South Africa can, therefore, be regarded as an inefficient innovator. Considering the outputs measured, and comparing these to the outputs TTOs in South Africa are tasked with, as mentioned above, an improvement in the efficiency of university technology transfer would have an impact on the outputs measured by the GII. Specifically within the knowledge creation, knowledge diffusion and intangible asset categories. It should be noted that the GII uses tangible and intangible assets as categories which does not align with the definition of tangible and intangible assets as anticipated in this study.

The Department of Science and Technology (DST), the Southern African Research and Innovation Management Association (SARIMA), NIPMO, the Human Sciences Research Council (HSRC) and the Centre for Science, Technology and Innovation Indicators (CeSTII) released the inaugural baseline study of TTOs in South Africa for the period 2008–2014 in 2017. The South African National Survey of Intellectual Property and Technology Transfer at Publicly Funded institutions, as the report is called, established some baseline indicators to track activity in IP management and technology transfer (DST et al., 2017).

The survey was sent to 23 higher education institutions and ten science councils. Valid responses were obtained from 24 institutions. Of these, 23 indicated that they have either established a dedicated TTO, have dedicated technology transfer individuals or are members of a regional TTO. The key findings of this report include:

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- *Management of IP increased more rapidly than the increase in research expenditure. On average, 100 new technologies were added annually between 2011 and 2014 to the portfolio managed by respondent institutions.*
- *There has been a quadrupling in the actual number of licences executed per year in the period. The majority of IP transactions yielded less than R100 000 per year.*
- *In total, 45 start-up companies were formed over the period to commercialise the institutions' technology, 73% of which were based on publicly funded IP.*
- *Most institutions are performing a range of activities within the categories of technology transfer and research commercialisation.*

The survey concludes with a confirmation of the research gaps identified above. A significant number of indicators which the survey had set out to measure were not reported on due to the paucity of data and, in some instances, the activities not being undertaken by one or more institutions. Therefore, not only has very little research been undertaken determining the efficiency of technology transfer in South Africa, but there is also limited tangible data available with which to determine efficiency. This finding advocates the use of intangible data.

1.4 How can the efficiency of university technology transfer be improved?

University technology transfer can be improved at three levels: internal, interoffice and intra-organisation. At an internal level, a TTO may improve its efficiency by identifying weaknesses and activating steps to improve. A TTO may also identify barriers which prevent successful technology transfer, and attempt to address these barriers. Weckowska (2015) showed that TTOs learn through experimentation and failure, and by sharing these experiences with other TTOs. Therefore, the efficiency of technology transfer can also be improved by sharing best practices at an interoffice level. There are, however, some barriers to successfully sharing best practice between TTOs. Sharing best practices have many challenges, such as differences in the social context and socio-cultural environment where the best practice is found, and where it will be adopted (Kostova, 1999). Yet, in the context of TTOs, there are the added complexities around understanding how well a TTO is performing at present and why it is not performing better (Granieri & Frederick, 2015) at an internal level. These barriers become more evident in the case of developing countries, as very little research has been done on measuring the performance of TTOs in developing countries.

There is a substantial body of literature from developed countries which documents and investigates technology transfer and TTOs and provides insight on how to be more efficient at technology transfer (Rasmussen, 2008). However, the application of these insights to the developing country context has not been very successful (Kloppers et al., 2006). The barriers preventing this sharing of best practice extends to cross-country differences in negotiations, leadership and distribution of power, authority in organisations, and human resource management practices. Thus, there is not only a need to determine the efficiency of technology transfer using intangibles but also a need to share best practices more effectively to improve efficiency. In addition, the efficiency of technology transfer can be improved at an intra-organisation level, where top management of the university strategically intervenes to improve weaknesses identified within the TTO or barriers identified by the TTO. Top management of the university may also intervene to create an enabling environment for the sharing of best practices between TTOs. However, for this kind of high-level, strategic intervention to take place, university management must understand how the TTO is performing and where these interventions can be best made to ensure a sustainable change and improvement in efficiency. Thus,

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there is a need to translate the efficiency of the TTO into a format which clearly shows where intervention is needed, and also suggests how to best achieve improvement in efficiency.

1.5 How is the efficiency of technology transfer determined?

The term 'technology transfer' is broad and not easily measurable (Agrawal, 2001). Technology transfer includes different phases and stakeholders, and the performance is measured by monetary income generated by the university. Despite the fact that nearly all universities carry out technology transfer activities, most of the TTOs are not making money out of their commercialisation activities (Rasmussen, 2008).

Data Envelopment Analysis (DEA) has been regarded as a proper approach to measuring university technology transfer efficiency (Kim et al., 2008). This approach focuses, however, on measurable outcomes of technology transfer which mostly relate to monetary or tangible factors. These include the number of disclosures, the annual number of patent applications, licensing agreements, the formation of university spin-off companies, and the financial revenue generated through these activities. Using income from technology transfer, however, does not measure real performance as it does not provide nor is it based on the potential for technology transfer based on university research (Vinig & Lips, 2015).

Intangibles and non-monetary factors are becoming essential in the value creation processes of regional and national economies (Ante, 2004). Sorensen & Chambers (2008) have emphasised the importance of the balance between economic metrics and non-monetary benefits for the assessment of technology transfer. Miller et al. (2016) state that technology transfer performance measurements are emergent with many measures not being adequately addressed such as tacit based activity costs and effectiveness and therefore, there is a need for more fine-grained technology transfer performance measures. Indeed, it would seem that no tool is currently in use which measures the efficiency of university technology transfer using intangibles, non-monetary indicators or determinants of effectiveness.

Framed on the above premises, this study will determine the efficiency of university technology transfer using intangible indicators. Making use of intangible indicators will aid in determining the efficiency of technology transfer in developing countries such as South Africa where there is a scarcity of data on tangible indicators. Once a determination can be made around the efficiency of technology transfer, steps can be taken to improve it, both internally and intra-organisationally. By understanding the barriers to sharing best practice and overcoming these, technology transfer may then be further improved.

Aside from the vast array of differences between developed countries (generally the holders of the best practices) and developing countries (generally the seekers of best practices), there is the added complexity of sharing best practices between TTOs as noted above. Taking this into account, the new tool will be created that is not only based on intangible indicators but can serve as a mechanism to understand the performance of the TTOs between whom the best practices will be shared.

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The Aim and Objectives of this study

The state of affairs of university technology transfer in South Africa has shown a variety of gaps in the literature, research, and practice. It seems very little literature exists on the efficiency of university technology transfer in South Africa, and that which is available highlights the lack of data. This shows that very little research has been done on this topic, because of the unavailability of tangible data which is used to determine the efficiency of technology transfer. Moreover, due to the complex nature of technology transfer, it is apparent that tangible data alone is not an indicator of the efficiency. Taking these two aspects into consideration supports the notion of making use of intangible data to determine the efficiency of university technology transfer.

From the little data available, it would also appear that South Africa and its TTOs are not performing well. An intervention is needed to improve the efficiency of technology transfer, and this can be achieved through a thorough understanding of the current performance of the TTO. Using intangible data would measure determinants of effectiveness, and as such, this data can be used to take steps to improve efficiency at an internal level. This will be supplemented by sharing best practices at an interoffice level, and because the performance of the TTO is understood, this will mitigate some of the challenges involved in sharing best practices between TTOs. Finally, the data will be translated into a format which allows intra-organisational intervention in a strategic and informed manner.

Therefore, three gaps have been identified which this study seeks to address:

- The use of intangible data to determine the efficiency of university technology transfer,
- A lack of understanding around the performance of TTOs in general which is a barrier to sharing best practice, and to enable high-level strategic intervention from top management at the university,
- Contributing to the body of research on university technology transfer in South Africa, and the global body of knowledge on the use of intangibles to determine university technology transfer efficiency.

1.6 Aim

The aim of this study, as articulated in the title of the portfolio, is to **improve the efficiency of university technology transfer in a way that applies to developing countries such as South Africa**. To achieve this aim several objectives, which will be discussed in detail in section 1.8, will need to be met.

As stated before, the efficiency of university technology transfer can be improved at three levels: internal, interoffice, and intra-organisation. Therefore this study will align its objectives to address these three levels.

1.7 Methodological Philosophy

The overarching research dimensions of this study will be discussed from sociological, ontological, teleological, epistemological and methodological aspects.

The sociological dimension of this study is to apply and tailor knowledge to address the problem of the efficiency of university technology transfer. The introduction of this study has dealt with defining the problem and the motivation for addressing the efficiency of university technology transfer, as well

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as the impact of efficient technology transfer in a broader socioeconomic sense. Thus this study takes the dimension of applied research, and because this study seeks to improve university technology transfer, the action research type of applied research will be employed. The purpose of this study is to understand how university technology transfer can be improved, and therefore a descriptive research approach will be used. Descriptive research employs most data gathering techniques—surveys, field research, content analysis, and comparative historical research.

As alluded to in the section on technology transfer above, the term is broad and not easily definable. Moreover, the process of transferring technology can take place in any discipline and within any industry. Consequently, the study of a process as complex as technology transfer would necessitate a multi-disciplinary approach. Therefore, the ontological dimension of this study specifically avoids domain- or discipline-based assumption. In order to have a common understanding of the research, specific terms will be used and defined throughout the study. To frame this study a brief ontology will be given here:

- Technology transfer: A process during which technology (science, knowledge or capabilities) is transferred or moved from one entity (person, group, organisation) to another for further development or commercialisation.
- Efficiency: The conversion of inputs (such as invention disclosures) to outputs (such as patents, licences, spin-out companies and income generated), and as such these tangible indicators are measured quantitatively.
- Effectiveness: The degree to which something is successful in producing a desired result (such as the outputs anticipated by efficiency) and, in essence, is measured qualitatively through intangible indicators.
- Intellectual capital (IC): Intellectual material that has been formalised, captured and leveraged to produce higher-valued assets.

In line with the aim of this study, to improve the efficiency of university technology transfer at three levels (internal, interoffice and intra-organisation), the teleological dimension of this study is encapsulated in several theoretical and practical objectives. As alluded to above in a general sense, the theoretical objective of this study is to address the lack of understanding around the performance of TTOs, and to contribute to the body of research on university technology transfer in South Africa. The practical objectives of the study are:

1. To create a tool using intangible indicators of efficient technology transfer. This objective will be epistemological in nature, and involve the review of extant literature on determinants of the effectiveness of technology transfer. This will lead to the creation of a tool which can be used to assess the TTO at an internal level. Given the qualitative nature of intangible indicators, this tool will take the form of a survey and necessarily be a self-assessment.

2. Translate the data collected with this tool to understand the performance of the TTO. This objective will also take an epistemological approach, combined with the ontological dimension previously defined. Therefore, a multi-disciplinary approach will be taken in identifying the appropriate format to reflect the performance of the TTO, which may take the format of a project management tool or a maturity level approach. This format will form the basis of the interoffice and intra-organisational level understanding of the performance of the TTO.

3. Validate and verify the tool through case study, expert interview, reiteration and live testing. As the data collected with the tool will be qualitative in nature, and as the tool will be novel, it would necessarily undergo rigorous testing to ensure a robust and applicable tool. A descriptive, yet action

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research approach is followed throughout this study, thus as an understanding is gained about how to improve the efficiency of technology transfer, it will be applied to the tool to ensure it solves the problem.

4. To create a mechanism for sharing best practice between TTOs based on their efficiency and maturity level. This objective speaks to the interoffice level of improving the efficiency of technology transfer. Again an epistemological approach will be followed, combined with the ontological dimension previously defined. Therefore, a multi-disciplinary approach will be taken in identifying the appropriate mechanism for sharing best practice, framed on the basis created in the second objective.

5. Visualise the performance of the TTO in a way that is relatable at all levels of university management. Based on the platform created in the second objective, this objective addresses the intra-organisational level of improving technology transfer efficiency. Again a multi-disciplinary approach will be taken in identifying the appropriate visualisation of the performance of the TTO.

6. Publish articles to act as a guideline to aid TTOs and university management to intervene and improve efficiency. As alluded to above, TTOs learn through sharing experiences, and conferences and publications serve as a way to share knowledge. The final objective of this study is aligned with the overarching sociological dimension of the research to improve the efficiency of technology transfer. This also motivates the structure this study has taken in presenting the findings in a portfolio format.

A variety of methodological approaches will be taken in this study as alluded to in its ontological and teleological dimensions. The overarching research theory or approach is based in the social sciences, which lends itself to the collection of qualitative and intangible data in a robust and empirical way. Yet, this study is submitted to Industrial Engineering, as this academic discipline focusses on the optimization of complex processes, systems and organizations. However, models and frameworks from other disciplines will be needed to address the multi-disciplinary nature of this epistemological, and in essence, constructivist study. The hypothesis is that the efficiency of university technology transfer can be improved in a meaningful way if the performance of the TTO is better understood, and that information is presented in the correct format to effect the necessary changes. It is assumed that intangible data would lead to this kind of understanding.

The nature of this study will necessarily be epistemological, as it will be reliant on gathering existing knowledge. To improve the efficiency of university technology transfer at an internal level, literature will be reviewed to understand how weaknesses can be identified and ameliorated. At an interoffice level, literature will be reviewed to understand how best practices might be shared to enable the sharing of experience and learning between TTOs. At an intra-organisation level, literature will be reviewed to understand how best to present the efficiency of a TTO to enable successful intervention.

The argument has been made for the creation of a tool which is based on intangible data. As intangible data is qualitative in nature, data will have to be collected through surveys and interviews, which would add empirical evidence to the body of intangible data that is collected. Aside from the creation of a tool to collect data, another tool will be created to identify and improve internal weaknesses. Moving from this, a tool would be needed to act as a mechanism to facilitate the sharing of best practices to improve efficiency at an interoffice level. Finally, the data would need to be converted into a format which allows easy visualisation to activate interventions to improve efficiency intra-organisationally.

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1.8 Objectives

Within the methodological philosophy of this study, six objectives have been clearly defined, which align with the three levels of intervention that may be taken to improve the efficiency of university technology transfer. Table 1.1 below gives a high-level overview of the content and layout of this portfolio documenting the findings of the study. Within each level of intervention, certain objectives are given as well as the chapter in which these are discussed within the portfolio. Thereafter the outcomes of the objectives, and methods used to achieve these outcomes, are given. Finally, the table concludes with the reference for the work addressing the objective, and details the methods and outcomes. The status of each work, published, accepted or submitted is given in the last column.

At the internal level of intervention, objective 1 is directed at the creation of a novel approach to understanding TTO performance. The outcome will therefore be a novel self-assessment tool based on intangible indicators. Research has shown that the optimal way of achieving this outcome is through a qualitative approach, by making use of a survey to administer the self-assessment tool.

Objective 2, also at the internal level of intervention, is directed at the translation of the data collected by the self-assessment tool to understand the performance of the TTO. The outcome will therefore be a novel maturity model, and research has shown that the project management process maturity model is the best basis for achieving this outcome. Objectives 1 and 2 are discussed in the published work presented in Chapter 2.

Continuing at the internal level of intervention, objective 3 is directed at the validation and verification of the novel approach (i.e. the self-assessment tool and maturity model). The outcome will therefore be evidence that the results from the self-assessment tool and maturity model are valid, and that they can be verified. Validation can be achieved through live-testing and expert interviews. Verification can be achieved through case study and expert interviews. Therefore the outcome will be achieved through qualitative methods:

1. Making use of a survey to live-test the tool in order to validate the tool.

2. Making use of expert interviews to validate and verify the tool.

3. Making use of a case study to verify the results of the tool.

The evidence of these qualitative methods, and thus the validation and verification of the self-assessment tool and maturity model are given in Chapter 3. Within Chapter 3 two works are presented, one published and one accepted work.

At the interoffice level of intervention, objective 4 aims to create a mechanism for sharing best practices between TTOs. In order to achieve this, evidence will be given that the novel self-assessment tool and maturity model (given in Chapter 2) can act as a mechanism for sharing best practice. Expert interview and reiteration were used to improve the novel approach (from Chapter 2) and to adapt it to serve this purpose. Thus, Chapter 4 presents an accepted work detailing, through theoretical case studies how the novel approach may be used as a mechanism to share best practices between TTOs.

Within the intra-organisation level of intervention, objective 5 seeks to visualise the performance of the TTO in a way that is relatable at all levels of university management. Given the complexity of TTO performance, it was decided that heat maps (data values represented as a collection of colours) would be the most effective way of communicating the performance of the TTO as weaknesses can clearly be highlighted. The unpublished work presented in Chapter 5, is a chapter of a book on intellectual capital.

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Finally, the sixth objective of this study is to distribute its results to act as a guide to assist TTOs and university management worldwide to improve the efficiency of university technology transfer. This objective is addressed in the conclusion of this study. Chapter 6 details the contributions of the study, in the form of conference proceedings and the published and unpublished works included in this portfolio.

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Table 1.1: High-level overview of objectives and layout of study

Level of intervention	Objective	Chapter	Method	References			Status
Internal	Create a self-assessment tool using intangible indicators of efficient technology transfer	**Chapter 2**	Qualitative, survey	Secundo, G., De Beer, C. & Passiante, G. (2016). Measuring university technology transfer efficiency: a maturity level approach. Measuring Business Excellence, Vol. 20 No. 3, pp. 42-54.			**Published**
	Translate the data collected with this tool to understand the performance of the TTO		Project Management Process Maturity Model				
	Validate and verify the tool	**Chapter 3**	Live testing, expert interview	Secundo, G., De Beer, C., Schutte, C. S. & Passiante, G. (2017). Mobilising intellectual capital to improve European universities' competitiveness: the technology transfer offices' role. Journal of Intellectual Capital, Vol. 18 No. 3, pp. 607-624.			**Published**
			Case study, expert interview	Secundo, G., De Beer, C., Schutte, C. S. & Passiante, G. (2017). Leveraging Intellectual Capital to assess the Technology Transfer Office: a South African University case. Accepted with revisions (Journal of Intellectual Capital)			**Accepted**
Interoffice	Create a mechanism for sharing best practice between TTOs based on their efficiency and maturity level	**Chapter 4**	Expert interview, reiteration	De Beer, C., Secundo, G., Passiante, G., & Schutte, C. S. (2017). A mechanism for sharing best practices between university technology transfer offices. Knowledge Management Research & Practice, Vol. 15 No. 4, pp. 523-532.			**Published**
Intra-organisation	Visualise the performance of the TTO in a way that is relatable at all levels of university management	**Chapter 5**	Heat Maps	Secundo, G., De Beer, C., Schutte, C. S. & Passiante, G. (2017). A Visual Representation of Technology Transfer Office Intellectual Capital Access. Submitted to Springer Books.			**Accepted**
All	Publish articles to act as a guideline to aid TTOs and university management to intervene and improve efficiency	**Chapter 6**	Conference proceedings, journal publications, book chapter	European Conference on Knowledge Management conference paper entitled: Assessing University Technology Transfer Efficiency in South Africa: A Maturity Level Approach	International Forum on Knowledge Asset Dynamics conference paper entitled: Technology Transfer Office type for increased access to University Intellectual Capital: Recommendations from Europe and UK (Appendix A)	International Conference on Entrepreneurship, Innovation and Regional Development conference paper entitled: A Novel Technology Transfer Office Typology Based on Lessons Learnt from the UK (Appendix B)	**Published**

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Each of these objectives will be discussed in the following chapters referring to published and submitted works in which the objectives were met. Each chapter will start with an introduction to the published or submitted work, and articulate how the work addresses the objective(s). Next, the work will be included and followed by a conclusion to reiterate how the objective(s) was addressed and how the project then progressed. The figure below provides a summary of the layout of the portfolio, and can be used as a guide throughout to gauge the progress of the study.

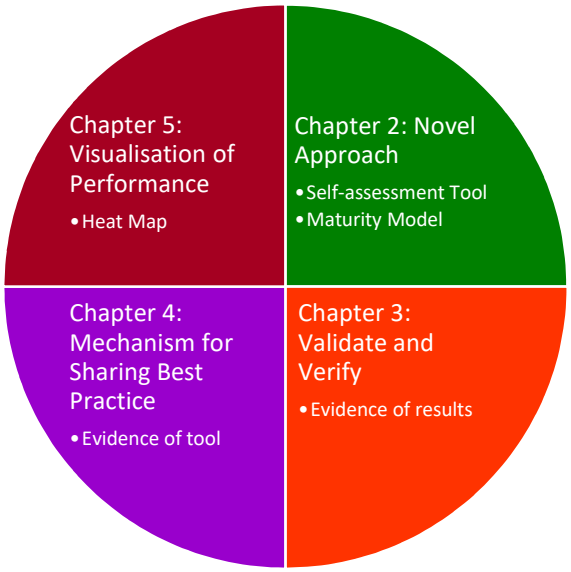

Figure 1.2: Contextual guide

It should be noted that the PhD candidate is not the first author of all the submitted works. It is general practice during the supervision of a PhD candidate that the supervisor acts as first author. However, the contributions of the candidate (as given in Appendix C) show that a significant amount of work was done by the candidate. Furthermore, the candidate is the first author on the final paper that was submitted (chronologically).

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CHAPTER 2: A Novel Approach to Understanding TTO Performance

The Creation of a Self-Assessment tool and Maturity Model

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A novel approach to understanding TTO performance

Introduction: Chapter 2

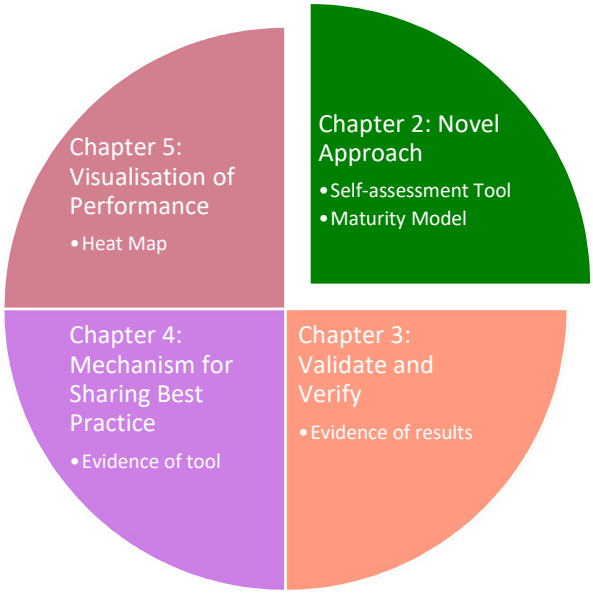

Figure 1.2: Contextual guide

As stated in the first chapter, the aim of this study will be achieved through addressing six objectives. The published article included in this chapter of the portfolio addresses the first two objectives, namely:

1. Create a self-assessment tool using intangible indicators of efficient technology transfer
2. Translate the data collected with this tool to understand the performance of the TTO

The use of intangible indicators to determine the efficiency of university technology transfer has its justification in two aspects. First, and of relevance in developing countries, is the paucity of tangible data. Most methods used to assess the performance of a TTO, focus on the efficiency of converting monetary inputs such as research income, to tangible outputs such as patents, licences, or spin-out companies. However, in developing countries tangible data is scarce, partly due to poor record-keeping, but mostly due to the fact that many TTOs lack sufficient resources to perform all these activities. Patenting is a very costly process, and TTOs often prioritise one technology to allocate resources to, or opt not to patent at all. In addition, many universities are legally prevented from creating a spin-off company. This barrier is usually addressed through the creation of an independent entity which functions as a commercial entity on behalf of the university, but this is again a costly process.

The second justification for the use of intangible indicators, is the wealth of literature on determinants of effectiveness (see Table 2.1a below). Effectiveness relates to the success at achieving a desired result, and efficiency is the conversion ratio of inputs to outputs. Research has focused on measuring the efficiency of TTOs, and then determining causality by investigating antecedent characteristics,

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organisational or best practices, or other variables. Conversely then, if the determinants of effectiveness are measured, understood and enhanced, a natural consequence will be the improvement of efficiency. Yet, no tools could be found which measure intangible and non-monetary indicators in this way.

Table 2.1a: Literature on various determinants of effectiveness of technology transfer

Determinant of Effectiveness	Reference(s)
Organisational structure and status	Anderson et al., 2007; Bercovitz et al., 2001; Thursby & Kemp, 2002
Size	Anderson et al., 2007; Macho-Stadler et al., 2007
Rewards or incentives	Anderson et al., 2007; Friedman & Silberman, 2003; Siegel et al., 2003a
Age and/or experience	Carlsson & Frith, 2002; Swamidass & Vulasa, 2008
Nature and stage of technology	Jung et al., 2014
Culture and norms of behaviour	Anderson et al., 2007; Bercovitz et al., 2001
Links to industrial partners	Granieri & Frederick, 2015; Jung et al., 2014
Location	Chapple et al., 2005; Friedman & Silberman, 2003
Context	Debackere & Veugelers, 2005; Siegel et al., 2003b
Specific legislation and regulation	Granieri & Frederick, 2015
Public policies	Bozeman, 2000

This led to the creation of the self-assessment tool, which is discussed in detail in the article following this introduction. At the risk of being repetitive, the tool was created after a thorough literature review on the determinants of effectiveness. These are embodied in intangible indicators such as vision and mission for technology transfer, personal relationships between TTO staff and researchers, strong university-industry links, and skills of TTO staff. Another embodiment is in non-monetary indicators such as number of TTO staff, age of TTO, or the presence of a medical school or business incubator. The tool was created to be a self-assessment tool used by the director or CEO of the TTO to determine:

- the presence of each of these determinants of effectiveness within the TTO,
- the access the TTO has to these determinants of effectiveness within the university.

To allow for both yes/no answers and degrees of access to determinants of effectiveness, the self-assessment makes use of a 5-point Likert scale. By incorporating both intangible and non-monetary indicators, and both presence and access questions, some of the subjectivity that arises from self-assessments are addressed. Some of the non-monetary indicators are tangible, and have been included in the tool. These indicators have been used in other studies and have been proven to have a demonstrable effect on efficiency, and therefore act as a second measure to control the answers and minimise the skewing effects of subjective assessment.

As discussed in detail in the article, the indicators were weighted using the fuzzy analytical hierarchy process (AHP). Fuzzy AHP uses pairwise comparison to weight indicators, and as such the research team individually weighted each indicator against another. The final weightings used in the paper are an average of the research team's expert opinion regarding the relative importance of each indicator. This was an initial weakness of the tool, which could only be addressed after the tool had been tested to confirm the assigned weightings. However, to ensure the tool was as robust as possible prior to testing, the tool was presented at the ECKM (European Conference on Knowledge Management). This conference paper, and the feedback from the discussions during the presentation of the paper, form the basis of the article.

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In order to address the second objective of this study, the weighted and prioritised data collected on determinants of effectiveness would need to be translated in a way which describes the performance of the TTO. Therefore, once the self-assessment tool was completed by the CEO of the TTO, and the score (1 to 5) for each indicator weighted according to the fuzzy AHP method, a final score would be calculated for the TTO. This score is an indication of the presence of or access to determinants of effectiveness, and therefore an indication of efficiency. To contextualise the score and the characteristics of the TTO, a maturity model was created.

In the article, the use of the Berkley $(PM)^2$ Model (Kwak and William, 2000) and its application to the creation of the maturity model is explained. This model was chosen due to its extensive use in project management, and the ability to use this model to identify weaknesses and intervene to improve. These aspects of the model suit the goal of the self-assessment tool, and as such it allows the use of the tool to not only determine efficiency, but also to determine weaknesses. Thus, upon completion of the self-assessment the TTO already has an indication of weaknesses to improve upon to enhance its efficiency at unit level.

The maturity model classifies the TTO at a maturity level based on the score from the self-assessment. This maturity level is described and characterised with the strengths a TTO should have at that level. These strengths are based in the literature reviewed about determinants of effectiveness, and selected based on the fuzzy AHP priorities. Therefore, the descriptions are a reflection of what literature and the research team (at that time) felt were the most important indicators, and therefore the most important strengths each TTO should exhibit. In this way the performance, characteristics and context of the TTO is better understood. These maturity levels were also further refined as the tool was used and tested.

The article in its published format follows this introduction. It should be noted that this article was published to align with the theme of the journal selected, and was written to include terminology that is used by readers of this journal.

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Measuring University Technology Transfer Efficiency: A Maturity Level Approach

Authors: Giustina Secundo[1], Christle De Beer, Giuseppina Passiante[1]

Stellenbosch University, Stellenbosch, South Africa

[1]University of Salento, Lecce, Italy

Abstract

Purpose The process of innovation in developing countries is different from that of developed countries, with mature technologies often being adopted with limited success. Universities are increasingly being viewed by policymakers as engines of innovation through the Technology Transfer Office (TTO). However, with the adoption of various new Intellectual Property Right (IPR) legislation, university TTOs in developing countries have had an inefficient approach to technology transfer. Framed in the above premises, this study aims to develop a Maturity Model to measure through non-monetary indicators, the efficiency of TTOs.

Design The Maturity Model is inspired by the Berkley (PM)[2] Model which allows an organization to determine strengths and weaknesses, and to focus on weak practices to achieve higher maturity. Fuzzy AHP is adopted to determine the priorities and weights of the non-monetary indicators, as they are ambiguous.

Findings The Maturity Model to measure the efficiency of TTOs cover the following efficiency areas: IP Strategy and policy; Organization design and structure; Human resource; Technology; Industry links; and Networking. The Model provides a theoretical continuum along which the process of maturity can be developed incrementally in TTO from one level to the next, moving from awareness, defined, managed, integrated, and sustained stage.

Research limitations The Maturity Model needs to be tested and applied in TTOs in developing countries.

Practical implications The Maturity Model provides a means to sustain the decision-making process more effectively, especially in those countries considered as an inefficient innovator.

Originality The findings inform the design of a customizable solution to barriers to the success of technology transfer and highlight weaknesses within each institution or TTOs efficiency.

Key words: Technology transfer, Maturity model, Technology Transfer Office (TTO), efficiency, non-monetary indicators.

Article classification: research paper

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2.1 Introduction

Globalization has created immense pressures on developing countries and in order to remain competitive, these countries need to redesign themselves using innovation (Job and Sanghamitra, 2010; Seema and Milind, 2010). Knowledge and intangible assets have become an essential element of the production of products and services and is nowadays the key engine of productivity and long-term economic growth (Acs and Audretsch, 2010; Ante, 2004; Agrawal, 2001; Schiuma and Lerro, 2008; Yasar and Schiuma, 2007). Therefore, economies in the developed and developing countries are becoming increasingly dependent on intangible assets and knowledge producers.

Universities are increasingly being viewed by policymakers as engines of innovation through the technology transfer office (TTO) (Libecap et al., 2005). In recent years, the transfer of knowledge from universities to industry, facilitated by the TTO, has gained considerable attention because knowledge produced in universities can spur business innovation, foster competitiveness, and promote economic and social development through academic entrepreneurship (Algieri et al., 2013; Romano et al., 2014; Secundo et al. (a), 2015). In the wake of various new Intellectual Property Right (IPR) legislation, TTOs at universities in developing countries have had a reactive rather than a proactive approach to technology transfer (Taylor, 2009). There are a number of barriers to successfully transferring best practice between TTOs, amongst these is the need to understand how well a TTO is performing at present, and why it is not performing better (Granieri and Frederick, 2015). These barriers become more evident in the case of developing countries. The process of innovation in developing countries is different from that of developed countries, with mature technologies often being adopted with limited success. Indeed, several papers have highlighted the problems that exist with transferring best practice in different countries due to the differences in maturity (Granieri and Frederick, 2015; Kostova, 1999). A recent paper (Weckowska, 2015) also highlights the importance of time and how the commercialization practices of each TTO shapes over time. The author adds that TTOs learn through experimentation and failure, and by sharing these experiences with other TTOs, thereby improving the technology transfer process.

Data Envelopment Analysis (DEA) has been regarded as a proper approach to measuring the university technology transfer efficiency (Kim et al., 2008). This approach focusses, however, on measurable outcomes of technology transfer which mostly relate to monetary values. A survey on TTOs in the USA found that over 50% lose money on their technology transfer operations while only 16% are self-sustaining (Abrams et al., 2009). Their study found furthermore, that fewer than 10% of U.S. institutions' technology transfer programs are primarily motivated by financial return. Considering then how few TTOS are financially self-sustaining and are motivated by financial returns, focussing on monetary values alone is not an accurate measure of efficiency. Especially in developing countries where the process of technology transfer is a fairly new development, such as South Africa where most TTOs have only had their inception in 2010.

Intangibles and non-monetary factors are becoming essential in the value creation processes of regional and national economies (Ante, 2004; Secundo and Elia, 2014). Sorensen and Chambers (2008) have emphasized the importance of the balance between economic metrics and non-monetary benefits for the assessment technology transfer. Furthermore, several papers (Oliveira and Teixeira, 2010; Bercovitz et al., 2001) have highlighted the importance of the formulation and implementation of a technology transfer strategy in improving efficiency. Within said strategy, non-

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monetary factors such as information flow, organizational design and structure, human resource management practices in the TTO and presence of reward systems should be addressed (Libecap et al., 2005).

Taking into consideration then, the research gaps articulated above, this paper aims to answer the following research question: which non-monetary indicators may be used to measure the efficiency of the Technology Transfer Office (TTO) according to different maturity levels in developing countries?

Framed in the above premises this study aims to develop a Maturity Model to measure the efficiency of the TTO using non-monetary indicators. The non-monetary indicators will be prioritized and weighted using the fuzzy analytical hierarchy process (AHP) as it employs a fuzzy set theory, based on literature, to handle the ambiguities inherent in non-monetary indicators (Javanbarg et al., 2012). The Maturity Model will be inspired by the Berkley $(PM)^2$ Model (Kwak and William, 2000) which allows an organization to determine strengths and weaknesses, and to focus on weak practices to achieve higher maturity. The main components of the model will cover the efficiency areas identified from the literature: Intellectual Property (IP) Strategy and policy; Organization design and structure; Human resource; Technology; Industry links; and Networking. The findings will then inform a customizable solution to barriers to the success of technology transfer and highlight weaknesses within each institution or TTOs efficiency which may be improved upon to further aid success.

The remainder of the paper will be organized as follows: section 2 will discuss relevant literature on technology transfer and efficiency indicators, highlighting the research gap addressed. Section 3 will detail the research methodology employed by this paper. Section 4 will discuss the findings of this study and explain the novel contribution. Section 5 will discuss and conclude the findings and possible applications.

2.2 Literature

University Technology Transfer Office

In the last few decades, the economies of developed countries have become increasingly knowledge dependent (Brinkley and Lee, 2006). The traditional roles of universities, as knowledge producers and disseminators, are now being reconsidered (Bercovitz and Feldman, 2006; Etzkowitz and Klofsten, 2005; Löfsten and Lindelöf, 2002). Universities have new responsibilities in helping transform knowledge generated by university researchers in the creation of value in terms of the socio- economic development (Redford and Fayolle 2014; Romano et al., 2014; Secundo et al. (b), 2015). However, to take benefits from knowledge, its necessary to transform the results of research from the university to society. This specific form of knowledge valorisation is known as university technology transfer (Vinig and Lips, 2015). It, therefore, comes as no surprise that technology transfer is generally recognized as an immensely valuable process, improving local economic development, generating novel products and services, and generally enhancing the quality of life through various spill-over effects (Shane, 2004). The majority of universities in the Western world have incorporated technology transfer in the university objectives, besides the traditional goals of education and research (Rasmussen et al., 2008). To assist and stimulate technology transfer, the majority of universities have established TTOs. TTOs are primarily responsible for the protection of university created IP, and the management of the commercialization process (Markman et al., 2005). A TTO can be considered, according to Tahvanainen and Hermans (2011) as a process catalyst, a knowledge converter and, an impact amplifier. Universities are not equally successful in commercializing their knowledge.

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Often TTOs are tasked with not only technology transfer but also research commercialization, which is the process of turning inventions into marketable products (Harman, 2010). The process of research commercialization, as Stock and Tatikonda (2000) rightly observe, depends on the technology and more over on the TTO. Siegel et al. (2004) published a linear model depicting the technology transfer process, including the research commercialization phase, and defined the phases as follows: Scientific discovery; Invention disclosure; Evaluation of the invention for patenting; Patent; Marketing of technology to firms; Negotiation of license; License to firm. Considering then the broader context of technology transfer, Figure 2.1 illustrates this process.

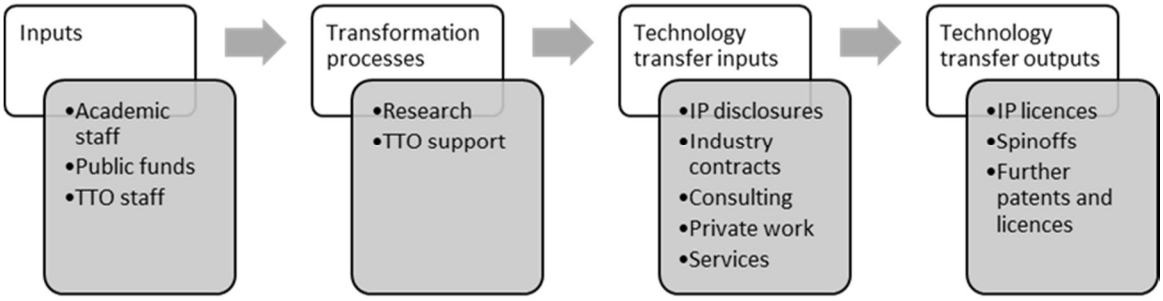

Figure 2.1: The technology transfer process (adapted from Rossi (2014))

Many stakeholders such as academic researchers, TTOs, and private industry are involved in the technology transfer process. Among those three players, TTOs are considered by many to be key stakeholders to determine a university's overall success at this business process (AUTM 2004). Several studies (de Falco, 2015; Tahvanainen and Hermans, 2011) have shown that a great deal of these TTOs operates inefficiently (Anderson et al., 2007). Oliveira and Teixeira (2010) state that only half of the TTOs in the USA are operating profitably. This may be due to the short term (5 to 10 years) their programs have been in operation. Considering then that many TTOs in developing countries have been in operation for such short terms, it is not surprising that they operate inefficiently.

Efficiency of Technology Transfer

The term 'technology transfer' is broad and not easily measurable (Agrawal, 2001). The technology transfer process includes different phases and stakeholders previously highlighted, and the performance is measured by monetary income generated by the university. Despite the fact that nearly all universities carry out technology transfer activities, most of the TTOs are not making money out of their commercialization activities (Rasmussen et al., 2008). Using income from technology transfer, however, does not measure real performance as it does not provide nor is it based on the potential for technology transfer based on university research (Vinig and Lips, 2015).

For these reasons literature reported a new way to measure the efficiency of university TTOs. Tools, such as DEA can and have been used in the past to explore organizational characteristics such as the existence of a medical school or being a private or a public university (Libecap et al., 2005; Thursby et al., 2001). Other non-monetary indicators such as the age (Carlsson and Frith, 2002) and size (Thursby et al., 2001) of the TTO has an impact on efficiency as well as the royalty shares to faculty (Friedman and Silberman, 2003; Lach and Schankerman, 2004; Debackere and Veugelers, 2005). The latter is generally governed by the IP policy of the institution (Siegel et al., 2007). Additionally, several papers have been

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published with recommendations to improve the efficiency of TTOs. Universities need to improve their understanding of the firms' needs that can potentially commercialize their technologies (Siegel et al., 2003; Anderson et al., 2007). Furthermore, the TTO should switch to incentive compensation and should recognize the value of personal relationships and social networks involving scientists (Curi et al., 2012). Another recommendation is to increase formal and informal networking between scientists, TTO staff and industry as it may lead to increased efficiency (Kim et al., 2008; Siegel and Waldman, 2003). According to Siegel et al. (2004) universities should: modify reward systems to reward technology transfer activities; provide more education to overcome informational and cultural barriers; devote additional resources to technology transfer; be less aggressive in exercising intellectual property rights; and increase marketing expertise in the TTO (Phan and Siegel, 2006).

Libecap et al. (2005) add several recommendations on the formulation and implementation of a technology transfer strategy. Within said strategy choices regarding information flow, organizational design and structure (Bercovitz et al., 2001), resource allocation, human resource management practices in the TTO and reward systems should be addressed. Additionally, the university should have a clear, transparent and consistent vision for technology transfer, with strategic goals and priorities, which will allow for more efficient matching between the TTO and scientists. A further recommendation is that universities must develop the expertise to manage their licensing portfolio as a set of options, as this type of management has implications for the selection, training and development of TTO personnel (Chapple et al., 2005). According to a model created by Heher (2006) it can take up to 10 years for an institution, and 20 years nationally, to attain a positive rate of return from an investment in research and technology transfer.

To our best knowledge very little literature has measured the efficiency of technology transfer in developing countries (de Falco, 2015), and up to now literature has only taken account of economic factors for measuring efficiency (Anderson et al., 2007; Curi et al., 2012; Kim et al., 2008; Siegel et al., 2007) and not non-monetary, intangible indicators. Furthermore, these indicators differ in their maturity level between developed and developing countries, as developed countries generally are more mature (Hobday, 2005). As mentioned above age is linked to the efficiency of technology transfer (Libecap et al., 2005; Siegel et al., 2003; Siegel et al., 2007) and yet no literature has connected maturity levels and efficiency of non-monetary indicators.

2.3 Research methodology

Framed in the above premise the study aims to answer the following research question: which non-monetary indicators may be used to measure the efficiency of the TTO according to different maturity levels in developing countries?

Research context

The Global Innovation Index (GII) (2015) report uses a tool measuring 84 metrics to gauge the "innovation index" per country (Cornell University, 2015). The GII (average) and Innovation Efficiency Ratio is the final function based on the two main sub-indexes, innovation input and innovation output. The Innovation Efficiency Ratio serves to highlight those economies that have achieved more with less as well as those that lag behind in terms of fulfilling their innovation potential. It is designed to assess the effectiveness of innovation systems and policies and can point out inefficient innovators. Technology transfer is considered to improve innovation performance and accelerate the dissemination of new technologies from universities through TTOs (Oliveira and Teixeira, 2010) and, therefore, has a crucial role to play in improving the efficiency of innovation.

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Research approach

The research approach is structured around three main phases. In the first phase, starting from the literature, several non-monetary indicators, which have been grouped into six efficiency areas, have been identified. Since each efficiency area which can be used to measure the efficiency of technology transfer is ambiguous, in the second phase of research, the fuzzy AHP is used to define the priorities and weights of each area.

The AHP is a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales (Saaty, 2008). AHP has successfully been applied to the ranking process of decision-making problems, and the main advantage of the AHP is its inherent ability to handle intangibles, which are present in any decision-making process (Javanbarg et al., 2012). The fuzzy AHP employs a fuzzy set theory, based on literature, to handle uncertainty and overcome this limitation. Next, a fuzzy comparison matrix of the above efficiency areas (C1 – C6) was created using Saaty's scale (Saaty, 2008). According to this scale the relative importance of the two sub-elements can be: 1 Equally important; 3 Moderately important with one over another; 5 Strongly important; 7 Very strongly important; 9 Extremely important. The comparison matrix was then used to calculate the relative priority weights of each efficiency area.

Finally, in the third phase, in order to measure the maturity level of each non-monetary indicator a scale is created and inspired by the Berkley $(PM)^2$ Model. The Berkley $(PM)^2$ Model (Kwak and William, 2000) breaks down project management (PM) processes and practices into nine PM knowledge areas and five PM phases based on best practice and literature reviews. The level of maturity ranges from 1 (low) to 5 (high) using a Likert scale, and allows an organization to determine PM strengths and weaknesses. The organization can therefore selectively focus on weak PM practices to achieve higher PM maturity.

2.4 Findings

In this section moving from the research approach above described, a Maturity Model to measure the efficiency of technology transfer by focussing on non-monetary indicators is developed. The literature synthesis has revealed non-monetary indicators can be grouped according to thematic similarity into the following six efficiency areas: IP Strategy and policy (Siegel et al., 2007); Organization design and structure (Bercovitz et al., 2001); Human resource (Phan and Siegel, 2006); Technology (Stock and Tatikonda, 2000); Industry links (Anderson et al., 2007); and Networking (Kim et al., 2008). The area of IP strategy and policy focusses on the institutional support given to technology transfer. Organization design and structure looks at the TTO and surrounding support functions. The human resources of the TTO are considered in terms of their skill sets. The technology area emphasizes the importance of the stage of development of the disclosed technology, as well as the academic merit of the discloser. Industry links are distinguished from the network area in that it is concerned with understanding the needs of industry, whereas the network area is concerned with the interaction between the parties involved. The AHP is used to help organize the critical aspects of a problem in a hierarchical structure, making the decision process easy to handle and, therefore, an analytical hierarchy model was set up as illustrated in Figure 2.2.

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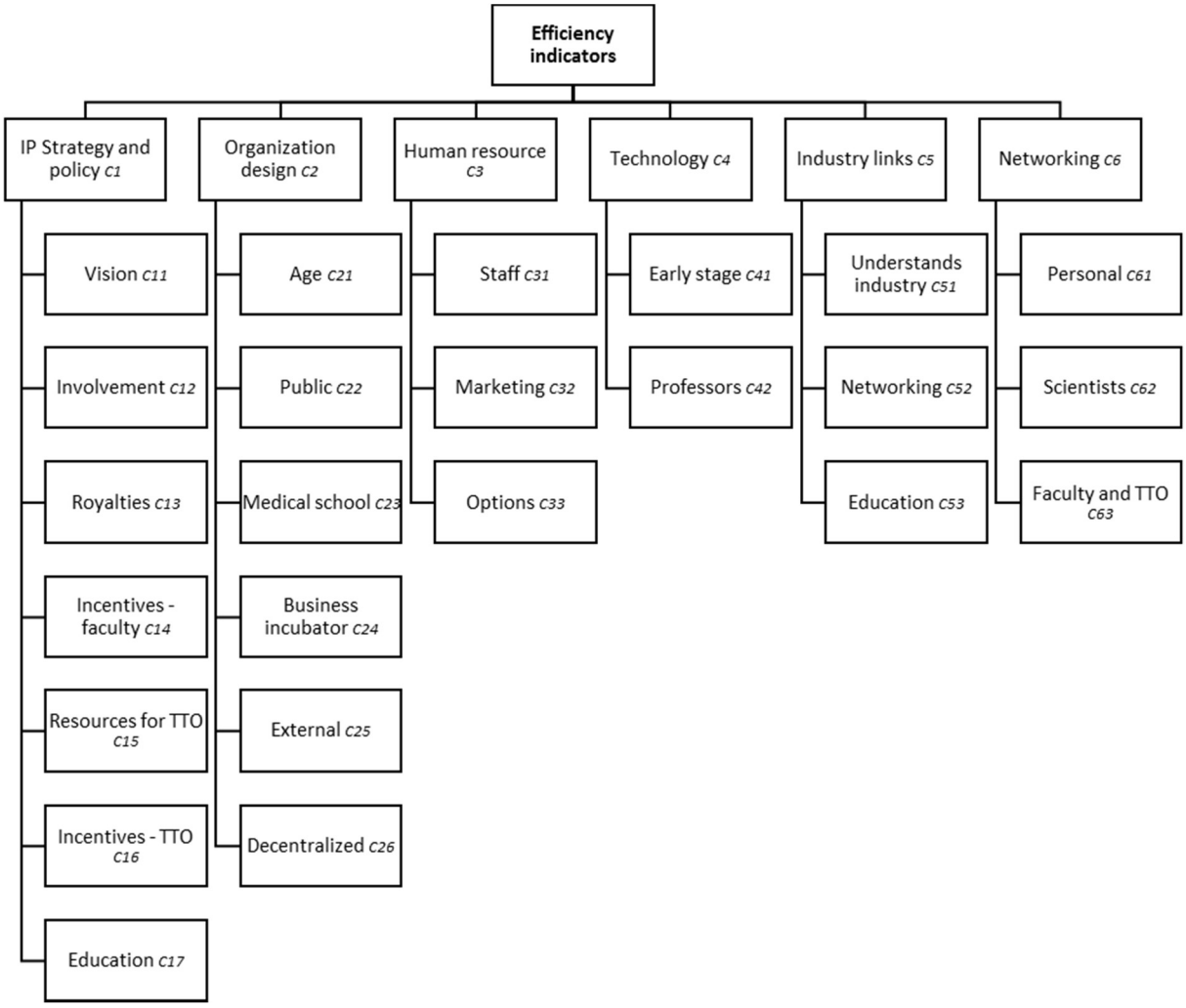

Figure 2.2: The hierarchy model of the evaluation of efficiency of technology transfer

The fuzzy AHP is then applied as a simple prioritization method to derive exact priorities from fuzzy comparison judgments. In this way, each area can be weighted by comparing the relative importance of each area with another using the Saaty scale. Therefore, a pair-wise comparison of each area, as shown in Figure 2.2, was conducted by assigning a value between 1 and 9 according to how much one area was considered more important than the other. A percentage is then assigned in accordance with the weight of each area. Using the fuzzy comparison matrix, the efficiency areas were prioritised and weighted in the following order: 1) Human Resource (100%); 2) IP strategy and policy (80%); 3) Networking (60%); 3) Industry links (60%); 5) Technology (40%); 6) Organization structure and design (20%). Networking and Industry links were ranked as equally important, sharing third place. The efficiency areas were accordingly arranged in the self-assessment tool (Table 2.1).

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Table 2.1: Self-assessment tool: Non-monetary indicators of efficiency of technology transfer

Efficiency area and indicators	Likert scale				
1. Human resource *C3*	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
C31 Staff: TTO has sufficient number of staff					
C32 Marketing: At least one staff member has marketing experience					
C33 Options: At least one staff member has the expertise to manage the licensing portfolio as a set of options					
2. IP Strategy and policy *C1*	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
C11 Vision: Clear, transparent and consistent vision for technology transfer, with strategic goals and priorities.					
C12 Involvement: Frequent and reciprocated involvement with faculty					
C13 Royalties: Royalty shares for faculty					
C14 Incentives - faculty: Incentives for faculty to disclose					
C15 Resources for TTO: Sufficient resource allocation to TTO					
C16 Incentives - TTO: Incentives for TTO staff					
C17 Education: Provide education to overcome informational and cultural barriers between TTO and Faculty					
3. Networking *C6*	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
C61 Personal: TTO has personal relationships with faculty					
C62 Scientists: TTO facilitates formal and/or informal networking between scientists					
C63 Faculty and TTO: Formal and/or informal networking between faculty and TTO					
3. Industry links *C5*	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
C51 Understands industry: TTO understands the needs of industry					
C52 Networking: TTO facilitates formal and/or informal networking between faculty and industry					
C53 Education: Provide education to overcome informational and cultural barriers between TTO and industry					
5. Technology *C4*	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
C41 Early stage: Most technology disclosed to TTO is not at an early stage					
C42 Professors: Most faculty members who disclose are Professors					
6. Organization design and structure *C2*	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
C21 Age: TTO has been established for 10 years or more					
C22 Public: University is publicly owned					
C23 Medical school: University has a medical school					
C24 Business incubator: A business incubator is available for faculty					
C25 External: TTO is positioned externally to the University					
C26 Decentralized: TTO has a decentralized management style					

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Each indicator (column 1) was rewritten to a statement (column 2) and will be assessed on an ordinal, 5 point Likert scale, according to the strength with which the statement is true (Table 2.1). The scores for each statement and its corresponding non-monetary indicators are then calculated for each efficiency area. For example: if a TTO has sufficient staff, at least, one of which has marketing experience and, at least, one of which has experience in managing the licensing portfolio as a set of options, then for the human resource area that TTO will receive a score of 15.

The priorities assigned to each efficiency area by the fuzzy AHP are then used to calculate a final score for the efficiency of technology transfer. Using the example above, the human resource area received the highest priority according to the fuzzy AHP, thus, 100% of the score will be used in the final calculation. If the same TTO in the example doesn't understand the needs of industry, doesn't facilitate networking between industry and faculty and doesn't provide education to overcome informational and cultural barriers between TTO and industry, then for the industry links area that TTO will receive a score of 3. The fuzzy AHP assigned a priority of 3rd place, and therefore 60% to this area. Therefore, the final score used in the calculation will be 1.8.

Accordingly, the highest score that can be obtained is that of 71 (Human resource – 15; IP strategy and policy – 28; Networking – 9; Industry links – 9; Technology – 4: Organization design and structure – 6). Similarly, the lowest score that can be obtained is that of 14.2. Based on this final score, the maturity level can then be assigned according to the principles of the Berkley $(PM)^2$ Model. Upon self-evaluation of each of the efficiency areas, a TTO will then be able to focus on weaknesses within their efficiency, and be able to achieve a higher maturity. The maturity levels are illustrated in Table 2.2.

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Table 2.2: Maturity level of TTO based on efficiency areas

Maturity Level	Key TTO characteristics
5 Sustained stage (71)	Sufficient amount of human resources with correct skill set Royalties AND incentive schemes for faculty and TTO Strong networks AND industry links Technology disclosed when market ready Decentralized, external TTO with business incubator
4 Integrated stage (52 – 70)	Some staff with marketing skills AND options training Royalties OR incentive schemes for faculty and TTO Strong networks OR industry links Technology disclosed when prototype is available Decentralized, external TTO without business incubator
3 Managed stage (34 – 52)	Some staff with marketing skills OR options training Royalties OR incentive schemes for TTO Networks OR industry links Technology disclosed when proof of concept is available Decentralized, internal TTO without business incubator
2 Defined stage (15 – 33)	Sufficient amount of human resources Royalties OR incentive schemes for faculty Networks Technology disclosed early stage Centralized, internal TTO without business incubator
1 Awareness stage (14.2)	Insufficient amount of human resources No royalties or incentive schemes No networks or industry links Technology disclosed prior to publication No structured management of TTO

Each maturity level as indicated in Table 2.2 provides a description of the characteristics associated with that level which may be used by the TTO to make strategic decisions on how to improve certain areas and to sustain the decision-making process more effectively.

2.5 Discussion and conclusion

There is a substantial body of literature from developed countries which documents and investigates technology transfer and TTOs and provides insight on how to be more efficient at technology transfer (Rasmussen, 2008). The application of these insights to the developing country context has not been very successful (Kloppers et al., 2006). Technology transfer remains a problematic topic for many universities because of the context into which they are trying to apply the best practice of developed countries. Literature revealed that even though non-monetary indicators have a significant impact on the efficiency of technology transfer, no studies had yet used these indicators as a measure of efficiency. This study, however, aims to break down these barriers of transferring best practice of technology transfer by recognizing the differences in maturity of TTOs.

At this aim a Maturity Model to measure the efficiency of TTO is developed. The non-monetary indicators found in literature can be grouped according to thematic similarity into six efficiency areas: IP Strategy and policy; Organization design and structure; Human resource; Technology; Industry links; and Networking. When trying to understand how a TTO is performing at present and why it is not performing better, looking at these efficiency areas should highlight weaknesses and strengths within each TTO. When addressing an identified weakness, the non-monetary indicators show

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what may be improved upon to increase the strength of an efficiency area. The Maturity Model allows the TTO to make strategic decisions in order to improve the efficiency of the TTO. Moreover, the Model provides a theoretical continuum along which the process of maturity can be developed incrementally in a TTO from one level to the next, moving from awareness, defined, managed, integrated, and sustained stages. The maturity levels can be used as an internal assessment, but also for external reporting by the TTO. Considering then the maturity level of the TTO as based on its strengths and weaknesses in each efficiency area and corresponding non-monetary indicator, the barrier to successfully transferring best practice, as identified by Granieri and Frederick (2015) is removed.

Therefore, if a best practice is identified in one TTO that may improve upon a weakness identified in another TTO, and if both these TTOs have the same maturity level as indicated by the Maturity Model then the chances of successfully transferring best practice is increased. Furthermore, should a TTO in a developing country identify a best practice in a developed country, but both these TTOs do not have the same maturity level, then the TTO in the developing country can make strategic decisions to increase its maturity level so that the best practice may be adopted successfully.

This Maturity Model is dynamic in its ability to evaluate the efficiency of technology transfer at a TTO using non-monetary indicators. Once completing the self-assessment using the tool created, the TTO has a snapshot of how it is performing at present. Repeating this self-assessment periodically can then provide the TTO with information on how it is performing over time. Thus, this Maturity Model has two typologies of insights, in time and space, which may be of value for the TTO. In space, the snapshot provides a standard for comparison with other TTOs, in order to determine which best practices may be transferred. In time, the Maturity Model may be used to monitor improvements and to predict future performance. Similar to the work that was done by Kim et al. (2008) a predictive efficiency pattern may be created in time.

The limitation of this study, however, is that the priorities and weights assigned to each efficiency area is based on fuzzy theory and next steps include collecting empirical data to determine the accuracy of the priorities and weights of the self-assessment tool. Future work will test and validate the Maturity Model in TTOs in developing countries.

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Conclusions: Chapter 2

The published article entitled: "Measuring University Technology Transfer Efficiency: A Maturity Level Approach" above was included in this chapter of the portfolio to address the first two objectives of this study:

1. Create a self-assessment tool using intangible indicators of efficient technology transfer.
2. Translate the data collected with this tool to understand the performance of the TTO.

As highlighted in Table 1.1 (Chapter 1, Heading 1.8, page 21) the outcomes of these two objectives are the self-assessment tool (as seen in Table 2.1 of the article) and maturity model (as seen in Table 2.2 of the article).

The self-assessment format was chosen given that the indicators are non-monetary and intangible in nature. The risk of using a self-assessment tool lies in the subjectivity of the assessor, and as such both yes/no and degrees of access indicators (rewritten as statements) are included in the self-assessment to minimise the risk. Additionally, certain non-monetary, tangible indicators were chosen (and rewritten as statements) which could be corroborated to correct any skewness of the data resulting from self-assessment.

The indicators were weighted using fuzzy AHP, which has been noted as a weakness of this tool. This will be corrected during the validation and verification of the tool in Chapter 3, where expert opinions will be used to weight the indicators. This will be the first reiterative improvement of the self-assessment tool.

The article illustrated how the self-assessment tool was created, which indicators were chosen, and how they were weighted and prioritised. The article also discussed the creation of the maturity model to translate the results from the self-assessment tool into a characterisation of the TTO's performance.

The project management process maturity model was selected as the basis for the maturity model created to allow for the internal level of intervention. The $(PM)^2$ model highlights strengths and weaknesses within a process, which allows the TTO to intervene to improve efficiency. Translating the data collected by the self-assessment tool in this way allows the TTO to understand its performance.

In summary, objectives one and two were addressed, and the creation of a new tool necessitates validation and verification. Thus, the following chapter will look at addressing the third objective and the various ways in which a new tool can be validated and verified.

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CHAPTER 3: Evidence Supporting the use of the Novel Approach

Validation and Verification

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Evidence supporting the use of the novel approach

Introduction: Chapter 3

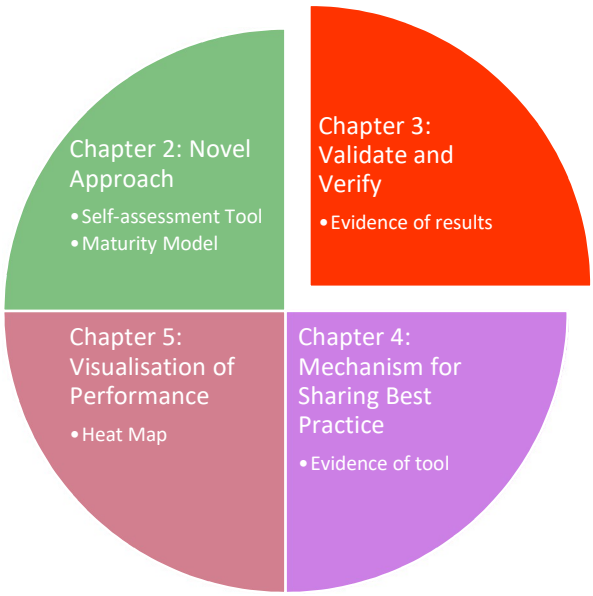

Figure 1.2: Contextual guide

In Chapter 2 the first two objectives of this study were discussed and addressed. A new self-assessment tool was created to measure the efficiency of university technology transfer using intangible and non-monetary indicators. This tool is supplemented by a maturity model which serves to translate the collected data into characteristics which can be used to understand the performance of the TTO.

However, as this is a new tool, both aspects of the tool need to be validated and verified and therefore the third objective of this study is:

3. Validate and verify the tool.

The outcome of this objective will therefore be evidence that the results from the self-assessment tool and maturity model are valid, and that they can be verified. Validation can be achieved through live-testing and expert interviews. Verification can be achieved through case study and expert interviews. Therefore, the outcome will be achieved through qualitative methods:

1. Making use of a survey to live-test the tool in order to validate the tool.

2. Making use of expert interviews to validate and verify the tool.

3. Making use of a case study to verify the results of the tool.

In this third chapter, one published and one accepted article are included. Therefore, Chapter 3 will be divided into two sections (3.1 and 3.2) to introduce each article individually.

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Introduction: Section 3.1

The first article tests the tool through live-testing, expert interviews and reiteration. In this case the tool was converted to an online survey and sent to TTOs in Europe. It was decided to test the tool in developed countries as these countries have been engaged in university technology transfer for longer than developing countries. As each TTO completed the survey, contact was made and an interview requested.

During the interview the results of the self-assessment tool were discussed with the TTO to determine the accuracy of the results. Interview questions included:

1. Please describe your TTO in terms of organizational structure, mission, age, staff and capabilities.
2. According to the self-assessment your TTO scored XX and is therefore at maturity level X. Maturity level X is described as […]. Do you agree with this assessment?
3. According to the self-assessment the following weaknesses were identified:[…] Do you agree with this?
4. Are there any indicators which you believe should be included in the tool?
5. Do you agree with the framework chosen for the tool and maturity model?

The interviews also allowed the opportunity to discuss the tool, and to highlight any weaknesses or limitations of the tool to improve it through iteration.

The new self-assessment tool created is based on intangible and non-monetary indicators. Upon closer inspection of these indicators, strong correlations with intellectual capital are found. As such, another aspect discussed in this article is how intellectual capital in its classifications as human, relational and structural capital can be leveraged. The article argues that the self-assessment tool measures presence of and access to intellectual capital in the form of determinants of effectiveness of university technology transfer. Therefore, access to intellectual capital is a key factor in the efficiency of technology transfer.

It should be noted that at the time of submitting both these articles, the first article detailing the self-assessment tool and maturity model had not yet been published. As a result, there is some duplication in explaining the tool to the reader. In addition, as these articles were submitted to journals in different fields, the writing style and terminology differ to align with the theme of each journal.

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Mobilising Intellectual Capital to improve European Universities' competitiveness: The Technology Transfer Offices' role

Authors: Christle De Beer, Giustina Secundo[1], Corne Schutte, Giuseppina Passiante[1]

[1]University of Salento, Lecce, Italy

Stellenbosch University, Stellenbosch, South Africa

Abstract

Purpose Universities concerned with third mission activities are engines that increase regional competitiveness since their primary role in the knowledge-based economy is to stimulate innovation by transferring new knowledge and technologies to industry and society. Due to the correlation between efficient university technology transfer and intellectual capital (IC), this study will show how IC can be mobilised by university technology transfer offices (TTOs), so contributing to the third stage of IC research.

Design The application of the Maturity Model developed by Secundo et al., (2016) is expanded by collecting data from 18 universities in European countries to illustrate how IC can be used as a strategy and solution to the barriers faced by TTOs.

Findings TTOs with increased access to and utilization of IC tend to have higher maturity levels. This new application of the Maturity Model, proves that IC can be utilized to manage and improve the efficiency of TTOs.

Research implication An indication of the level of access that TTOs have to university IC is given leading to recommendations to improve university technology transfer.

Practical implications Knowing which IC components are essential to the efficiency of TTOs, and which IC needs greater utilization, will provide insights into policy and practical interventions to improve their efficiency, resulting in increasing universities' competitiveness.

Originality A new approach and perspective on utilizing IC to improve university technology transfer so contributing to the third stage of IC research calling for more practice-oriented research.

Research limitations Future research should include a wider sample of universities to increase the validation of the Maturity Model and to prove it as a suitable and strategic approach for IC management at TTOs.

Keywords: Intellectual Capital (IC), University competitiveness, University Technology Transfer, Maturity model, Technology Transfer Office (TTO), efficiency

Article classification: research paper

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3.1.1 Introduction

The third mission considers universities to be a key factor in economic and social development (Bercovitz and Feldman, 2006), in addition to their first mission, to teach, and their second mission, to research (Laredo, 2007). This evolving mission requires universities to shift from an administrative focus to a strategic one. To date, university management has been built around a culture of collegium and bureaucracy (McNay, 1995), but a 'new wave' of management thinking in the private sector is now permeating the public one (Brereton and Temple, 1999). This shift from traditional bureaucratic management to modern public management (Sotirakou and Zeppou, 2004; Cabrita and Vaz, 2006) is leveraged by the utilization of intellectual capital (IC) in the public sector encouraged by the success of IC in the corporate sector. In the knowledge economy, the importance of IC as a unique resource and foundation of business success, and as a source of competitiveness has been acknowledged equally by academics and practitioners (Sveiby, 1997; Bontis 1998; Lev and Daum, 2004; Pike and Fernstrom, 2005; Kong and Thompson, 2009; Edvinsson, 2013; Dumay and Rooney, 2016).

For this reason, increasing attention is being paid to IC in the management literature (Secundo et al., 2015). During the last two decades, some attempts have been made to apply IC models in universities and research centres especially in European countries (Leitner et al., 2014; Ramirez and Gordillo, 2014; Veltri and Silvestri, 2015) because intangible assets and IC constitute the largest proportion of a universities' assets (Sánchez et al., 2009; Secundo et al., 2010). The competitiveness of individuals, organizations and regions tend to increase based on their capacity for managing and valorising their knowledge assets or IC (Schiuma, 2009; Schiuma and Lerro, 2010) and in the case of universities, this form of knowledge valorisation is known as university technology transfer (Vinig and Lips, 2015). It, therefore, comes as no surprise that technology transfer is generally recognized as an immensely valuable process, improving local economic development, generating novel products and services, and generally enhancing the quality of life through various spill-over effects (Shane, 2004).

Indeed, according to Siegel et al. (2003) success in university technology transfer is a critical factor in sustaining global competitiveness and therefore it is crucial to know how efficient a technology transfer office (TTO) is at this process (Resende et al., 2013). According to Resende et al. (2013), there is no generally accepted method to verify systematically the performance of an institution's TTO. Little is known about the performance of the TTO, if it is adequate, if it can be improved, if improvements are possible, or how to intervene to improve efficiency and effectiveness. TTO performance measurements are emergent in nature with many aspects of technology transfer not being adequately addressed, such as intangible assets (effectiveness, impact, efficiency) and thus there is a need for more fine-grained TTO performance measures (Miller et al., 2016).

Secundo et al. (2016) created a self-assessment tool and accompanying Maturity Model which aims to assess the efficiency of a TTO at university technology transfer through the adoption of indicators based on IC. Specifically, the self-assessment tool measures various intangible indicators grouped into six efficiency areas namely: human resources, technology, intellectual property (IP) policy and strategy, organization design and structure, networking, and university-industry links. These six efficiency areas incorporate the tripartite classification of IC, which structures IC with regard to three elements: human capital, structural capital or organizational capital and relational capital (Secundo et al., 2015). The Maturity Model (Secundo et al., 2016) therefore allows a university to evaluate the efficiency of university technology transfer using non-monetary

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indicators and IC, so contributing to the limitations of using just monetary indicators for profit purposes.

Moving from the mentioned gap and in accordance with the third stage of IC research that calls for more applications of IC in practice (Dumay, 2013; Dumay and Garanina, 2013), this paper aims to explore how the self-assessment tool (Secundo et al., 2016) may be applied to gain better insights into the relationship between the level of utilization of IC and the increased efficiency of the university TTO. The self-assessment tool measures the efficiency of a TTO at university technology transfer by focussing on how university IC is being managed by the TTO. By using the data collected by the self-assessment tool of European TTOs this paper will, however, determine the level of access a TTO has to the IC of the university, and if the IC is being sufficiently utilized to improve university technology transfer. Discussions about the regional competitiveness of the countries where the university TTOs are located will be highlighted.

The remainder of the paper will be organized as follows: the next section will discuss relevant literature on the role of the university in increasing competitiveness in European countries, university TTOs, and mobilising IC as a tool to improve technology transfer efficiency. Next, the research methodology adopted and findings will be described. The final section will discuss and conclude the paper highlighting implications for theory and practices as well as future research.

3.1.2 Literature background

This section aims to shed some light on this field by examining the role of universities in contributing to regional development, how the university TTO and its efficiency influences competitiveness, what IC is in the context of universities and how it can be used to improve the efficiency of university technology transfer.

The role of universities in European countries for regional competitiveness

Literature pertaining to National Innovation Systems (e.g. Lundvall, 1992), Regional Innovation Systems (e.g. Cooke et al., 1997), and developments surrounding the Triple Helix (e.g. Etzkowitz and Leydesdorff, 2000) have explained the role of universities in economy and society. Recent studies have focused on the changing role of the university with the move from first mission (teaching) and second mission (research) activities, towards embracing the third mission (closer connections with society). Generally, "third mission" activities comprise three dimensions performed by universities in relation to external environments: technology transfer and innovation, continuing education, and social engagement (E3M, 2010). Hsu et al. (2015) remarked the key role of the transfer of university technology to industry through a multitude of mechanisms including launching technology-oriented start-ups, and providing collaborative research, contract research, consulting services, technology licensing, graduate education, advanced training for enterprise staff, exchange of research staff, and other forms of formal or informal information transfer.

The changing funding environment and innovation systems in which universities now operate has called for universities to not only have greater dialogue between science and society but also to contribute towards regional development through basic and applied research endeavours, and the development of human capital and cultural capital for social cohesion (OECD, 2008; European Commission, 2014). More emphasis is placed on higher education institutions contributing measurable results to justify the amount of public funding received (Edwards, 2013), thus requiring universities to abandon their "ivory tower" status (Hershberg et al., 2007), and become more connected with society at large. European public policies

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regarding higher education are highlighting the role of such institutions in knowledge-based economies (Gonzalez-Loureiro and Teixeira, 2011). As stated by European Commission (2003), the main goals for universities must be production, diffusion and knowledge transfer. Therefore, the traditional roles of universities, as knowledge producers and disseminators, are now being reconsidered (Bercovitz and Feldman, 2006). Universities have new responsibilities in helping transform knowledge generated by university researchers in the creation of value in terms of the socio-economic development (Redford and Fayolle, 2014).

Innovation is viewed as a strategic asset for the competitiveness of individuals, organizations and countries. At a territorial level, this competitiveness increases depending on the capacity of acquiring, developing and managing intangible assets for creating the conditions of socio-economic wellness for a wide community of stakeholders (Romano et al., 2014). Indeed, measures of the innovation levels of countries, such as the European Innovation Scoreboard (EIS) are becoming increasingly important (EIS, 2016). The EIS distinguishes between three main types of indicators – Enablers, Firm activities, and Outputs – and eight innovation dimensions, capturing in total 25 indicators. The Enablers capture the main drivers of innovation performance and differentiate between three innovation dimensions: Human resources; Open, excellent and attractive research systems; and Finance and support. Firm activities capture the innovation efforts and differentiate between three innovation dimensions: Firm investments; Linkages & entrepreneurship; and Intellectual assets. Outputs capture the effects of firms' innovation activities and differentiate between two innovation dimensions: Innovators and Economic effects.

In the 2016 report, countries in Europe were analyzed and grouped into four different performance groups based on their average innovation performance. Denmark, Finland, Germany, the Netherlands, and Sweden are innovation leaders with innovation performance well above that of the EU average. Austria, Belgium, France, Ireland, Luxembourg, Slovenia, and the UK are strong innovators with innovation performance above or close to that of the EU average. The performance of Croatia, Cyprus, Czech Republic, Estonia, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Slovakia, and Spain is below that of the EU average. These countries are moderate innovators. Bulgaria and Romania are modest innovators with innovation performance well below that of the EU average. The dimensions measured by the EIS are strongly affected and influenced by the performance of universities, specifically within the context of technology transfer. This demonstrates the capacity of universities, with reference to the third mission, to improve a closer connection with the society. Increased efficiency in university technology transfer will influence intellectual assets most strongly, which is a dimension of the firm activities indicator measured by the EIS. This may, therefore, be seen as a means to improve the overall performance of the country.

University Technology Transfer Offices (TTOs)

Research and development institutions, both university-related and others concerned with technology transfer can be seen as the engines that increase industry competitiveness (Sanchez and Tejedor, 1995) and as such the transfer of knowledge from universities, usually undertaken by the TTO, has gained considerable attention. Knowledge produced in universities can spur business innovation, foster competitiveness, and promote economic and social development through academic entrepreneurship (Algieri et al., 2013; Romano et al., 2014; Secundo et al., 2015). The majority of universities in the Western world have incorporated technology transfer in the university objectives, besides the traditional

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goals of education and research (Rasmussen et al., 2008) and to assist and stimulate technology transfer, the majority of universities have established TTOs. University technology transfer is defined as a process, in which science, knowledge or capabilities are transferred or moved from one entity to another for the purpose of further development or commercialization (Lundquist, 2003; Swamidass and Vulasa, 2008).

There are many different types of universities (research university, public university, private university, teaching university), and each university has a different managerial approach and maturity level in terms of the management of intangibles and IC, as well as IP, depending on the national law and internal policies of the university (Secundo et al., 2015). For this reason, there is also a diversity of governance models of technology transfer processes. Recently Schoen et al. (2014) performed a qualitative analysis in which four main types of TTOs are identified: (1) classical TTO; (2) autonomous TTO; (3) discipline-integrated Technology Transfer Alliance; and (4) discipline-specialized Technology Transfer Alliance (TTA). These four types are categorized by four structural dimensions:

1) Degree of discipline specialization – this refers to the disciplines served by the TTO, either all disciplines (discipline integrated) or one discipline (discipline specialized)

2) Degree of task specialization – this refers to technology transfer activities performed by the TTO. Fully integrated would be a TTO which performs research funding services, IP management, and spin-out services. Forward integrated would provide only IP management and spin-out services, backward integrated would provide only research funding services and IP management, and IP specialized would provide only IP management.

3) Level of autonomy – this refers to the dependency of the TTO on university administration, either independent or dependent.

4) Degree of exclusivity – this refers to the amount of universities served by the TTO. Generally, a TTO would serve one university (exclusive) and a TTA would serve more than one university (non-exclusive).

Therefore, the four over-arching types of TTOs identified by Schoen et al. (2014) can be described as follows. The classical TTO is discipline-integrated, dependent, and exclusive. The TTO can be responsible for either all technology transfer activities (fully integrated), or it can be backward integrated or forward integrated and can also be considered as the "internal" type of TTO. The autonomous TTO is similar but has a significantly higher degree of autonomy from the university's administration. The TTO model can be fully integrated, backward integrated, or forward integrated, but not IP specialized. This model can also be considered as the "external" type of TTO. The third type is the discipline-integrated TTA. In contrast with the other two types, it serves more than one university. This TTO model is compatible with full integration, forward integration, or IP specialization. It should be noted that universities using the services of a discipline-integrated TTA usually have an internal university-specific TTO, with a reduced size, and this can be considered as a "combination" type of TTO. The discipline-specialized TTA is similar, but the degree of discipline specialization is high and the TTA can be specialized on IP management and spin-out services (forward integrated) or on all three transfer activities (fully integrated). The optimal design of a TTO depends on the university it serves, on its institutional history, and evolves over time.

Many stakeholders such as academic researchers, TTOs, and private industry are involved in the technology transfer process and usually, the performance of the TTO is measured

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by monetary income generated by the university. One would expect, that due to the fact that nearly all universities carry out technology transfer activities this would be an efficient process, but research shows that most TTOs are operating inefficiently (Rasmussen et al., 2008). Therefore, it is essential that TTOs are given access to everything needed to increase and improve efficiency. As the research by Secundo et al. (2016) shows, and which will be given greater attention in the methodology section, IC might be the source needed by TTOs. Greater access to, and utilization of, IC may serve to solve some of the challenges faced by TTOs in increasing efficiency. Additionally, IC may alleviate some of the barriers to improving the efficiency of university technology transfer.

IC as a resource for university TTOs

Intellectual capital (IC) can be defined as "… the sum of everything everybody in a company knows that gives it a competitive edge … Intellectual Capital is intellectual material, knowledge, experience, IP, information… that can be put to use to create [value]" (Stewart, 1997). The inclusion of the word 'value' in the definition is justified by the application to the public-sector context and not just the 'wealth creation' as described by Stewart. The concept of value, rather than wealth creation, seems to be more appropriate because although value can include wealth, the outputs of a university are mainly intangible (Dumay and Guthrie, 2012). Nevertheless, these definitions seem to agree that IC is a stock of focused, organized information (knowledge) that the organization can use to create value (Edvinsson, 2013). This complexity of defining and conceptualizing IC has become one of the impediments for its acceptance especially, in the public-sector organizations.

IC in a university is, ultimately, the set of intangible and knowledge assets that drive the mechanisms of value creation according to the targets defined by stakeholders of the internal and external environment (Redford and Fayolle, 2014). In the context of universities, IC can be classified with respect to three elements (Secundo et al., 2015). 1. Human capital (HC): the individual competencies, such as expertise, knowledge, and experiences of researchers, professors, technical staff, Ph.D. students and administrative staff. 2. Structural Capital (SC): the research infrastructure, the research and education processes and routines, the university culture and the governance principles. 3. Relational Capital (RC): the university's internal and external relations with public and private partners, the position and image of the university in networks, its academic prestige, its brand, partnerships with the business sector and regional governments, its links with non-profit organizations and civil society in general, collaborations with national and international research centers.

Considering these dimensions in isolation does not explain IC sufficiently. HC, RC, and SC can be useful for universities in general only if they are considered as a whole, with interconnections (Vagnoni and Oppi, 2015). This capital dimension interconnectivity aspect is thus a fourth dimension to consider, to highlight that in knowledge intensive organizations like universities and research centers, the three IC dimensions are related to and interconnected with each other (Habersam and Piber, 2003). In practical terms, the vocation of universities in achieving the third mission requires a focus on the university ecosystems where intangible assets and IC are created and developed on a wider scale (Borin and Donato, 2015). Therefore, the changed IC definition including the fourth dimension aligns with the third mission of universities.

Research devoted to understanding IC has evolved beyond the first and second stage which evaluated IC's influence on financial performance, into its third (Dumay, 2013; Dumay and Garanina, 2013) and fourth stages of

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research (Dumay and Garanina, 2013). Third stage research examines how IC can be used as a management technology in practice (Guthrie et al., 2012), and highlights that identifying and measuring intangible assets is important for increasing the impact of IC (Dumay and Garanina, 2013). Moreover, the third stage considers value as not just monetary (Dumay, 2009). In this case, all evaluation methods of IC become just tools for managers of companies who are more concerned with real implications of IC management for value creation than pure IC measurement. The third stage of IC research focuses on how organizations understand, adapt and apply IC as a management technology (Guthrie et al., 2012), i.e., how IC works inside organizations or IC management through praxis (Dumay and Garanina, 2013). Its central premise is to provide a better view of IC's impact, rather than just producing IC measures (Guthrie et al., 2012). Dumay and Rooney's (2011) findings are consistent with Mouritsen and Roslender (2009) who posit "if the intellectual capital concept is as central as some claim it to be, it is vital that it is fully understood and exploited in the quest for social betterment".

According to the third stage of IC research, IC could be a valid management tool for universities because the way universities are being evaluated by society is also changing (Paloma Sánchez and Elena, 2006; Paloma Sánchez et al., 2009). Universities were once focussed on teaching and research. Today, universities need to contribute to a third mission: developing society and economies (Bercovitz and Feldman, 2006; Laredo, 2007), technology transfer and innovation, continuing education, and social engagement (E3M, 2010). In the university system, the question how IC helps to create value for the society and increase the competitiveness of the region in which the university operates (Dumay and Garanina, 2013; Dumay, 2014) becomes the real concern. To this end, a fourth stage of IC research is emerging that extends IC's boundaries into wider ecosystems like countries, cities, and communities as opposed to specific firms (Dumay and Garanina, 2013).

In the case of university TTOs the use of IC, and more specifically how IC is utilized by TTOs during technology transfer activities, has not been fully investigated. Identifying which IC components are essential to the efficiency of the TTO, and which IC needs greater utilization, will provide insights into policy and practical interventions to improve the efficiency of the TTO, resulting in increased university competitiveness.

3.1.3 Research methodology

Framed on the premises outlined above, this study seeks to answer the question: How can intellectual capital be mobilised as a tool to improve the efficiency of university technology transfer?

Research context and Data collection

To answer the question, the self-assessment tool (Secundo et al., 2016) has been used as methodology. The tool measures the efficiency of university TTO through various intangible indicators (see Appendix 1) grouped into six efficiency areas namely: 1. Human resources, 2. Technology, 3. IP policy and strategy, 4. Organization design and structure, 5. Networking, and 6. University-industry links. These six efficiency areas incorporate the tripartite classification of IC, which structures IC with regard to three elements: a) Human Capital, b) Structural Capital or Organizational Capital and c) Relational Capital (Secundo et al., 2015).

Through internet searches the number of universities per EU member state was identified, and those with a TTO (or similar unit) were contacted by email requesting participation in this study and asked to complete the self-assessment tool. A total of 34 TTOs responded, of which the results of 18 TTOs from Austria, Belgium, Czech Republic, Denmark, Estonia, Germany, Greece, Italy, Netherlands, Poland, Romania, Spain, and Sweden were used.

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Participation in the study was voluntary and some TTOs chose to keep their answers anonymous, therefore only 18 of the 34 responses could be used for the purposes of this study. In the Appendix 2, the complete list of the respondents' universities is given.

Within each university, a different type of TTO structure exists, depending on the chosen IP management strategy. Some universities adopt an internal structure for their technology transfer activities often incorporating technology transfer into research development, research commercialization or research valorisation offices. Alternatively, an internal TTO is established (or a classic TTO), that reports to senior management of the university, often within the ambit of research. Some universities instead establish an external entity (or an autonomous TTO), in the form of a company wholly owned by the university, responsible for technology transfer. In some exceptional cases, universities have opted for a combination model where certain technology transfer services (such as legal counsel) are provided by the university (internal) to the university's external TTO company. In other cases, a different combination model was opted for, where the TTO forms part of a TTA. Each of the 18 respondents' universities was researched to determine which type of structure their technology transfer activities have.

The data have been collected using the self-assessment tool created by Secundo et al. (2016) and the correlation between the intangible indicators in the six efficiency areas of Secundo et al's model and the tripartite classification of IC is as follows (Table 3.1.1):

Table 3.1.1: Correlation between efficient university technology transfer and intellectual capital

a) Human capital (HC) – Expertise, knowledge, and experiences of researchers, professors etc.	
1. Human resources Staff with specific skills (marketing experience, options experience).	**2. Technology** The expertise of researchers leads to the development of high-quality technology.
b) Structural capital (SC) – IP, research infrastructure, research and education processes and routines, university culture and governance principles.	
3. IP policy and strategy Incentives for staff, royalties on license agreements, resources for TTO, Faculty involvement, IP awareness, and education.	**4. Organization design and structure** Structure of technology transfer office and university.
c) Relational capital (RC) – Relations with public and private partners, partnerships with the business sector and regional governments, links with non-profit organizations and civil society in general, collaborations with national and international research centers, networks and alliances.	
5. Networking Within the university between faculty and technology transfer office.	**6. University-Industry links** Relationships and partnerships with industry.

The self-assessment tool, therefore, measures various intangibles and IC within each of the six efficiency areas on an ordinal 5 point Likert scale, each area is weighted using the fuzzy analytical

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hierarchy process (AHP), and a final score is calculated for the efficiency of a TTO at university technology transfer. This score then classifies the TTO at a certain maturity level using the Maturity Model created by Secundo et al., (2016), which indicates which of these intangibles need strategic interventions to increase the efficiency. This is possible because the Maturity Model is based on the Berkley $(PM)^2$ Model (Kwak and William, 2000) which breaks down processes and practices into efficiency areas based on best practice and literature reviews. The level of maturity ranges from 1 (low) to 5 (high) and allows for the determination of strengths and weaknesses, and can, therefore, enable the TTO to selectively focus on weak practices to achieve a higher maturity. The levels of maturity are the Awareness stage (1), Defined stage (2), Managed stage (3), Integrated stage (4) and Sustained stage (5). Each level is furthermore described in terms of the key processes and practices needed for optimal efficiency.

Data analysis

The data collected by the self-assessment tool can be analyzed in a different way. Due to the proven correlations between the efficiency areas and IC, it can be argued that a TTO's relative performance in an efficiency area is a reflection of the access to IC. Therefore, if a TTO's unweighted score in an efficiency area, is expressed as a percentage of efficiency in said area, and this is again expressed as a percentage of IC, some general impressions can be gathered as to the access to IC within the university. As an example, a TTO which scores a total of 6 out of 15 for the efficiency area human resources, can be presented as having 40% of the human resources needed for efficient technology transfer. This same TTO scores a total of 2 out of 10 for the efficiency area technology and thus has access to 20% of the technology needed for efficient technology transfer. The two efficiency areas human resource and technology make up the human capital element within IC. Thus, for the aforementioned TTO, 30% of the HC needed for efficient technology transfer, and available within the university is being accessed.

This value should not be seen as a literal measurement, but instead as an indication of an area where IC can be better utilized as resource to improve TTOs efficiency. Two efficiency areas make up each of the three IC elements and it is assumed that each area constitutes 50% of the IC element which is not necessarily the case, but for ease of calculations, an equal distribution was assumed. The indicators within the efficiency areas are not exhaustive, and their correlation with IC is only within the context of technology transfer. As such, some IC within the university is not essential for efficient technology transfer. This calculation furthermore assumes that all the IC needed by the TTO is available within the university (for example access to marketing) and that it would be possible to access the IC (and utilize it to improve efficiency).

3.1.4 Findings

Each participant university was researched online to determine the typology of their TTO, either an internal department (part of the university structure), an external entity (wholly owned by the university) or a combination of both. For each TTO the results from the self-assessment tool were calculated and the corresponding maturity level (in brackets) assigned (see Table 3.1.2). The relative IC access percentage, expressed as percentage human capital (HC%), structural capital (SC%) and relational capital (RC%) are shown in the following three columns. In the last column, the results from the EIS (European Innovation Scoreboard) for each country represented was added.

Most TTOs in the sample set have a managed maturity level (3) which means that the university has started to actively manage its technology transfer activities. Within the managed level, we see TTOs with scores that show they have just reached this level (34.8) and TTOs who are on the

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border to crossing to the next level (52). Indeed, a few TTOs with level 4 maturity (integrated stage) is seen. What this means is that technology transfer is integrated at every level of the university. This is strongly reflected by the percentage of IC being accessed and utilized.

A TTO in Sweden, with the highest score (56.8) and maturity level of 4, also has the highest percentage of SC (82%) and RC (84%). Similarly, the other high scoring TTOs; Czech Republic (53), Belgium (52,8), Estonia (52) and Denmark (50) all reflect this pattern. In each of these top 5 TTOs SC and RC percentages are much higher than HC and overall higher than that of other TTOs.

These top 5 TTOs however, each have a different type of TTO. In Sweden, the TTO has an external structure, and for the other 4, it is internal. It is interesting to note that a second TTO in Belgium (50,6) has a combination structure, which puts it in equal 5th place with Denmark.

The EIS ranks the top 5 most innovative countries in Europe (which also forms part of this study as) Sweden, Denmark, Germany, Netherlands, Belgium. Therefore, four of the six high scoring TTOs reside in highly innovative countries.

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Table 3.1.2: Results from self-assessment with the added dimension of IC access presented as a percentage

COUNTRY	TTO TYPOLOGY	SELF-ASSESSMENT SCORE AND MATURITY LEVEL		HC%	SC%	RC%	EIS* RANKING
AUSTRIA	Internal	34.8	(3)	45	54	47	10
BELGIUM 1	Combination	50.6	(3)	69	70	80	7
BELGIUM 2	Internal	43	(3)	62	46	74	7
BELGIUM 3	Internal	52.8	(4)	59	76	74	7
CZECH REPUBLIC 1	Internal	42.6	(3)	60	60	57	16
CZECH REPUBLIC 2	External	49.6	(3)	60	64	71	16
CZECH REPUBLIC 3	Internal	48	(3)	77	63	55	16
CZECH REPUBLIC 4	Internal	53	(4)	60	75	74	16
DENMARK	Internal	50	(3)	52	74	70	2
ESTONIA	Internal	52	(3-4)	60	75	80	14
GERMANY	Internal	39.8	(3)	64	55	67	4
GREECE	Internal	36.6	(3)	57	48	64	19
ITALY	Internal	37.2	(3)	42	49	57	17
NETHERLANDS	Internal	45.8	(3)	47	77	67	5
POLAND	Internal	48.4	(3)	44	69	67	23
ROMANIA	Internal	46.8	(3)	62	57	77	28
SPAIN	Internal	42.4	(3)	57	62	67	20
SWEDEN	External	56.8	(4)	67	82	84	1

*European Innovation Scoreboard 2016

3.1.5 Discussions

The close correlation between intellectual capital (IC) and efficient university technology transfer has been shown in Table 3.1.1 above, as each of the efficiency areas measured by the self-assessment tool is essential for efficient university technology transfer. Therefore, each of the IC elements (HC, SC, RC) captured in Table 3.1.1 is essential for efficient university technology transfer. We can see from the self-assessment scores and corresponding maturity levels in Table 3.1.2, many TTOs are at a managed (3) level. The managed level, as defined by Secundo et al. (2016) is a mid-level TTO with efficiency in some areas, but in need of strategic

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intervention to propel it to the integrated (4) level. At the integrated level the TTO should be well established and closely linked at all levels of the university, allowing for more active utilization and access to IC.

This trend is also reflected in the percentage of IC elements accessed and utilized by the TTO. Very few TTOs at level 3 access more than 60% of the HC available within the university, or more than 70% of SC and RC. It seems that most TTOs have difficulty utilizing or accessing the HC of the university. This may be because the required HC is not available within the university (such as marketing). As noted before in this study it is assumed that efficiency of university technology can be improved by accessing and utilizing the IC of the university, due to the fact that the needed IC is available. It is furthermore assumed that the type of TTO structure (internal, external, combination) will not hinder the access of the TTO to university IC. In the case of a level 4 TTO, which is at the integrated level, we would expect it to be utilizing and accessing 75% or more of university IC due to the close integration. This is evidenced by the TTO in Sweden, which at maturity level 4 accesses 82% of SC and 84% of RC. This TTO needs to focus on more actively utilizing HC, as only 67% is being accessed at the moment.

Therefore, we can clearly see that increased access to and utilization of IC leads to increased efficiency of university technology transfer. As stated before, success in university technology transfer is a critical factor in sustaining competitiveness. By mobilizing IC in this way at the TTO level, the efficiency of individual universities may be improved leading to increased competitiveness. If this trend is sustained, then eventually the competitiveness of the country may be improved through its universities.

IC can be mobilized in many ways to improve the efficiency of university technology transfer. For example, within HC, the following are essential for efficient university technology transfer: expertise, knowledge, and the experiences of researchers or professors. It is very difficult for a TTO to employ staff with all the expertise and knowledge needed to valorise every single technology disclosed by the researchers in the university. But within the university, such expertise and knowledge may necessarily be available in the form of HC. This element of IC can thus be used as a tool by the university to improve the efficiency of university technology transfer. Similarly, with SC (IP, research infrastructure, research and education processes and routines, university culture and governance principles) and RC (Relations with public and private partners, partnerships with the business sector and regional governments, links with non-profit organizations and civil society in general, collaborations with national and international research centres, networks and alliances), each of these elements of IC can be used to address the barriers faced by the TTO. It is therefore suggested that IC be mobilised as a tool by senior management of the university to implement changes in a top-down approach. This may be facilitated through policy changes, strategic interventions, or re-allocation of resources.

This novel application of the data collected with the self-assessment tool allows universities to use IC as a tool because it allows for the identification and relative measurement of intangible assets, and serves as an indication of how IC is accessed and used by the TTO. Through this identification of which IC components within the university are essential to the efficiency of the TTO, and which IC needs greater utilization, insights are provided into policy and practical interventions to improve the efficiency of the TTO, resulting in increased competitiveness. Therefore, IC can now be used in practice at the university level to improve the efficiency of TTOs, so contributing to the third stage of IC research.

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The answer to the research question, how can intellectual capital be mobilised as a tool to improve the efficiency of university technology transfer? can be illustrated using one of the universities studied above as an example. A TTO in Poland with an internal structure, self-assessment score of 48.4 and corresponding maturity level of 3. This TTO is currently accessing 44% of human capital (HC), 69% of structural capital (SC) and 67% of relational capital (RC). By using this information about the amount if IC being accessed by the TTO, we can use IC as a tool to improve the efficiency of university technology transfer. A recommendation for this TTO would be to increase access to HC, and the specific types of HC needed by the TTO for efficient technology transfer are: expertise, knowledge, and the experiences of researchers or professors. To increase access to expertise, mechanisms are needed to identify the relevant expertise within the university and to allow the TTO to access this information and make contact with those individuals within the university. The TTO needs to be furthermore enabled to utilize this expertise, and mechanisms are needed to allow the individuals with the expertise to engage with the TTO in a sustainable way. In a similar way, each of these types of HC needs to be evaluated, identified, and supporting structures, mechanisms and policies created by the university to allow for closer interaction between the TTO and the individuals within the university holding the HC.

3.1.6 Conclusions

Creating and sharing knowledge is considered crucial for gaining competitive advantage (Nonaka and Takeuchi, 1995). Universities through their TTOs share the knowledge created by transferring technology to industry. Efficiency at this process is, therefore, essential to maintaining a university's competitive advantage. By using the Maturity Model created by Secundo et al. (2016) the efficiency of TTOs can be assessed using intangible indicators, and this information can also be used to gain insights into IC. The more efficient a TTO, and therefore the higher the maturity level, the greater the access to and utilization of IC. Mobilising IC as a tool, therefore, allows universities to improve the efficiency of their TTOs so contributing indirectly to universities' competitiveness and regional development.

Implications for theory

This research contributes to the third stage of IC research, showing how IC can be used in practice to improve the efficiency of TTOs. This may signify a move away from looking for external solutions to the barriers faced by TTOs, and instead looking inward. Closer connections to the university, through strategic and policy interventions, will allow greater access to IC. Furthermore, by accurate application of the Maturity Model created by Secundo et al. (2016), more information will be available as to which IC needs to be utilized, and how it can be mobilized to solve the challenges faced by the TTO. Practically, this would mean that senior management at the university would have knowledge of the IC within a university that is essential to the efficiency of the TTO, which IC needs greater utilization and guidance about which interventions are needed to improve the efficiency of university technology transfer. Furthermore, the application of IC as a solution to the barriers faced by the TTO, has not been attempted before and therefore paves the way to a paradigm shift, away from focussing on external solutions to looking internally for solutions. By assessing TTOs in a non-monetary way, the performance of the TTO and consequently university competitiveness is seen in a new light, and gives a more comprehensive and holistic view of the impact of the university towards regional competitiveness.

Implications for practice

The Maturity Model can be used to identify which aspects of IC (HC, SC or RC) might be leveraged more effectively to improve the efficiency of

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TTOs at university technology transfer. Using IC as a lens, the Maturity Model allows the identification of the most critical knowledge-based resources within the university that may be accessed and utilised to address the challenges faced by TTOs. The practical implications of using the Maturity Model are more strategic interventions in managing and leveraging IC. Through the self-assessment tool an indication of the level of access to, and utilisation of IC is given. This results not only in more effective management of IC but also increased efficiency at university technology transfer. This, in turn, leads to a more tailored approach in leveraging individual university's IC.

Thus, this Maturity Model has two typologies of insights, in time and space, which may be of value for the TTO. In space, the snapshot provides a standard for comparison with other TTOs in terms of IC utilised and efficiency, in order to determine which best practices may be transferred. In time, the Maturity Model may be used to monitor improvements and to predict future performance. Similar to the work that was done by Kim et al. (2008) a predictive efficiency pattern may be created in time.

Future research

As noted before, this study makes several assumptions. These are limitations, and future research should focus on accurately measuring the access to IC. Additionally, an audit of the IC available within a university would be helpful in determining interventions. It is furthermore recommended that a wider sample of universities are researched to increase the validation of the Maturity Model and to prove it as a suitable and strategic approach for IC management at TTOs.

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Introduction: Section 3.2

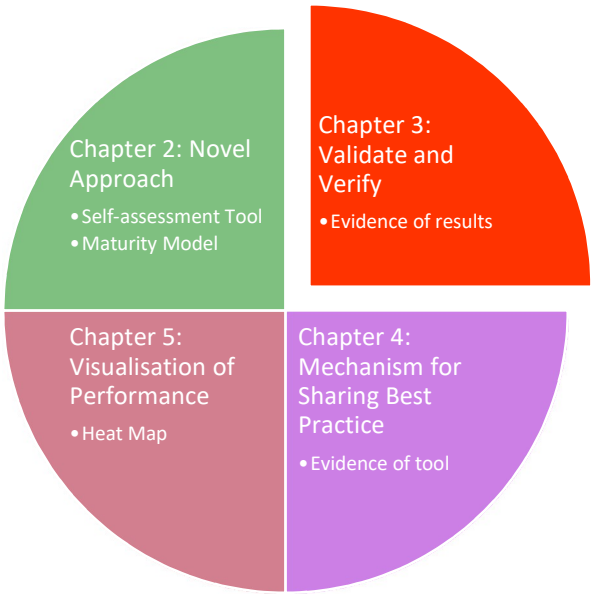

Figure 1.2: Contextual guide

The tool was tested in developed countries, as mentioned before, given that university technology transfer has been undertaken for a longer period of time. Another reason for testing the tool in developed countries, is the presence of tangible data and pre-established benchmarking that could be drawn upon to verify the tool.

The second article tests the tool through a case study of a university in South Africa, followed by in-depth interviews with the TTO. The interview questions listed in section 3.1 were asked, but the candidate allowed the interview to flow naturally and asked additional probing questions to gather detailed information. These questions included:

1. How well does your TTO perform (as compared to local TTOs and international standards)?
2. Do you feel traditional benchmarking is sufficient to reflect the performance of TTOs in developing countries?
3. How much do intangible indicators contribute to providing a holistic view of the performance of the TTO?

The results of the efficiency of the TTO are compared with the traditional tangible indicator method used (Data Envelopment Analysis) and the new tool created. The tangible data was provided by the TTO, and the Excel add-in for DEA was used to determine the DEA results for the TTO based on the data provided.

In this article the link between the tool and intellectual capital is again explored, advocating for the use of intellectual capital as a strategy and solution to the barriers faced by TTOs. This will further improve the efficiency of technology transfer.

Seeing as validation and verification go hand in hand, both articles provide evidence as to the validity of the results of the tool, and evidence of the accuracy of the results, thereby verifying the tool.

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It should be noted that at the time of submitting both these articles, the first article detailing the self-assessment tool and maturity model had not yet been published. As a result, there is some duplication in explaining the tool to the reader. In addition, as these articles were submitted to journals in different fields, the writing style and terminology differ to align with the theme of each journal.

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Leveraging Intellectual Capital to assess the Technology Transfer Office: a South African University case

Authors: Giustina Secundo[1], Christle De Beer, Corne Schutte, Giuseppina Passiante[1]

[1]University of Salento, Lecce, Italy

Stellenbosch University, Stellenbosch, South Africa

Abstract

Purpose This study aims to apply a Maturity Model which measures the efficiency of university technology transfer (UTT) (Secundo et al., 2016) in the South African context. The Maturity Model is based on intangible indicators and lends itself to understanding how a university's intellectual capital (IC) can be leveraged to assess its technology transfer office.

Design This paper builds on the Maturity Model (Secundo et al., 2016) by application in a case study of a South African university, and proves the accuracy of the results through comparison with traditional benchmarking.

Findings The Maturity Model measures UTT efficiency through intangible indicators grouped into six areas: human resources, intellectual property policy and strategy, networking, university-industry links, technology, and organization design and structure. The links between these intangible indicators and IC show that IC can be leveraged to assess UTT efficiency.

Research implication The Maturity Model provides a means to leverage IC as a new way to improve UTT, especially in developing countries.

Practical implications The Maturity Model can be used as a self-assessment tool by technology transfer offices to increase their operations. Moreover, it can be used by other stakeholders who are interested in evaluating UTT value generation performances.

Originality The findings inform the connection between efficient UTT and IC and provide a means by which developing countries can monitor UTT efficiency through the implementation of the maturity model and the self-assessment tool adopting intangible indicators.

Keywords: University Technology Transfer (UTT), Maturity model, Technology Transfer Office, efficiency, intellectual capital (IC), intangible indicators

Article classification: research paper

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3.2.1 Introduction

Universities are operating in a highly competitive environment mainly due to decreased funding and a subsequent demand by their stakeholders for the effective use of public funding and greater transparency of information (Ramírez Córcoles et al., 2011; Veltri et al., 2014 Veltri and Silvestri, 2015). Moreover, around the world, the increasing recognition of universities' roles in economic growth and regional development in the modern knowledge society is acknowledged (Etzkowitz, 2016). Universities are becoming a strategic actor in regional growth coalitions (Feldman, 1994), recognizing their effective role as inventor, and knowledge and technology transfer agent. As knowledge assumes increased significance as a production factor, in both high tech and older manufacturing industries, universities are increasingly being viewed by policymakers as engines of innovation through the technology transfer office (Libecap et al., 2005). In recent years, the transfer of knowledge from universities to industry, facilitated by the technology transfer office, has gained considerable attention because knowledge produced in universities can spur business innovation, foster competitiveness, and promote economic and social development through academic entrepreneurship (Algieri et al., 2013; Etzkowitz, 2016; Siegel and Wright, 2015).

Intangible assets and intellectual capital (IC) constitute the largest proportion of universities' assets (Sánchez et al., 2009; Secundo et al., 2010) and represent a valuable asset at national level (Bounfour, 2005; Ståhle and Bounfour, 2008). IC could be described as intellectual material that has been formalized, captured and leveraged to produce higher valued assets (Schiuma, 2009). Accordingly, because of IC's changing focus, we adopt Dumay's (2016, p.16) IC definition, being "… the sum of everything everybody in a company knows that gives it a competitive edge … Intellectual Capital is intellectual material, knowledge, experience, intellectual property, information… that can be put to use to create value". Dumay (2016) replaces the word 'wealth' in Stewart's (1997, p. x) original definition, with the word 'value' to incorporate utility, social and environmental concerns. Most of the value created in universities is intangible because profit is not their primary objective (Dumay and Guthrie, 2012), and thus Dumay's definition is more suited to public organisations such as universities. This implies that in such research organizations, IC created through university technology transfer should be used to measure direct or indirect social value (Castellanos and Rodriguez, 2004). Prioritizing scarce resources and systematically monitoring intangible assets and IC in universities contributes to economic improvement and better accomplishment of strategic objectives (Bornemann and Wiedenhofer, 2014).

In the past two decades, public policy has placed great emphasis on the university process of knowledge transfer in both developed and developing economies (Lee, 1996; Shane, 2004; Kwiek, 2005). Knowledge transfer can be defined as the formal and informal transfer of new discoveries and innovations resulting from research (usually scientific) conducted at universities to the commercial and non-commercial sector for public benefit. Key issues in knowledge transfer include the openness of university intellectual property (IP) policy, the existence of formal access gateways to university areas and the efficiency of technology transfer offices (Gibb, 2012). To benefit from the knowledge generated by university research and technology, universities are transforming research results with the aim to create socio-economic value (Redford and Fayolle, 2014; Siegel and Wright, 2015). This specific form of knowledge enhancement is known as university technology transfer (UTT) (Vinig and Lips, 2015; Secundo et al., 2016) and is mainly performed by the technology transfer office.

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Universities are not equally successful in commercializing their knowledge, especially through their technology transfer offices, as many operate inefficiently (Oliveira and Teixeira, 2010; Tahvanainen and Hermans, 2011; de Falco, 2015). According to Oliveira and Teixeira (2010), this may be due to the short periods (established less than 10 years) that they have been in operation. Considering then that many technology transfer offices in developing countries and especially in South Africa have been in operation for such short times, it is not surprising that they operate inefficiently. Indeed, most technology transfer offices in South Africa began due to the new Intellectual Property Rights from Publicly-Funded Research and Development Act (IPR Act), in which universities are tasked with the identification, protection, development, commercialization and benefit-sharing arrangements of all IP disclosed to them. Furthermore, due to various other factors such as insufficient financial resources, support from university management, complimentary incentives and policies many technology transfer offices have been unable to produce the readily measurable, tangible impacts of UTT. Within the developing country context, there is a paucity of tangible data, and this could further motivate the necessity for and use of a tool that measures efficiency through IC.

Anderson et al., (2007) define efficiency in UTT as a function of converting inputs to outputs by the involvement, amongst others, of technology transfer offices. Indeed, many federal agencies include narratives of technology transfer success stories in their annual reports, demonstrating the acceptance by practitioners that public value is an important criterion for evaluating technology transfer activity (Bozeman et al., 2015). Among the models and tools developed to measure and assess UTT efficiency, the Maturity Model and the self-assessment tool created by Secundo et al., (2016) and further validated (Secundo et al., 2017) measure various intangible indicators and IC to assess the efficiency of UTT and seek to understand how it can be improved. The scores assigned to each intangible indicator in the self-assessment tool are used to determine how mature a technology transfer office is in this process and consequently the technology transfer office is classified according to a Maturity Model. This Maturity Model may be used to monitor improvements and to predict future performance, but also serves as a basis for comparison of performance between different technology transfer offices. Moving from previous research (Secundo et al., 2016; Secundo et al., 2017), this study aims to apply the Maturity Model in the South African context by measuring the maturity and UTT efficiency through intangibles and IC. The South African context was chosen as not much tangible data is readily available, yet many technology transfer offices in South Africa are seen as successful compared to others within the greater southern Africa.

The remainder of the paper will be organized as follows: the next section will discuss relevant literature on technology transfer offices in South Africa, measuring UTT, and the Maturity Model to assess UTT performance. Next, the research methodology adopted and findings will be described. The final section will discuss and conclude the paper highlighting implications for theory and practice as well as future research.

3.2.2 Literature

University Technology Transfer Offices in South Africa

University technology transfer (UTT) is defined as a process in which science, knowledge or capabilities are transferred or moved from one entity to another for the purpose of further development or commercialization (Lundquist, 2003; Swamidass and Vulasa, 2008). The perspective of UTT as a process belongs to the studies in literature that have focused on the distinction between intermediation as a process and intermediaries as organizations (Howells, 2006). Taking the perspective of intermediation

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as a process, the studies predominantly focus on two main functions associated with intermediation: the information scanning and gathering function and the communication function, both of which may be associated with the 'front end' of innovation intermediation (Lynn et al., 1996; Wolpert, 2002). Other studies referring to intermediaries as organisations are more focused on specific technologies transferred between firms and organizations. The emphasis here is on existing technologies finding new uses and applications in different sectors and industries.

With the adoption of the new IPR Act, university technology transfer offices in South Africa have had an inefficient approach to technology transfer (Taylor, 2009) due to the fact that most of them have had a reactive rather than a proactive approach to UTT. As a result, very few technology transfer offices have achieved the tangible impacts expected of them. Through observation of UTT in developed countries (such as the USA and UK), and based on traditional performance measures, South African technology transfer offices are seen as inefficient. The IPR Act governs all IP developed in the course of all research activities that have received any public funding. It was promulgated in 2008 and came into effect in August 2010, therefore, most universities do not have long-established technology transfer offices. The primary purpose of the IPR Act and its Regulations is to ensure that IP outcomes from publicly financed research and development with the potential to create social and/or economic value are protected and commercialised for the benefit of the people of South Africa.

Even though the IPR Act is a fairly new development in South Africa, efforts to promote technology transfer started in the mid-1990s (Wolson, 2007; Alessandrini et al., 2013) with the establishment of technology transfer offices at 4 universities. Since the introduction of the IPR Act and the establishment of NIPMO (National Intellectual Property Management Office), however, NIPMO supports and assists every one of the 23 public funded universities in South Africa to some extent in engaging in technology transfer. Not every university has a fully functioning technology transfer office, and according to Alessandrini et al. (2013) there are presently 13 active and registered technology transfer offices associated with universities in South Africa. Therefore the South African context was chosen as many technology transfer offices in South Africa are seen as successful compared to others within the greater southern Africa.

Measuring University Technology Transfer

Despite the increasing interest in looking for solutions to develop entrepreneurship within higher education institutions; e.g., to develop so-called academic entrepreneurship (Gibb et al., 2009; Siegel and Wright, 2015), governments and universities lack specific information and tools to monitor and evaluate overall entrepreneurial performance (Wright et al., 2004) and especially technology transfer. In attempting to measure the performance of a technology transfer office, universities are generally greatly interested only in the financial returns of a given IP portfolio and in revenues from publicly funded IP rights. A study by Anderson et al. (2007) discusses the series of models built to establish efficiency metrics and models. These studies focused mainly on the efficiency of converting disclosed ideas/research/IP into patents, and thereafter the efficiency of converting granted patents into licensing agreements. Siegel and Phan (2004) described data envelopment analysis (DEA) and stochastic frontier estimation (SFE) as the two most widely used tools to carry out the assessment of efficiency. SFE looks at cost to profit efficiency (in economic models), while DEA looks at the conversion ratio of inputs to outputs. As regards output, in particular, the available studies use a variety of measures, including licenses and other UTT agreements executed,

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amount of royalties, amount of patents, citation analysis, patent applications, and invention disclosures. Among non-parametric applications, the DEA model utilized by Thursby and Kemp (2002) has the advantage of estimating productivity scores using multiple outputs. They explored UTT efficiency by looking at the organizational issues. Anderson et al. (2007), included weight restrictions on output to perform the productivity evaluation applied to UTT. Thursby and Thursby (2002) presented a three-stage process using DEA to assess the source of growth in university technology transfer outcomes. Through such a decomposition of the UTT process in three stages, the authors have also been able to take into account the influence of intermediate inputs (as well as intermediate outputs) on the overall performance of technology transfer intermediaries.

DEA (Charnes et al., 1978) has been proposed as a consulting and management tool for evaluating IC performance (Leitner et al., 2005) and has been regarded as a proper approach to measuring UTT efficiency (Kim et al., 2008). Indeed, many benchmarking activities of technology transfer offices in the USA and the UK have used this method (Anderson et al., 2007; Chapple et al., 2005; Thursby and Thursby 2002). DEA is an approach to estimate the production function of organizations and organizational units and enables the assessment of their efficiency. In its application to measuring UTT efficiency, DEA firstly measures the performance of the university independent of the technology transfer office by considering variables such as number of faculty publications, graduate student enrollment and number of Ph.D. students. After evaluating the "excellence" of the university, an analysis is done of how said excellence relates to the resources for technology transfer. This analysis includes the number of disclosures, the annual number of patent applications, licensing agreements, the formation of university spin-off companies, and the financial revenue generated through these activities (Hauksson, 1997).

Universities are indexed by the DEA as $i = 1, 2\ldots,n$ and each university has input measures denoted by $X_{i,r}$ $r = 1,2\ldots,R$ and output measures denoted by $Y_{i,s}$ $s = 1,2\ldots,S$. When calculating the excellence or success score, each of these inputs and outputs is weighed, with input weights denoted as *vr* and output weights denoted as *ws*. Using these, the efficiency score of university *i* is then defined as:

$$e_i = \frac{\Sigma_{s=1}^{S} w_s Y_{i,s}}{\Sigma_{r=1}^{R} v_r X_{i,r}} \qquad (1)$$

In the case of universities, it is often difficult to weight inputs and outputs, but DEA deals with the ambiguity of this problem by providing each university the chance to perform optimally. This means that in determining the efficiency of a university, DEA chooses a weight that will result in the best possible efficiency for the university. The efficiency score (between 0 and 1) is calculated for each university through the DEA by choosing weights that maximize the ratio of a linear combination of the university's outputs to a linear combination of its inputs (Chapple et al., 2005). DEA then fits a piecewise linear surface on the optimal edge of the observations referred to as the efficient frontier where $e_i = 1$ and the distance from this frontier is regarded as the technical inefficiency of the university.

UTT efficiency can be measured in numerous ways; however, there is a clear and widespread dissatisfaction with many of the metrics currently used (Carayannis et al., 2014). Most of the methods discussed above are based on the return on investment (ROI) concept, which has been criticized by researchers as "restraint on innovation" (Faulkner, 1996). This is because the concept of ROI only measures short-term benefits, rather than the long-term gains brought by research. In UTT, similar arguments have been made due to the over-simplified metrics used to

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evaluate the efforts of technology transfer offices. In evaluating UTT, one problem that is constantly faced is prescribing improvements; there are no standards for the metrics used in evaluation and therefore there is no consistent level of performance against which a technology transfer office can be measured (Carayannis et al., 2014). Using monetary indicators to measure the efficiency of technology transfer, however, does not measure real performance as it does not provide for, nor is it based on, the potential for technology transfer based on university research (Vinig and Lips, 2015). It is important to highlight that most technology transfer offices do not create net revenue, even in the USA (Mars, 2005).

Thus, UTT needs an overall evaluation that goes beyond these specific aspects, and which should consider wider social and economic benefits, such as the dissemination of knowledge and the contribution to employment for social, cultural and economic development (Wright et al., 2004). Many researchers (e.g. Taylor and Massy, 1996) have highlighted the strategic perspective of measuring UTT office performance as essential elements to activate the dialogue inside universities and between their environment and society. Thus, a system devoted to measuring overall UTT efficiency should consider the different views and expectations of every stakeholder, considering at the same time the strategic dimension (e.g. data and information related to university policies and strategies for medium and long-term planning) and the operational dimension (e.g. data and information concerning the development of joint initiatives and programs) (Agostino et al., 2012). The resulting UTT performance measurement system would therefore represent a valuable support in assessing universities' value-generation process and thus defining the limited and reduced public budget for financing research (Arena and Arnaboldi, 2013).

Self-Assessment Tool and Maturity Model for Measuring University Technology Transfer

Besides DEA methodology, other tools and methodologies for TTO performance measurement have been developed in the literature (Thursby and Kemp, 2002; Phan and Siegel, 2006; Anderson et al., 2007); some of them are focused on management and development strategies of universities' key intangible assets (Arena et al., 2009). It is worth highlighting that these performance management systems (Broadbent and Laughlin, 2009; Esposito et al., 2013; Secundo and Elia, 2014) incorporate IC and intangible assets, for many reasons:

- The increasing importance of technology transfer (Perkmann et al., 2013);
- The increasing cooperation between university and industry (Secundo et al., 2010);
- The need to search for funding is associated with the pressure of demonstrating the ability to generate research outputs providing a positive value for the wider society (Senker, 2001; Coccia, 2004; Leitner and Warden, 2004);
- The exploitation of university research and inventions (DiGregorio and Shane, 2003) requires universities to set up an effective performance system for attracting established industrial firms and investors and thus supporting the creation of academic or corporate spin-offs (Rosenberg and Nelson, 1994).

Moving from these premises, previous research developed a Maturity Model and a corresponding self-assessment tool (Secundo et al., 2016) to understand how well UTT is being undertaken by a technology transfer office and how it can be improved. This proposal is grounded in the literature of Besson et al (2012), which argues that statistical approaches like DEA, are 'black box' and they propose to use their maturity

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model "Innovation, Knowledge- and Technology Transfer Process Capability Model – innoSPICETM" to dissect innovation and technology transfer activities into single processes and performance description.

Furthermore, previous research showed that even though there is a substantial body of literature from developed countries, which provides insight on how to be more efficient at technology transfer, the application of these insights to the developing country context had not been very successful. This is due to the context into which universities are trying to apply the best practice of developed countries, as the process of innovation in developing countries is different from that of developed countries. In developing countries, mature technologies are often being adopted with limited success mainly due to differences in maturity (Kostova, 1999; Granieri and Frederick, 2015). The Maturity Model, therefore, serves to highlight these differences in maturity through intangible indicators, as developed countries generally are more mature.

Increasing attention is being paid to IC in the management literature starting from the assumption that the economic growth of knowledge-based economies is primarily led by intangibles (Schiuma, 2012; Bornemann and Wiedenhofer, 2014; Secundo et al., 2015). Therefore, economies in developing countries, such as South Africa, are becoming increasingly dependent on intangible assets and knowledge producers (Schiuma and Lerro, 2008; Yasar and Schiuma, 2009).

The self-assessment tool therefore measures various intangible indicators grouped into six efficiency areas; namely, human resources, technology, IP policy and strategy, organization design and structure, networking, and university-industry links. These six efficiency areas incorporate the tripartite classification of IC as illustrated in Table 3.2.1.

Table 3.2.1: Correspondence of efficiency indicators (Secundo et al. 2016) and intellectual capital (Habersam and Piber, 2003) components

Efficiency areas of self-assessment tool (Secundo et al., 2016)		**Tripartite classification of intellectual capital (Habersam and Piber, 2003)**	
Human resources	Staff with specific skills (marketing experience, options experience)	**Human capital (HC)**	Expertise, knowledge, and experiences of researchers, professors etc.
Technology	The expertise of researchers for the development of high-quality technology		
IP policy and strategy	Policies - incentives for staff, royalties on license agreements, and resources for technology transfer office Strategies - faculty involvement, IP awareness, and education	**Structural capital (SC)**	IP, research infrastructure, research and education processes and routines, university culture and governance principles
Organization design and structure	Structure of technology transfer office and university		
Networking	Within the university between faculty and technology transfer office	**Relational capital (RC)**	Relations with public and private partners, partnerships with the business sector and regional governments, links with non-profit organizations and civil society in general, collaborations with national and international research centers, networks and alliances
University-Industry links	Relationships and partnerships with industry		

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The self-assessment tool (Secundo et al., 2016) measures various intangibles and IC within each of the six efficiency areas on an ordinal 5-point Likert scale; each area is weighted using the fuzzy analytical hierarchy process (AHP), and a final score is calculated for the efficiency of a technology transfer office at UTT. This score then classifies the technology transfer office at a certain maturity level using the Maturity Model created by Secundo et al. (2016). The results of the self-assessment tool also indicate which of these intangibles need strategic interventions to increase the efficiency. This is possible because the Maturity Model is based on the Berkley $(PM)^2$ Model (Kwak and William, 2000) which breaks down processes and practices into efficiency areas based on best practice and literature reviews. The level of maturity ranges from 1 (low) to 5 (high) and allows for the determination of strengths and weaknesses, and can, therefore, enable the technology transfer office to focus selectively on weak practices to achieve a higher maturity. The levels are the Awareness stage (1), Defined stage (2), Managed stage (3), Integrated stage (4) and Sustained stage (5). Each level is furthermore described in terms of the key processes and practices needed for optimal efficiency.

What makes this tool unique is that it focusses solely on intangibles to assess efficiency, whereas the general approach is to use monetary indicators (Kim et al., 2008). Previous research revealed that even though non-monetary indicators have a significant impact on the efficiency of technology transfer, no studies had yet used these indicators as a measure of efficiency (Secundo et al., 2016). Therefore a new tool, the Maturity Model to measure the efficiency of UTT, was developed (Secundo et al., 2016) and validated within the European Context (Secundo et al. 2017). Moving from these, the research the aim of this study to apply the Maturity Model in a South African university where UTT is seen as inefficient (Alessandrini et al., 2013).

3.2.3 Research methodology

Moving from the above premises, this paper intends to apply the self-assessment tool and consequently the Maturity Model developed by Secundo et al. (2016) in the South African context, by measuring through intangibles and IC UTT efficiency. For this purpose, the results of the DEA performed for a university in South Africa will be compared to the results of the self-assessment tool. As both approaches seek to measure the efficiency of technology transfer, this is regarded as an appropriate comparison. The comparison of these results serves to prove the accuracy of the Maturity Model and to answer the following research question: How is it possible to measure and assess university technology transfer in South Africa, leveraging on indicators based on intellectual capital?

The Maturity Model created by Secundo et al., (2016) can be used as an approach to understanding how efficient technology transfer is at the university level and which strategic interventions may be made to improve the efficiency. This, in turn, will result in improved leveraging of IC, allowing the university to accomplish the main goal to become a primary driver of social and economic development. Furthermore, as this model is based on measuring intangibles which are the IC of the university, it will also provide insights into the efficient use of IC by the technology transfer office.

Research context

The development of the concept of intellectual capital is still very much in its infancy in emerging economies (Firer and Stainbank, 2003). In addition, since emerging from apartheid, South Africa has been a country in transition and has been actively working towards altering the country's economic base from a traditional reliance on natural resources to a base that encompasses IC (Firer and Stainbank, 2003). Universities have also recognized the importance

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of managing IC and have adopted frameworks used to manage and measure IC (Kok, 2007). The 1996 white paper on science and technology established the concept of a national system of innovation in South Africa and was furthermore supported by the national research and development strategy released in 2002. This strategy contained a proposal to introduce measures to encourage better protection and exploitation of IP, which led to the 2006 framework for Intellectual Property Rights from Publicly Financed Research (Wolson, 2007).

Technology transfer in South African universities is governed by the IPR Act, which dictates the university's responsibility in managing IP as well as the role of the technology transfer office. The main objective of the IPR Act is, together with the other Acts and the supporting governmental organizations, to make provision for the development of IP from publicly funded organizations. Furthermore, the IPR Act aims to ensure that IP from publicly funded research and development is utilized and commercialized for the benefit of South Africa. The developing country context was chosen as few tangible impacts of UTT are seen here, which illustrates the usefulness and applicability of the Maturity Model measuring intangibles and IC.

For this study, we will apply the self-assessment tool and Maturity Model at one of these universities in South Africa, which we will refer to as university alpha, for anonymity. University alpha has had a technology transfer presence for 22 years, which is currently established as an independent company wholly owned by the university with 7 full-time employees. University alpha has received many awards for being the most successful at technology transfer within the SADC region. South Africa was chosen as the context given the new (fewer than 10 years) IP legislation that enabled UTT, and because it is seen as the leader in UTT within the greater southern Africa region.

Research approach

This case study applied both the self-assessment tool and the Maturity Model. Firstly, the case study aimed at proving that the self-assessment tool is accurate in assessing the technology transfer office's efficiency at university alpha (thus TTO alpha) as compared to other tools. In this case, DEA was selected due to its widespread use and availability of comparison data. Secondly, the case study serves to prove that the self-assessment tool and Maturity Model are accurate outside of a theoretical application. Thus, the findings of the Maturity Model was compared to data available from other studies, and discussed with TTO alpha to confirm the accuracy of the results according to their day-to-day experience.

TTO alpha completed the self-assessment tool (Secundo et al., 2016) in June 2016, as a team, and the results were analyzed to determine the maturity level of TTO alpha as based on the Maturity Model. TTO alpha indicated on a scale of 1 to 5 how true each statement is in terms of their daily experience working in TTO alpha. Each statement in the self-assessment tool is based on an intangible indicator, which in turn relates to one of the six efficiency areas. The score of each of these statements (1 to 5) is also weighted using the fuzzy AHP, and as such, the final calculation is made taking into consideration the relative importance of each of the six efficiency areas to UTT. The final score is then used to classify TTO alpha according to a certain maturity level, as described in the Maturity Model.

The data collected from TTO alpha and used in the DEA included the number of inventions disclosed, the number of national patent applications filed and the number of license agreements signed for every year since 2010. These indicators were chosen based on the three-stage model of Thursby and Thursby (2002) and the limited availability of data from TTO alpha. DEA was applied in this study as it extends to a double-input, single-output efficiency

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analysis. Furthermore, the input-oriented basic CCR (Charnes, Cooper, and Rhodes) model was chosen, as in practice it is much easier to intervene on the inputs (invention disclosures and patent applications), rather than outputs (license agreements) (Leitner et al., 2005). The CCR model calculates the relative efficiency of a decision-making unit (DMU) as a ratio of virtual weighted output over virtual weighted input. A DMU is regarded as the entity responsible for converting inputs into outputs, in this case, being the technology transfer office. Two ratios were calculated based on the data, license agreements over invention disclosures and license agreements over patent applications for six years. The efficiency frontier was then calculated to determine the relative efficiency for TTO alpha for each year. To create the efficiency frontier, the efficiency of each DMU (in this case the same DMU but over the course of 6 years) needs to be calculated and then compared to other DMUs to find the optimal solution (the best possible weights). The DMU with a final efficiency equal to 1 is considered the efficiency frontier.

An average efficiency was calculated for TTO alpha and then compared with the maturity level assigned to TTO alpha by the Maturity Model (Secundo et al., 2016). These results were compared with other studies (Thursby and Thursby 2002; Chapple et al., 2005; Anderson et al., 2007) to determine the relative efficiency of TTO alpha. The results were discussed with TTO alpha in this case study.

3.2.4 Findings

The self-assessment results for TTO alpha are shown in Table 3.2.2 on the next page, in which the staff of TTO alpha assigned a score to each indicator, indicating the strength with which each statement was true. Using the weights assigned by the fuzzy AHP, the weighted score for each efficiency area was calculated and the final weighted score for TTO alpha was 43. For the Maturity Model, the scores are categorized as follows: Awareness stage (14.2), Defined stage (15 - 33), Managed stage (34 - 52), Integrated stage (53 - 70) and Sustained stage (71). Therefore, TTO alpha has a maturity level of 3. This level is called the managed stage, suggesting the technology transfer office is managing its UTT but has not yet integrated (level 4) or sustained (level 5) it.

From the results, TTO alpha is managing university alpha's IC but several areas need improvement. In terms of the HC, TTO alpha's human resources can be supplemented. The technology being disclosed is mostly by professors, a good source of disclosures. SC is a strong area for TTO alpha with organization design and structure scoring mostly 5's. RC is not being fully leveraged by TTO alpha and improvements in networking and university-industry links are needed to improve efficiency.

The DEA double-input, single-output efficiency analysis was then performed using Solver, an Excel add-in, which solves the DEA equation (SEQ eq 1) for each DMU or in this case each year of data (Table 3.2.3). For each DMU, a weight (*v,w*) of 1 was assigned because the weights are a decision variable, and once Solver is used, it will produce an optimal weight for each DMU. Furthermore, an efficiency (*ei*) of 1 was assigned because the efficiency is an unknown decision variable, and Solver will return this value to its optimal value once the equation is solved. To enable Solver to solve the equation, the constraints were set up so that the inputs (X1 or X2) are always less than or equal to the sum of the inputs; and so that the output (Y1) are always greater than or equal to the sum of outputs.

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Table 3.2.2: Self-assessment of a university technology transfer office in South Africa (TTO alpha)

Efficiency area and indicators		Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
Human resources	TTO has sufficient number of staff		2			
	At least one staff member has marketing experience	1				
	At least one staff member has the expertise to manage the licensing portfolio as a set of options					5
	Weighted score	**8**				***Score = 8***
IP Strategy and policy	A clear, transparent and consistent vision for technology transfer, with strategic goals and priorities.		2			
	Frequent and reciprocated involvement with faculty				4	
	Royalty shares for faculty					5
	Incentives for faculty to disclose			3		
	Sufficient resource allocation to TTO		2			
	Incentives for TTO staff	1				
	Provide education to overcome informational and cultural barriers between TTO and Faculty				4	
	Weighted score	**16.8**				***Score = 21***
Networking	TTO has personal relationships with faculty			3		
	TTO facilitates formal and/or informal networking between scientists				4	
	Formal and/or informal networking between faculty and TTO				4	
	Weighted score	**6.6**				***Score = 11***
University-Industry links	TTO understands the needs of industry			3		
	TTO facilitates formal and/or informal networking between faculty and industry		2			
	Provide education to overcome informational and cultural barriers between TTO and industry		2			
	Weighted score	**4.2**				***Score = 7***
Technology	Most technologies disclosed to TTO is not at an early stage	1				
	Most faculty members who disclose are Professors				4	
	Weighted score	**2**				***Score = 5***
Organization design and structure	TTO has been established for 10 years or more					5
	University is publicly owned					5
	University has a medical school					5
	A business incubator is available for faculty					5
	TTO is positioned externally to the University				4	
	TTO has a decentralized management style			3		
	Weighted score	**5.4**				***Score = 27***
	Total weighted score	**43**				***Total score = 79***

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Table 3.2.3: TTO alpha performance metrics 2010 – 2015 and DEA results

YEAR	INPUT 1	INPUT 2	OUTPUT 1	DEA RESULTS
	Invention disclosures	National Patent Applications	License Agreements	Efficiency Scores
2010	45	23	3	0.71
2011	61	27	7	0.60
2012	25	20	7	1
2013	33	16	19	1
2014	39	27	9	0.70
2015	59	21	23	0.76
AVERAGE				0.8

The sum of the weights was also set to be equal to 1. In Solver, the objective was set to be equal to 1 and the goal was set to minimize the weights and efficiency until that objective was met. The constraints were added, a simplex linear programming solving method was selected, and Solver was selected to solve the equation. The results from the DEA performed with Solver for each DMU are shown in the last column of Table 3.2.3. Under the optimal weighting, the efficiency for each year was calculated. These scores were used to calculate the efficiency frontier represented by the solid line in Figure 3.2.1. The unweighted efficiency scores were then plotted on the same graph (illustrated by the dots) to show how far each year is from being efficient. Based on the efficiency frontier, years 2013 and 2015 are the closest to being efficient with relative efficiencies of 0.58 and 1.19 (2013) and 0.39 and 1.10 (2015) respectively. These two relative efficiencies refer to the ratio output /input 1 and 2 respectively.

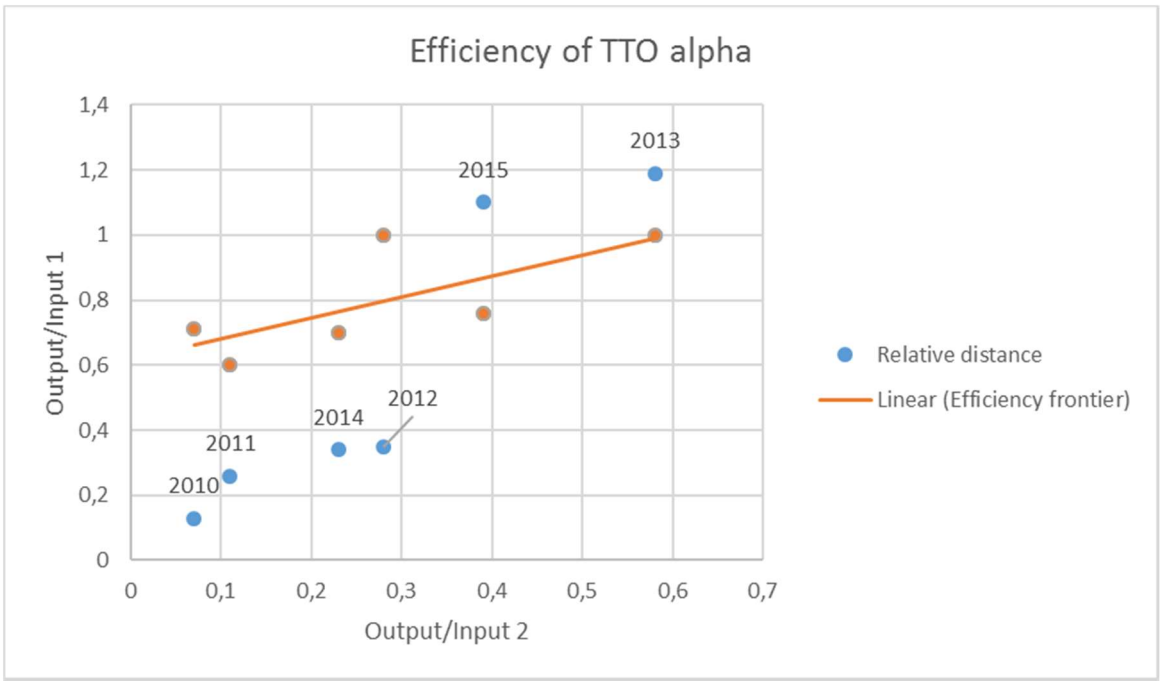

Figure 3.2.1: Data plot and relative distance from efficiency frontier

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Thus, TTO alpha has an average efficiency (the sum of the efficiency ratios output/input 1 divided by 6, and the sum of the efficiency ratios output/input 2 divided by 6) of 0.28 (input 1) and 0.56 (input 2). When trying to understand what these ratios mean, the guidance given by DEA is the relative distance from efficiency designated as 1. Therefore, TTO alpha is 28% and 56% efficient, which when collated means TTO alpha is 42% efficient.

To understand what TTO alpha's DEA efficiency score would mean in terms of relative maturity, and to make it easily comparable with the Maturity Model of Secundo et al (2016), percentages can easily be assigned to each level. As a result then, the Awareness stage (0 – 9%), Defined stage (10 – 39%), Managed stage (40 – 69%), Integrated stage (70 - 99%) and Sustained stage (100%). If we then categorize TTO alpha according to its percentage DEA score (or efficiency score) of 42%, it is again within the Managed stage.

This confirms the result of the self-assessment tool, which classified TTO alpha at maturity level 3, the managed stage. The results of the DEA, therefore, confirm the results of the self-assessment tool and the corresponding Maturity Model, because the result of both tools classify TTO alpha as 42% efficient or at maturity level 3, which means TTO alpha is managing its technology transfer activities.

Currently, most studies on efficient technology transfer offices are from the UK and USA, and it can be argued that the most efficient technology transfer happens in these countries due to their high number of internationally renowned universities, high levels of national support for technology transfer, and long history of technology transfer activities (since the early 1980s) (Lockett et al., 2015). Therefore, by comparing TTO alpha with DEA results from technology transfer offices in the UK and USA, we can determine how efficient the scores are, and if this really does reflect a maturity level of 3 or the Managed stage as anticipated by the Maturity Model.

TTO alpha on average has an efficiency of 0.28 (input 1) and 0.56 (input 2). A study by Chapple et al., (2005) on UK universities found that the average performance of technology transfer offices at converting invention disclosures (input 1) to license agreements (output 1) to be 0.188. Anderson et al., (2007) evaluated universities in the USA and found 7 of them to be efficient of which selected results are shown in Table 3.2.4. If we consider the same indicators for TTO alpha on average, the efficiency ratio of output 1 to input 2 is 0.56, which shows that TTO alpha can improve as compared to other technology transfer offices.

It is important to note that in both studies (The UK (Chapple et al, 2005) and the USA (Anderson et al, 2007)) that were used as the basis for comparison, the efficiency ratio is not equal to 1 and this is because in both studies mentioned other inputs and outputs were also considered, which influences the final efficiency ratio.

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Table 3.2.4: Selected results from DEA by Anderson et al., (2007)

University	Input 2 (National Patent applications)	Output 1 (License agreements)	Efficiency ratio
A	110	30	0.27
B	965	273	0.25
C	217	203	0.94
D	436	134	0.31
E	450	45	0.1
F	33	28	0.85
G	287	35	0.12

The findings of the DEA, however, do not show a technology transfer office where or how to improve. The findings of the Maturity Model classified TTO alpha as a level 3, managed stage, and therefore TTO alpha can, by looking at the description, immediately be made aware of the strategic areas that need intervention. The description of managed stage states that a technology transfer office would have sufficient human resources with the correct sets of skills, royalties or incentive schemes in place for technology transfer office staff, established networks or university-industry links, technologies disclosed at a later stage, and a decentralized internal structure. If TTO alpha does not meet any of these requirements, then those would be the areas in need of intervention. For in-depth insights into specific weaknesses that may be strengthened, TTO alpha would study the results of the self-assessment tool (Table 3.2.2) for specific intangible indicators in that specific efficiency area. Nonetheless, the results correlate well with the findings of the self-assessment tool and corresponding maturity level classification, which show that TTO alpha still has areas in which to improve.

These results were, furthermore confirmed, through discussion with the staff at TTO alpha. In recent years, TTO alpha has been moving closer to the efficiency frontier, but steps still need to be taken to ensure efficiency. The managed stage of the Maturity Model states that a technology transfer office at this maturity would still need several interventions to operate efficiently. The staff at TTO alpha agreed with this assessment, and that this was their daily experience working in TTO alpha. Therefore, the maturity level assigned to TTO alpha is supported by the DEA results (as compared to universities in the UK and USA) and confirmed by the staff working in TTO alpha.

3.2.5 Discussion and conclusion

The aim of this study was to show how it is possible to measure and assess university technology transfer in South Africa, leveraging on indicators based on intellectual capital through the adoption of the Maturity Model (Secundo et al., 2016). Worldwide, IC has been recognized as one of the most important resources for profit and non-profit organizations, especially for developing countries. IC can be used as management and performance tools at the university level where intangibles and IC represent the most valuable part of what is developed (Secundo et al., 2010). To do so, consultants and managers have so far been using widespread tools that help to underline the relevance of IC. However, these tools also have limitations; e.g., with respect to the calculation, comparability, and evaluation of the efficient use of IC (Leitner et al., 2005). These drawbacks have led to the search and development for alternative tools aimed to assess the university's entrepreneurial performance. Among these methods, the Maturity Model (Secundo et al.,

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2016) allows a university to evaluate the efficiency of the university technology transfer (UTT) office using non-monetary indicators and IC. Upon completing the self-assessment tool linked to the Maturity Model, the university can see how its IC is being managed by the technology transfer office, and through leveraging IC as efficiency indicators, the technology transfer office has a snapshot of how it is performing at present. Repeating this self-assessment periodically can then provide the technology transfer office with information on how it is performing over time.

The Maturity Model has been validated and verified through its application to a case study of university alpha in South Africa. By using data on the performance of TTO alpha, and comparing that to the results of the self-assessment tool and maturity level, we could show that the results not only compare well to DEA (data envelopment analysis) (Leitner et al., 2005) but also to the daily experience of the staff working at TTO alpha. Considering then the results of the self-assessment tool which classified TTO alpha at maturity level 3, these results correspond well with the result of the DEA which shows that TTO alpha is at intermediate efficiency (of 42%). Comparing the DEA results of the South African TTO alpha to other studies reveals that TTO alpha still has some adjustments that can be made to improve its efficiency. The self-assessment tool shows exactly where TTO alpha can make adjustments.

In terms of the human capital (HC), the human resources of TTO alpha can be supplemented, as the self-assessment showed a lack of necessary staff and skills. Here we can see that there is not sufficient IC, in terms of HC, for TTO alpha to leverage. Therefore, this IC indicator shows an area where the IC of university alpha can be improved. Structural capital (SC) is a strong area for TTO alpha with organization design and structure scoring mostly 5's. However, University alpha's policies may need to be amended to make provision for incentives for technology transfer office staff and to allocate sufficient resources. The university mission needs to incorporate technology transfer in its strategic goals and priorities. Here, using the IC lens, we can see strategic interventions that university alpha can take to improve TTO alpha and UTT efficiency. Relational capital (RC) is not being fully leveraged by TTO alpha and improvements in networking and university-industry links are needed to improve efficiency. In terms of leveraging IC, TTO alpha may capitalize on the university's internal and external relations to improve its network and industry links efficiency areas.

Implications for theory

This model enables the effective leveraging of IC and additionally improved UTT, from a strategic but very specific point of view, which moves beyond the current methods to a new dimension of tailor-made interventions. Since the Maturity Model results give insights into the weaknesses of the technology transfer office, it provides universities with the answers they seek to improve UTT and overcomes the limitations of monetary indicator-based methods. Furthermore, because the Maturity Model measures efficiency based on IC indicators, the university now has an additional way to leverage its IC. Applying the IC lens to evaluate UTT performance has not been attempted before and therefore paves the way to a paradigm shift away from ROI based performance measurement. Assessing UTT in a non-monetary way also has an influence on how the impact of the technology transfer office, and consequently, of the university, is seen and measured. Incorporating IC into the overall assessment of UTT activity gives a more holistic and comprehensive view, but also guides universities in leveraging their IC.

Implications for practice

It is the opinion of this study that the Maturity Model, can be used to identify which aspects of IC (HC, SC or RC) might be leveraged more

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effectively to improve UTT efficiency. Using IC as a lens, the Maturity Model allows the identification of the most critical knowledge-based resources used in the development of UTT in the South African context. The practical implications of using the Maturity Model are more strategic interventions in managing and leveraging IC. Through the self-assessment tool, weaknesses can be pinpointed, and steps can be activated to improve these weak areas. The result will be not only more effective management of IC but also increased efficiency at UTT. Increased efficiency at UTT will furthermore lead to more effective leveraging of IC. This, in turn, leads to a more tailored approach in leveraging individual universities IC. The self-assessment tool provides insight into how the university can improve the leveraging of its IC. The added dimension of the Maturity Model also gives insight into how IC needs to be managed over time so that the university can move to increased leveraging of IC and increased UTT efficiency. On completing the self-assessment using the tool created, the technology transfer office has a snapshot of how it is performing at present. By repeating this self-assessment periodically for each technology transfer office at country level, it will be possible to gain insights about the UTT efficiency at country level. Thus, this Maturity Model has two types of insights, in time and space, which may be of value for the technology transfer office (Secundo et al., 2016).

Limitations of the study and future research

The Maturity Model has only been applied to one university (university alpha) in one developing country (South Africa). Future research sees this model applied to assess technology transfer offices at universities in different developing countries and application of the results to inform more effective leveraging of IC and improved efficiency at UTT.

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Conclusion: Chapter 3

In Section 3.1 the published article titled: "Mobilising Intellectual Capital to Improve European Universities' Competitiveness: The Technology Transfer Office's Role" was included to address the third objective of this study:

3. Validate and verify the tool.

As highlighted in Table 1.1 (Chapter 1, Heading 1.8, page 21) the outcome of this objective is evidence of the validity of the results of the tool, and evidence of the accuracy of the results. The article shows the results of the live-testing of the tool in Table 3.1.2, and thus provided evidence of the validity of the results collected with the tool. The results correlated with other benchmarking tools (as shown in Table 3.1.2) and they were confirmed through expert interview.

In Section 3.2 the accepted article titled: "Leveraging Intellectual Capital to Assess the Technology Transfer Office: A South African University Case" was included to further address the third objective of this study. The article shows the results of a case study in Table 3.2.2 and thus provided evidence of the validity of the results collected with the tool. The results were correlated with other benchmarking tools (as shown in Table 3.2.3 and Table 3.2.4) to provide evidence of the accuracy of the results. Finally, the results were confirmed through expert interview as a final step in the verification of the tool.

Chapter 3 therefore addressed the validation and verification of the newly created self-assessment tool and maturity model. This was achieved through a case study and comparison with traditional benchmarking data, live testing through a survey and expert interviews with respondents. The tool was further improved through testing the fuzzy AHP weightings and priorities assigned and through iteration. The improved tool and maturity model are discussed in Chapter 4.

However, an important finding from this validation and verification was the correlation with the tool and intellectual capital. Indeed, the articles have also served to prove the importance of intellectual capital. The research has shown which intellectual capital components are essential to the efficiency of TTOs. The tool showed which intellectual capital needs greater utilisation in order to improve the efficiency of technology transfer.

Thus, the tool no longer just measures presence of or access to intangibles and non-monetary indicators which have shown to be determinants of effectiveness. The tool now also indicates access to intellectual capital, and highlights the importance of managing intellectual capital as a performance measure, while also leveraging it as a means to improve efficiency. Therefore, the efficiency of university technology transfer can now not only be improved at the internal level through strengthening weaknesses. The efficiency can also be improved at an intra-organisational level by facilitating access to intellectual capital.

This dual purpose of intellectual capital is further explored in Chapter 5. The following chapter discusses how the maturity model can be utilised to share best practices between TTOs more effectively, to improve efficiency as well as the improvements made to the tool.

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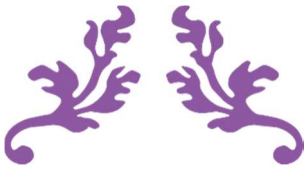

CHAPTER 4: Enabling Interoffice Intervention

A Mechanism for Sharing Best Practices

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Enabling Interoffice Intervention

Introduction: Chapter 4

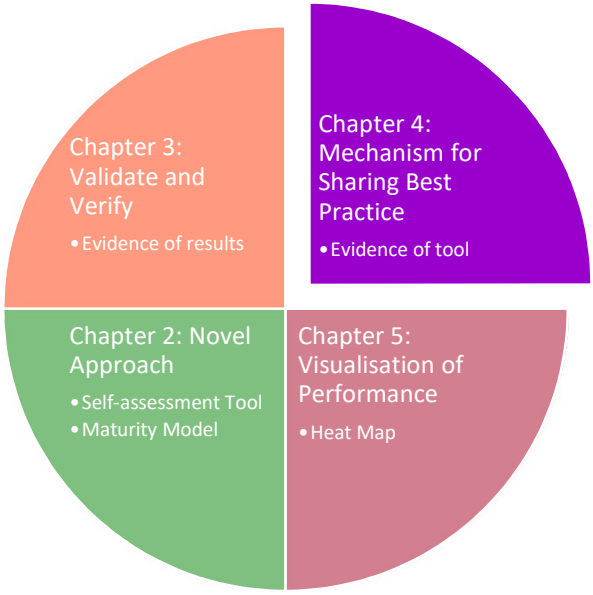

Figure 1.2: Contextual guide

In the previous chapter, two articles were included to show how the tool was validated and verified. These articles also further highlighted some weaknesses in the tool, to which improvements could be made. In addition, the articles alluded to the possibility of using the maturity model as a means to understanding the TTO and using it as a basis for sharing best practice. Through the right use and application of the tool the fourth objective of this study can be met:

4. Create a mechanism for sharing best practice between TTOs based on their individual efficiency and maturity level.

The outcome of achieving objective 4 is evidence of the applicability of the tool as a mechanism.

The overarching aim of this study is to improve the efficiency of university technology transfer in South Africa. Being a developing country, South Africa faces many of the challenges other such countries face when it comes to innovation, technology transfer and entrepreneurship. These include a lack of sufficient resources to actively engage in and pursue the aforementioned activities. These activities, when pursued in a university context are regarded as the third mission, moving universities towards becoming more entrepreneurial.

However, due to a lack of resources in developing countries, there is also a lack of tangible, monetary data from which to determine the current efficiencies of university technology transfer. Therefore, in keeping with the aim of this study, to improve the efficiency, the current efficiency must first be measured and understood. This led to the creation of the self-assessment tool and maturity model.

The tool also aids the TTO, not only in measuring current efficiencies but also in highlighting internal weaknesses which may be improved upon to increase efficiency. Additionally, to enhance efficiency, barriers to success must be addressed. The strong correlation between the tool and intellectual capital

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provides a means through which this may be achieved. A barrier to the success of technology transfer is sufficient staff with the required skills to perform technology transfer. By leveraging the intellectual capital of the university, specifically human capital, the university can collectively support the TTO. Through policy intervention, incentives and an enabling environment, access to human capital may be facilitated within the university to aid the TTO.

Another means of improving the efficiency of university technology transfer is through sharing best practices. As mentioned in the first chapter, sharing best practices between two organisations in the same country is challenging. Moreover, these challenges get exponentially more complex when the two organisations are in different countries, differ in developed status, and all the resultant contextual differences. Add to that the complexity of the university environment, indicates that sharing best practices between TTOs is no small feat.

The following submitted article presents the self-assessment tool and maturity model with the improvements that have been made post validation and verification. The tool is also tested further by increasing the sample size to include universities in the United Kingdom. Again, the tool is tested in the developed country context given the long history of university technology transfer activities being undertaken. The article then continues to illustrate how the tool may be used as a mechanism to facilitate the effective sharing of best practices between TTOs. The intention is to use the tool to share best practices between TTOs based in developed countries, or based in developing countries or even between TTOs in developed and developing countries as appropriate.

It should be noted that this article was submitted to a journal with a very different formatting style and readership from the previous articles.

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A Mechanism for Sharing Best Practices Between University Technology Transfer Offices

Authors: Christle De Beer[2], Giustina Secundo[1], Giuseppina Passiante[1], Corne Schutte[2]

[2]Stellenbosch University, Stellenbosch, South Africa

[1]University of Salento, Lecce, Italy

Abstract

Research has shown that university technology transfer offices (TTOs) learn through experimentation and failure, and by sharing these experiences with others. There are many barriers to successfully sharing best practice between TTOs. The Maturity Model (MM) created by Secundo et al. (2016) provides a means by which the performance of a TTO can be better understood to allow for the effective sharing of best practices. The aim of this study is to improve and validate the MM to formalize a mechanism through which best practices can be identified and shared between TTOs. This was accomplished by testing the MM in 54 TTOs across Europe and the United Kingdom. Findings regard several improvements of the intangible indicators and the maturity levels of the MM. This research improves the rigor of the MM and formalizes its application as a mechanism for sharing best practices through the Improved MM.

Key words: Best Practice, Maturity Model, Technology Transfer Office (TTO), efficiency, performance measure, intangible indicators.

Article classification: Research paper

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4.1 Introduction

Universities are seen as key actors or organisations in national innovation systems (Libecap et al., 2005; Bercovitz and Feldman, 2006; Guan and Zhao, 2013) and within such systems, are the vehicles for technology transfer and a conduit through which knowledge exchange is made more effective (Redford and Fayolle, 2014; Siegel and Wright, 2015a; Miller et al., 2016). Thus, universities are, through their technology transfer offices (TTOs), engaged in several activities, including intellectual property (IP) patenting and licensing, and the creation of spin-out and spin-in companies (Bercovitz and Feldman, 2006). In the USA, as well as many countries in Europe, an increase in these knowledge valorisation activities has been observed (Grimaldi et al., 2011; Vinig and Lips, 2015). Following this trend, almost all European research universities today have a TTO with professional support for commercialization (Jonsson et al., 2015).

Technology transfer has changed dramatically since the time universities first established TTOs in the 1980s and 1990s (Lockett et al., 2015) and in some circles, has come to be known as 'academic entrepreneurship' (Siegel and Wright, 2015a) which shows the wide and ever-expanding scope of technology transfer (Miller et al., 2016). However, there is little evidence regarding the effectiveness of the university TTOs in promoting academic entrepreneurship (Siegel and Wright, 2015b). It is debatable how far models applied to elite universities are applicable to other universities (Wright et al., 2008) and indeed how effective universities are at technology transfer. Miller et al (2016) state that technology transfer performance measurements are emergent in nature with many measures not being adequately addressed such as tacit based activity costs and effectiveness, and therefore, there is a need for more fine-grained technology transfer performance measures. In light of the evolution of technology transfer, traditional methods of assessing university performance in technology transfer also need to evolve. When studying TTOs Miller et al (2016) found that contextual sets of performance measures are needed rather than assuming a general standard approach.

A recent paper (Weckowska, 2015) highlights how TTOs and their commercialization practices have evolved over time and that TTOs learn through experimentation and failure. TTOs then share these experiences with other TTOs, thereby improving the technology transfer process. However, there are several barriers to successfully sharing best practice (Sharma et al., 2012) between TTOs, amongst these the most important is the need to understand how well a TTO is performing at present, and why it is not performing better (Granieri and Frederick, 2015). In a study of the transnational transfer of strategic organizational practices, Kostova (1999) identifies social context, the sociocultural environment in which the best practice is found and will be adopted, to be another barrier. This extends to cross-country differences in negotiations, leadership and distribution of power, authority in organizations, and human resource management practices. When considering the vast differences between TTOs, however, transnational transfer may be too limited to understand the complexity of sharing best practices. It, therefore, stands to reason that to truly measure a TTO's performance, it needs to be contextually characterized. Once the context of the TTO is defined, the best practices of the TTO can be articulated more clearly and shared with other TTOs, thereby improving the efficiency.

Framed in the above premises, this paper aims to show the duality of the Maturity Model (MM) created by Secundo et al (2016), which can be used to both measure the performance of a TTO and also as a mechanism for the effective sharing of best practice between TTOs. This will be achieved by testing the MM in 54 TTOs across Europe and the United Kingdom (UK), and through interviews with 25 of these TTOs and reiteration, improve the MM. The Improved MM (IMM) will provide a means to strategically intervene to improve the efficiency of the TTO,

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and also act as a mechanism for the sharing of best practice.

The remainder of the paper will be organized as follows: section 4.2 will discuss relevant literature on technology transfer highlighting the research gap addressed. Section 4.3 will detail the research methodology employed and Section 4.4 will discuss the findings of this study. Section 4.5 will explain the improvement on the MM and detail the novel contribution. Finally, the paper concludes the findings and possible applications.

4.2 Literature

Technology Transfer Office (TTO)

The success of universities as research institutions depends, at least in part, on the creation and commercialization of new knowledge and of know-how embedded in new technologies (Brecia et al., 2016). These commercialization services are being demanded from the university technology transfer office (TTO), as well as scrutinized, by a myriad of stakeholders (Fitzgerald and Cunningham, 2015). Research (Muscio, 2010; Bozeman, 2000) has shown that the efficiency and effectiveness of technology transfer are influenced by many factors. These factors may include culture clashes, bureaucratic inflexibility, poorly designed reward systems, and ineffective management of the TTO (Siegel et al., 1999). Therefore, the performance of the TTO is not just an empirical issue but also a policy issue regarding both the operations and the purposes of universities (Siegel et al., 2007). Operationally, universities persist in efforts to promote technology transfer, even though several studies (de Falco, 2015) have shown that a great deal of TTOs operates inefficiently (Anderson et al., 2007).

Additionally, universities often have a culture that is not conducive to technology transfer or they do not possess the complementary assets to be successful therein (Siegel and Wright, 2015a). Yet, universities continue their technology transfer activities for two reasons. The first, is increasing pressure on universities to generate money because technology transfer and cooperation between universities, industries, and the government generate benefits for the myriad of stakeholders (Algieri et al., 2013; Siegel and Wright, 2015a). The second reason is the competitive pressure, through the benchmarking of technology transfer based on the Association of University Technology Managers (AUTM) metrics. These metrics may not be the full set of true 'outputs' of technology transfer, as they focus mainly on monetary indicators, yet they can drive strategic decision-making by university administrators. Therefore, it is crucial to know how well universities implement a process as complex as technology transfer, and because TTOs are central to this, it is even more crucial to know how efficient and effective a TTO is at conducting its missions (Resende et al., 2013). Considering the evolution in technology transfer, universities need to consider whether to pursue technology transfer and the traditional methods of assessing university performance in technology transfer also need to evolve (Siegel and Wright, 2015a).

Performance Measurement of the Technology Transfer Offices

Empirical studies evaluating the performance of TTOs, are usually based on measuring the conversion ratio from 'inputs' to 'outputs' of technology transfer (Thursby and Kemp 2002; Siegel et al., 2003a; Chapple et al., 2005; Link and Siegel 2005; Schoen et al., 2014) or so called, Data Envelopment Analysis (DEA). DEA (Charnes et al., 1978) has been regarded as a proper approach to measuring technology transfer performance (Kim et al., 2008) and many benchmarking activities of technology transfer offices in the USA and the UK have used this method. Findings from one such benchmarking study, by Rogers et al. (2000) showed that universities with effective TTOs were characterized by (1) higher average faculty salaries, (2) a larger number of staff for technology licensing, (3) a higher value of private gifts, grants and contracts, and (4) more R&D funding from industry and federal sources. Yet DEA does not indicate whether TTO performance

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is adequate, if it can be improved, and if improvements are possible, how to intervene to improve efficiency and effectiveness (Resende et al., 2013). Research has shown that factors, such as technology attributes (Pries and Guild, 2011), have an impact on which strategy is chosen when transferring technology, which makes it difficult to evaluate TTO performance. Furthermore, organisational factors such as faculty reward systems, TTO staffing/compensation practices, and cultural barriers between universities and firms (Siegel et al., 2003b), are critical to the productivity of TTOs. As such, these often-used metrics – for example counting patents (Anderson et al., 2007) – have little to do with overall performance (Resende et al., 2013). Larsen (2011) states that patenting is only a small part of technology transfer and its measurability. Miller et al (2016) suggest that technology transfer performance measurements are emergent in nature because of on-going change in the external environment, and that contextual performance measures such as institutional and geographic factors involving regional stakeholders and societal based innovation users are required as opposed to a 'one size fit all' approach. Another suggestion by these authors is that the performance measurement of technology transfer should consider specific constraints in interacting with industry (or external organisations) inherent in scientific disciplines such as:

- Health Sciences
  - Difficulty in reaching agreement with external organisation on terms of the interaction such as IP
  - Unwillingness of external organisation to meet the full cost of the interaction
- Science, Technology, Engineering and Maths
  - Unwillingness of external organisation to meet the full cost of the interaction
  - Lack of resources in the external organisation to manage the interaction
  - Difficulty in identifying partners
  - Lack of interest by external organisations
  - Difficulty in reaching agreement with external organisation on terms of the interaction such as IP
- Arts and Humanities
  - Lack of time to fulfil all university roles
  - Insufficient rewards from the interaction
  - Poor marketing, technical or negotiation skills
- Social Sciences
  - Bureaucracy and inflexibility
  - Insufficient resources devoted to activities with external organisations
  - Differences in timescale
  - Lack of experience in the external organisation in interacting with academics
  - Cultural differences between academics and businesses

The Maturity Model (MM) and self-assessment tool were created by Secundo et al (2016) with the aim to inform the design of a customizable solution to barriers to the success of technology transfer, thereby overcoming the "one size fit all" approach followed by other models. The self-assessment tool measures various intangible indicators, on a scale of 1 (disagree completely) to 5 (agree completely), grouped into six efficiency areas. These six areas are human resources, IP policy and strategy, networking, university-industry links, technology, and organization design and structure. The human resources of the TTO are considered in terms of their skill sets and the area of IP strategy and policy focusses on the institutional support given to technology transfer. University-Industry links are distinguished from the network area in that it is concerned with understanding the needs of industry, whereas the network area is concerned with the interaction between the parties

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involved. The technology area emphasizes the importance of the stage of development of the disclosed technology, as well as the academic merit of the discloser. Organization design and structure looks at the TTO and surrounding support functions.

Then, using the fuzzy comparison matrix (or Fuzzy AHP), the efficiency areas where prioritised and weighted, and the priorities assigned to each efficiency area were then used to calculate a final score for the efficiency of technology transfer. Based on this final score, the maturity level of the TTO can then be assigned per the MM. The maturity levels of the original Maturity Model were:

- *Awareness stage* – No structured management of TTO.
- *Defined stage* – A structured TTO (usually centralized and/or internal) exists, with essential human resources.
- *Managed stage* – A structured TTO (usually decentralized and/or internal) exists, with sufficient human resources, including some specialist skills.
- *Integrated stage* – A structured TTO (usually decentralized and/or external) exists, with technologies disclosed at a variety of technology readiness levels, some with a prototype available.
- *Sustained stage* – A structured TTO (usually decentralized and external) exists, with specialist human resources. TTO has well established and strong networks and close industry links. TTOs at this stage usually own (or has access to a university-owned) business incubator.

The self-assessment tool allows for different project managers to assess the performance of the TTO. This means that a health science project manager or a social science business developer would be able to assess the relative performance, based on their discipline-specific experience. The overall performance can then be understood from a holistic point of view, by allowing the director or CEO to complete the self-assessment, but also from a discipline-specific point of view. The scores assigned to each intangible indicator in the self-assessment tool is used to determine how mature a TTO is at technology transfer and consequently the performance of the TTO is classified per the MM. Each intangible indicator used to measure the performance of the TTO also gives insight into understanding how performance can be improved, as such overcoming the limitations of DEA. The MM highlights weaknesses within each university or TTO's efficiency using various intangible and intellectual capital indicators, moving away from the limitations of monetary and tangible indicators. The MM summarizes the strategic decisions and interventions that can be made to improve performance, it may be used to monitor improvements and to predict future performance, and it can serve as a basis for comparison of performance between different TTOs.

Sharing Best Practice Between TTOs

Benchmarking or best practice management is increasingly being recognized as a powerful performance improvement effort for processes, business units, and for entire corporations (Jarrar and Zairi, 2000; Jonsson, 2015). Indeed, interest has increased in the phenomenon of organizational learning; on how organizations create, retain, and transfer best practice (Szulanksi, 2000; Usoro et al., 2007; Moustaghfir, and Schiuma, 2013). It is, therefore, apparent that the performance of a TTO, the measurement thereof, and the sharing of best practice to improve performance are all closely linked. Accordingly, the barriers to sharing best practice will have some similarities to the barriers in transferring technology. Indeed, the more common terminology is 'transfer of best practice', and as Szulanksi (1996) explains, connotes the replication of an internal practice that is performed in a superior way and is deemed superior to internal alternate practices and known alternatives. The word "transfer" is used to emphasize the movement of knowledge as a distinct experience and not a gradual process

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of dissemination. The word “practice” refers to the organization's routine use of knowledge and often has a tacit component (Szulanski, 2000; Jarrar and Zairi, 2000). Transfers of best practice are thus seen as dyadic exchanges of organizational knowledge between a source and a recipient in which the identity of the recipient matters. To avoid confusion, however, this paper will refer to sharing best practices to improve technology transfer.

Organizations often engage in sharing best practices that reflect core competencies and superior knowledge that may improve efficiency and synergy (Kostova, 1999; Yeo and Marquardt, 2015). As mentioned before, many universities through their TTOs are not efficient at technology transfer, and in response to this state of affairs, numerous practices have been proposed for improving technology transfer. These include, amongst others, improving the management of the process, overcoming organizational and human barriers to success, making the process more systematic, improving the conveying of technologies, and increasing the users' willingness to adopt new technologies (Souder et al., 1990; Goh, 2002). Indeed, the sharing of best practices like these are seen as important drivers to improve performance (Schiuma, 2009) yet impediments to the sharing of best practice have received little attention (Szulanski, 2000). If TTOs want to fully exploit the benefits from the sharing of best practices, the difference between `doing’ and `learning’ needs to be clearly understood, as the problems often associated with the sharing of best practices are of a behavioural nature rather than ones of mechanics and systems. The process of sharing best practices include six phases (Jarrar and Zairi, 2000):

1. Searching – In this phase best practices need to be identified which can be shared. The challenge in this phase is that finding best practices are very difficult.

2. Evaluating – In this phase the identified best practices need to be understood contextually and it must be noted that the best practices are subject to the specific situation and group/person involved.

3. Validating – In this phase the quality of each practice is scrutinized in greater depth and related to the impact it creates in terms of benefits.

4. Implementing – This phase is the process of adopting and adapting the selected practices, and faces the most challenges out of all six phases. This phase is influenced by enabling the best practice (willingness to adopt) and sharing the best practice (applying in a new configuration or location).

5. Review – This phase is essential to determine if the implementation of the best practices have managed to close a performance gap.

6. Routinizing – Making best practices part of the culture of work is the ultimate goal for complete and effective transfers.

As alluded to above, the implementation phase faces the most challenges, and these challenges are often referred to in the literature as internal stickiness (Szulanksi, 2000). Prior research (Szulanski, 2000) suggests that four sets of factors are likely to influence this: (1) characteristics of the best practice shared, (2) characteristics of the source of the best practice, (3) characteristics of the recipient of the best practice, and (4) the context in which the sharing takes place. There are additional barriers to successfully sharing best practice between TTOs, amongst these the most important is the need to understand how well a TTO is performing at present, and why it is not performing better (Granieri and Frederick 2015).

Taking into consideration then, the challenges articulated above, this paper aims to improve and validate the MM in order to formalize a mechanism through which best practices can be identified and shared more effectively between TTOs. Therefore, this study seeks to answer two questions: 1) How can the MM created by Secundo et al (2016) be tested and validated to

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result in an Improved Maturity Model (IMM)? and 2) How can the IMM be used as a mechanism to share best practice?

4.3 Research methodology

In order to answer the first research question, the MM will be tested in TTOs and these TTOs will be interviewed to validate the MM. Furthermore, to result in an IMM, individual weightings for the intangible indicators will be collected. By addressing these two weaknesses of the MM, as cited by the authors, the MM will be improved.

The second research question will be addressed by an extensive discussion of the results from the IMM to illustrate how it can be used as a mechanism for sharing best practices.

Data collection

The MM was translated to an online survey using eSurveyCreator. Each individual intangible indicator was rewritten to a statement and assessed by the participant on an ordinal, 5-point Likert scale, according to the strength of which the statement is true. Additionally, each statement was weighted by the participant as being (1) not important at all, (2) not important, (3) important, and (4) extremely important. Therefore, the individual intangible indicators can be weighted based on expert opinion which improves on the MM.

The survey was sent to one mid-level employee at 234 TTOs in the UK (116) and Europe (118). All surveys were administrated electronically between the beginning of June and end of October 2016 to the email addresses of TTO staff. Data on TTOs and their staff were collected using the websites of individual universities. A mid-level employee was considered as someone with a post-graduate degree and a minimum of 5 years' experience. The person was selected based on their online profile and job title.

By sending the MM in a survey format, it allowed testing of the MM, to which 54 TTOs responded, 20 from the UK and 34 from Europe. The survey had a response rate of 23% in total, 17% from the UK and 29% from Europe, was completed anonymously, but the participants had the option to include their contact details to enable a follow-up interview to discuss the results. After completion, 6 TTOs in the UK and 19 TTOs in Europe were interviewed to further improve the model through face validation and reiteration.

Face validity refers to experts accepting that the MM appears to be sound and relevant in that it looks like what it is intended to measure (Nunnally, 1967). Therefore, face validity afforded the opportunity to determine the accuracy of the results of the self-assessment and the corresponding maturity level assigned to the TTO. Interviews were conducted in a semi-structured manner with a common set of questions, while allowing interviewees to elaborate on their answers and enabling us to ask additional probing questions. Generally, interviews lasted 30 minutes and were conducted on site or via Skype call. Therefore, the MM was improved reiteratively after each interview with each TTO. 25 interviews were conducted in total.

Data analysis

The completion of the online survey by 54 TTOs allowed the determination of the weightings of the indicators, through the calculation of the average weight assigned by each participant. As these participants are mid-level employees at TTOs it can be assumed that their expert judgment weights the indicators accurately. However, these weights were further confirmed once the maturity level of the TTO was determined and discussed with the TTO. If the maturity level did not reflect the true performance of the TTO, then the weightings would prove to be inaccurate.

Through face validity it was therefore determined: (1) if the intangible indicators accurately captured the performance of the TTO, (2) if the weightings of the individual indicators were accurate (3) if the maturity levels in the MM reflected the true performance of the TTO, and (4) if the characteristics of the TTOs are captured by the MM. It should be noted however that face validity is still a subjective assessment, but due to

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the relatively high number of TTOs involved (25 out of 54 TTOs, thus an interview ratio of 46%), there is confidence in the average results. After each interview, the MM was adapted to reflect the inputs from the participants in the aforementioned four areas, and thus through reiterations, the MM was improved.

4.4 Findings

Moving from the research approach described above, the Improved Maturity Model (IMM) is presented to reflect the true performance and characteristics of the TTO. The self-assessment tool is reorganized according to the weights assigned by the participants, and the corresponding weight of each indicator is shown (Table 4.1). The final column of the self-assessment tool has been completed to reflect the maximum scores a TTO can achieve. The priorities assigned to each intangible indicator are then used to calculate a final score for the efficiency of technology transfer. Based on this final score, the maturity level can then be assigned according to the principles of the Project Management Process Maturity Model $(PM)^2$ Model (Kwak and Ibbs, 2002). Each maturity level provides a description of the characteristics associated with that level which may be used by the TTO to make strategic decisions on how to improve certain areas and to sustain the decision-making process more effectively. Upon self-evaluation of each efficiency area, a TTO will then be able to focus on specific intangible indicators that show weaknesses within their efficiency and can achieve a higher maturity. After face validity by 25 TTOs each of these levels are better defined to characterize the TTO as illustrated in Figure 4.1. The defined (25.95), managed (46.71) and integrated (67.47) stages are further divided into early and late stages (at the score in brackets) to highlight the different characteristics of TTOs at these transitional levels. Additionally, due to the individual weightings of the indicators, the maximum scores for each maturity level have been adjusted to reflect these new scores. Some excerpts from the face validity of the IMM include:

- *"The assessment was spot on, and showed weaknesses I had already anticipated was present in my TTO"* – A TTO in Czech Republic

- *"I think this performance measure reveals a lot more of the activities we engage in as a TTO"* – A TTO in Sweden

- *"The MM describes my TTO exactly"* – A TTO in the UK

Table 4.1: Self-assessment tool: Intangible indicators of the efficiency of technology transfer

Rank		Likert scale					Survey
	Human resource	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	**Weight**
1	At least one staff member has the expertise to manage the licensing portfolio as a set of options					4	80%
2	TTO has sufficient number of staff					3.9	78%
3	At least one staff member has marketing experience					3.6	72%
	IP Strategy and policy	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	
1	A clear, transparent and consistent vision for technology transfer, with strategic goals and priorities.					4.15	83%
2	Frequent and reciprocated involvement with faculty					3.85	77%
3	Sufficient resource allocation to TTO					3.75	75%
4	Provide education to overcome informational and cultural barriers between TTO and Faculty					3.25	65%
5	Incentives for faculty to disclose					3.2	64%

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6	Royalty shares for faculty					3.05	61%
7	Incentives for TTO staff					2.75	55%
	Networking	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	
1	TTO has personal relationships with faculty					3.95	79%
2	Formal and/or informal networking between faculty and TTO					3.5	70%
3	TTO facilitates formal and/or informal networking between scientists					3.1	62%
	University-Industry links	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	
1	TTO understands the needs of industry					4.45	89%
2	TTO facilitates formal and/or informal networking between faculty and industry					4	80%
3	Provide education to overcome informational and cultural barriers between TTO and industry					3.2	64%
	Technology	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	
1	Most technologies disclosed to TTO is not at an early stage					2.7	54%
2	Most faculty members who disclose are Professors					1.65	33%
	Organization design and structure	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	
1	A business incubator is available for faculty					3.35	67%
2	TTO has been established for 10 years or more					2.8	56%
3	TTO has a decentralized management style					2.65	53%
4	University has a medical school					2.55	51%
5	TTO is positioned externally to the University					2.5	50%
6	University is publicly owned					1.95	39%

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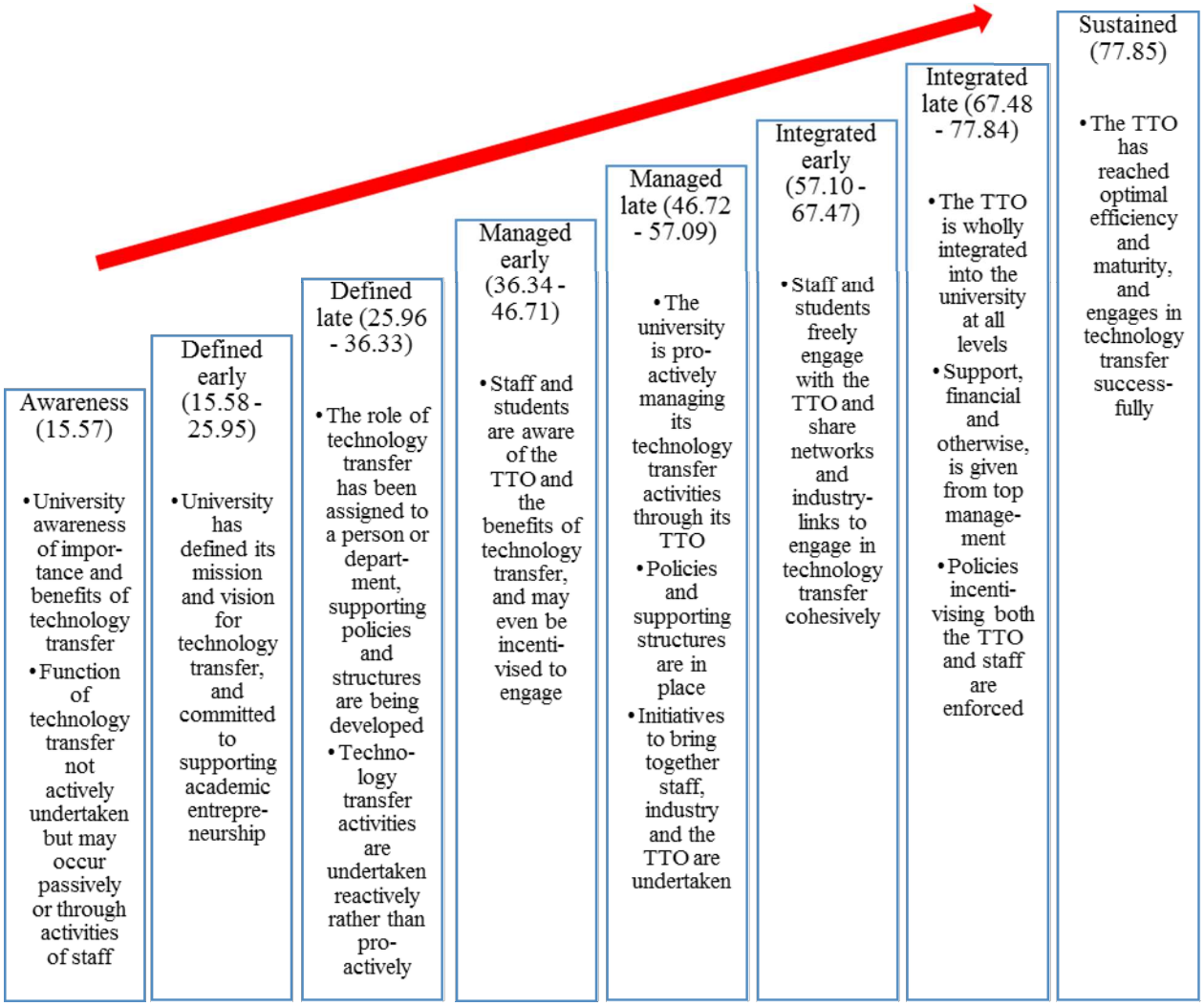

Figure 4.1: Maturity level of TTO based on efficiency areas with key TTO characteristics defining each stage

4.5 Discussions

The findings have shown that the first research question of this paper has been answered. The MM can be tested in survey format and validated through follow-up interviews. The MM can be improved through iteration post interviews and through the inclusion of individually weighted indicators. These new weightings led to new scores for each of the maturity levels, and new definitions of the different maturity levels. These new levels of maturity were further described and characterised through interview data, and thus the MM was improved upon.

The second research question seeks to answer how the Improved MM (IMM) can be used as a mechanism to share best practice. As mentioned before the most important barrier in successfully transferring best practice between TTOs is understanding how well the TTO is performing and why it is not performing better. The IMM overcomes this barrier by not only measuring the performance of a TTO but also highlighting specific strengths and weaknesses of TTO performance which may be improved upon. The process of sharing best practice includes 6 phases: identify, evaluate, validate, implement, review and routinize. As mentioned before the implementation phase has the most challenges. By using the self-assessment tool the best practice to be shared is characterised by the intangible indicators, thereby overcoming the first challenge of the implementation phase. The

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IMM then characterises the source and recipient of the best practice and contextualises the sharing of the best practice, overcoming the final three challenges of this phase.

To illustrate how the IMM can be used as a mechanism in the process of sharing best practice and overcome these barriers a fictional scenario will be discussed.

A well-performing university TTO in the UK (TTO A), with a Late Integrated stage maturity level, wishes to share a best practice with another TTO (TTO B). By completing the self-assessment tool, TTO A has identified a best practice to share. Based on the intangible indicators this best practice is characterised and allows for the evaluation of the best practice. The best practice is validated by the IMM, as the high maturity level of TTO A serves to prove the success of the best practice. Next, to implement the best practices, there are 3 barriers that are overcome by the IMM. TTO A has used the IMM to capture the information about the context in which it operates as well as the characteristics of the TTO (source of best practice). TTO B now uses the IMM to capture the information about the context in which it operates as well as the characteristics of the TTO (recipient of best practice). In this scenario, TTO B is also at a university in the UK, but at the Late Managed stage maturity level.

Therefore, to enable TTO A to share its best practice with TTO B, TTO B needs to activate internal steps to move to the Integrated stage (at the very least early stage) to allow for the effective sharing of best practice. To allow this, TTO B looks at the raw data from the self-assessment tool to determine which specific weaknesses exist which may be improved upon. The strategic interventions can be simple and inexpensive, for example: increasing involvement with faculty; or involve the employment of another staff member with specialized skills, or providing training for the TTO to acquire these skills. Once TTO B has achieved the desired maturity level the best practice can be shared more effectively.

In this scenario, the sharing of best practice is facilitated by the IMM because the characteristics of both the source and recipient of the best practice are known beforehand, and defined in a standard and consistent way. The context in which the best practice will be shared is known as both TTOs are university-based, and based in the UK, and as such, they are aware of any cultural, social or institutional barriers prior to attempting to share the practice. Additionally, the best practice is characterised by the self-assessment tool through the intangible indicators. Finally, the IMM may be used periodically by TTO B to review the implementation of the best practice and to determine if there has been an improvement in performance.

4.6 Conclusions

This study has succeeded in improving the Maturity Model (MM) created by Secundo et al (2016) by improving the weighting, re-defining the maturity levels and testing the model with experts and through live testing. This study has also shown how the improved MM (IMM) may be used as a mechanism for sharing best practices, specifically between TTOs, as it addresses some of the challenges involved in sharing best practices.

The implications for theory is that the IMM shows a holistic approach to the measurement and improvement of performance, as well as sharing of best practices. Considering how closely these aspects are linked to each other, one and the same mechanism should be used to measure, improve and share best practices. The IMM is such a mechanism, and due to its customizable nature, it lends itself to both measuring performance and sharing improvements. Practically, this means a TTO will be able to measure and compare performance with the IMM and at the same time use the IMM to identify and share best practice. Furthermore, the TTO now also has the means to determine how successful the best practice has been implemented and if it has resulted in an improvement in performance.

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The limitation of this study is that the IMM has not yet been used to share a best practice between TTOs, and as such case-based research will be needed to verify the IMM. Future work will test and validate the Improved Maturity Model for application in TTOs in developing countries, to enable sharing of best practices between developed and developing countries. The novel contribution of this study is the IMM and the application thereof as a mechanism for sharing best practices.

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Conclusion: Chapter 4

The improved self-assessment tool and maturity model is presented in this accepted article titled: "Mechanism for Sharing Best Practices Between University Technology Transfer Offices". This article was included in Chapter 4 to address the fourth objective of this study:

4. Create a mechanism for sharing best practice between TTOs based on their efficiency and maturity level.

As highlighted in Table 1.1 (Chapter 1, Heading 1.8, page 21) the outcome of this objective is evidence of the applicability of the self-assessment tool (as seen in Table 4.1 of the article) and maturity model (as seen in Figure 4.1 of the article) as a mechanism for sharing best practices.

Comparing the self-assessment tool (as seen in Table 2.1 of the article in Chapter 2) and maturity model (as seen in Table 2.2 of the article in Chapter 2) to the ones presented in the article above, some changes are noted. Firstly, the self-assessment tool now includes detailed weightings. As discussed in Chapter 2, fuzzy AHP was initially used to weight the efficiency areas (the overarching 6 areas that the indicators were grouped into). Now, the individual efficiency indicators are weighted based on expert opinion.

Secondly, the maturity model is now expanded to 8 levels (instead of 5) and more descriptive characteristics are given. As discussed in Chapter 2, the maturity levels were described based on the research team's opinions and literature evidence of the most important characteristics of each level. Now each level is described based on interviews with experts, and further elaborated on to enhance the depth of the descriptions. The interviews followed the format described in Chapter 3, where certain specific questions were asked, but the interview was also allowed to flow naturally with probing questions where necessary for clarity.

Therefore, the tool is not only validated and verified, as discussed in Chapter 3, it now also includes the improvements from the various iterations and expert interviews. The weaknesses of the tool that were noted in the previous chapters are now also addressed, and a more robust tool is presented.

Furthermore, the article shows though hypothetical case examples, how the tool can be used as a mechanism to facilitate the sharing of best practices. This still leaves room for future work to test the mechanism in real case studies. Future work will also investigate Snowden's Cynefin model (best practice, good practice, emergent practice and novel practice) thus introduce complexity in this sharing mechanism.

This article also addresses the second level of intervention, at the interoffice level, enabling the sharing of best practices between TTOs to allow for the improvement of university technology transfer. Thus the four articles that have been presented so far in this portfolio, show a means to measure and improve the efficiency of university technology transfer at two levels of intervention.

However, the strong correlation with intellectual capital noted in the articles in Chapter 3 has opened the door to another avenue of investigation. If the data collected with the tool can be translated into a format that any reader can understand, and this is linked to intellectual capital, then the university may strategically intervene to improve the efficiency of university technology transfer. Therefore, Chapter 5 will further investigate this correlation with intellectual capital and use this as the basis for visualisation of the performance of the TTO.

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CHAPTER 5: Visualising the Performance of the TTO

Heat maps of TTO access to intellectual capital

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Visualising the performance of the TTO

Introduction: Chapter 5

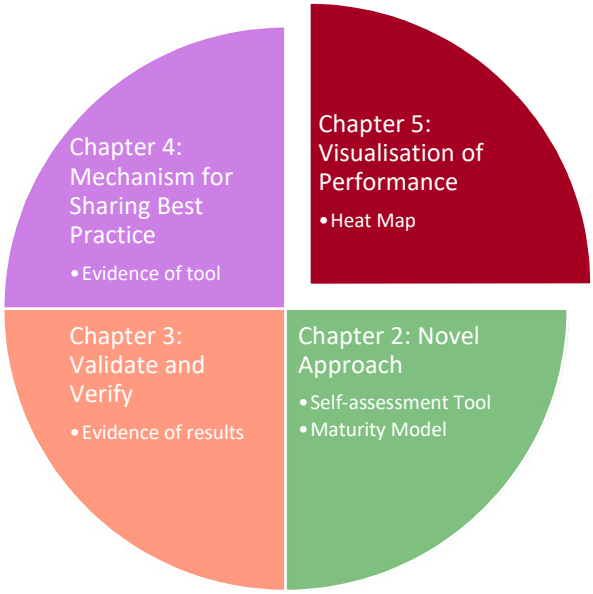

Figure 1.2: Contextual guide

In Chapter 4, the use of the tool to understand and characterise the performance of the TTO was discussed. By contextualising the TTO in this way, some of the barriers to sharing best practices were addressed, allowing a TTO to improve its efficiency at an interoffice level. This interoffice level intervention can take place irrespective of the status of the country (developed or developing) as the TTOs are now all characterised in the same, consistent manner. Some interventions, however, require buy-in from top management at the university (intra-organisational intervention). Often the complexity of technology transfer, and improving its efficiency is not well understood by university management, which can cause delays or even disapproval of the necessary strategic interventions. Therefore, the fifth objective of this study is necessary to improve the efficiency of university technology transfer:

5. Visualise the performance of the TTO in a way that is relatable at all levels of university management.

In Chapter 3 the correlation between the tool and intellectual capital was discussed. The book chapter presented as part of the portfolio in Chapter 5 builds on this relationship. The two articles in Chapter 3 found that access to intellectual capital was essential for improving the efficiency of university technology transfer. This access can be viewed in two ways: First, that the organisational structure of the TTO allows access to intellectual capital. Secondly, that the TTO has access to the intellectual capital it most needs for efficiency.

These two ideas of access were investigated in the form of two conference papers. The first was presented at IFKAD (International Forum on Knowledge Asset Dynamics) and discusses the importance of the organisational structure of the TTO (see Appendix A for complete paper, page 144). Some key findings from this conference paper are given in section 5.1 below.

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Section 5.1

Technology Transfer Office type for increased access to University Intellectual Capital: Recommendations from Europe and the UK

The aim of this study was to determine which TTO organisational structure would be the most suitable to enable access to IC in developing countries. The paper postulates that TTOs with high maturity levels should have maximum access to IC. Based on the typology suggested by Brescia et al., (2016), all the organisational structures are noted in high-performing TTOs as identified from the interviews with 24 TTOs. A prevalent typology is a mixed or internal multi-office model.

From the results in Table 1, a multi-office organisational model is preferred, which fully supports the postulation above because these organisational structures have maximum access to IC. Through the addition of another office within the university to the TTO organisational structure, the TTO has increased access to university IC, specifically HC and SC. Similarly, when the TTO is in a distributed structure, due to the proximity to the researchers or staff of the university, the TTO has increased access to university IC, specifically, HC and RC.

Table 5.1.1: Results of 24 TTOs in the EU and UK sorted in ascending order according to score

Country	***Score***	***Type of TTO***
Austria	*34.8*	*Internal multiple offices*
Greece	*36.6*	*Internal single office*
Italy	*37.2*	*Internal multiple offices*
UK VI	*42.2*	*Internal multiple offices*
Czech Republic II	*42.6*	*Internal single office*
Belgium II	*43*	*Internal single office*
UK II	*43.2*	*Internal multiple offices*
UK V	*48*	*Internal single office*
Czech Republic I	*48.2*	*Internal multiple offices*
Netherlands	*49.2*	*Mixture of internal and external offices*
Czech Republic III	*49.6*	*Internal multiple offices*
Denmark	*50*	*Internal single office*
Belgium I	*50.6*	*Internal multiple offices*
UK III	*50.8*	*Internal multiple offices*
Bulgaria	*51.8*	*External joint offices*
Estonia	*52*	*Internal multiple offices*
Belgium III	*52.8*	*Internal single office*
Czech Republic IV	*53*	*Internal multiple offices*
Belgium IV	*53.6*	*External joint offices*
France	*55.2*	*External joint offices*
Sweden	*56.8*	*Mixture of internal and external offices*
Switzerland	*60*	*External joint offices*

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UK IV	*60.4*	*External multiple offices*
UK I	*61*	*External single office*

Our preliminary findings (Table 5.1.1) indicate that the multiple office (either mixed, external or internal) organisational structure is, in the opinion of this study, the most-preferred structure for a new TTO in a developing country. Of course, when establishing a TTO for the first time it may be costly to start with this organisational structure, and it is recommended that developing countries start with an internal multi-office TTO until sufficient capacity, skills and funding are established. From there, adding an external TTO which works closely with the internal TTO should move the TTO to a higher maturity level. In certain countries, an external TTO may not be necessary if the internal TTO has strong university-industry links, or there is no legal requirement preventing the university from engaging directly in commercialisation activities.

As stated in Chapter 3, the tools created in this study were tested in developed countries whence the most useful learnings and best practices could be adopted. Therefore, even though the intent of the study is to improve university technology transfer in developing countries, the learnings would come from developed countries. The organizational structure suggested above would support a new TTO by providing access to intellectual capital, and thus the recommendation that developing countries adopt this structure.

The second paper was presented at ICEIRD (International Conference on Entrepreneurship, Innovation and Regional Development) and discusses the importance of the vision/mission statement of the university for technology transfer (see Appendix B for complete paper, page 155). From the intellectual capital indicators utilised by the tool, the mission statement has been shown to be the most important. Some key findings from this paper are given in section 5.2.

Section 5.2

A novel Technology Transfer Office typology based on lessons learnt from the UK

Our study is at a nascent stage. It is obvious that the sample size is a fundamental weakness of our study and that our findings need to be interpreted with a good deal of caution. Our intention is to repeat this study with other TTOs across several EU nations thereby building up our sample and the robustness of our findings. Nevertheless, there are some potential early lessons emerging for universities in developing nations attempting to establish their own TTOs.

First, a clear mission statement is needed. A university needs to decide what the main focus of their TTO will be, and accordingly, which TT activities it will pursue. Depending on which activities the TTO undertakes, an appropriate measure of the success at pursuing these activities should be adopted. The Maturity Model allows for the assessment of TTOs with different mission statements.

The second lesson learnt from TTOs in the UK, is that a clear mission statement needs to be paired with an appropriate governance structure for the TTO. As alluded to by the typology of TTOs in Table 5.2.1, an external structure enables a TTO with a commercial focus to be successful. Impact-focused TTOs should employ a hybrid structure, as this allows for an integrated and holistic approach to knowledge transfer within the university to strategically impact regional development. It is not possible to

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comment on relationship-oriented TTOs due to there being only two and each adopted a different governance structure and has different levels of maturity.

Table 5.2.1: Emerging typology of TTOs

			Mission Statement	
		Commercial	Impact	Relationships
Governance structure	Internal	**3**(OU1)		**3** (OU6)
	Hybrid		**3**(OU2), **3**(OU3), **3**(OU4)	**4** (OU5)
	External	**4** (RG1), **4**(RG2)		

We conclude that when a university attempts to establish a TTO it needs to consider the maturity of its TT activities and use the factors within this measure to determine if it might successfully adopt a predominantly commercial, impact (or relationship-building) mission. This should be clearly reflected in its mission statement as a signal to potential partners and the university should adopt a governance structure that enables the TTO to fulfil its primary mission.

Section 5.3

Moving on from these findings, the visual representation of the performance of a TTO was created as anticipated in the outcomes of objective 5. On the one hand the visual representation allows access to IC to be seen in the form of a heat map (data values represented as a range of colours). On the other hand, the visual representation allows for filters such as organisational structure or mission statement to arrange the results. This shows, practically, which aspects are essential for access to intellectual capital to increase the efficiency of university technology transfer, and will therefore enable intra-organisational intervention.

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A Visual Representation of Technology Transfer Office Intellectual Capital Access

Giustina Secundo*
Department of Innovation Engineering
University of Salento
Lecce, Italy
E-mail: giusy.secundo@unisalento.it
*corresponding author

Giuseppina Passiante
Department of Innovation Engineering
University of Salento
Lecce, Italy
E-mail: Giuseppina.passiante@unisalento.it

Christle de Beer
Department of Industrial Engineering
Stellenbosch University
Stellenbosch, South Africa
Email: 18867790@sun.ac.za

Corne S.L. Schutte
Department of Industrial Engineering
Stellenbosch University
Stellenbosch, South Africa
Email: corne@sun.ac.za

Abstract

The aim of this chapter is to illustrate how intellectual capital (IC) may be visualised and monitored in the university context, using the technology transfer office (TTO) as a unit of observation. The TTO is responsible, in many cases, for supporting academic entrepreneurship. Research has shown that access to IC influences the efficiency of the TTO in performing its functions. Moving from this, the perceived access a TTO has to university IC can be measured across the tripartite classification of IC: human capital (5 indicators), structural capital (13 indicators) and relational capital (6 indicators). These data sets are then used to create a visual representation of the access that each TTO perceives to have to university IC and to compare it to their overall efficiency. The visual representation allows management at both university and TTO level, to have a clearer understanding of the performance of the TTO and how IC may be leveraged to improve it. These interventions, will improve the performance of the TTO and increase success at academic entrepreneurship. This in turn, will aid the university in its pursuit of entrepreneurialism, competitiveness and sustainability.

Key words: Intellectual Capital, Sustainability, Technology Transfer Office, University.

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5.3.1 Introduction

Among the first explanations of the enhanced role universities are required to play is presented by Etzkowitz (1998) and Etzkowitz et al. (1998). The authors explain the emergence of the entrepreneurial university as a response to the increasing importance of knowledge in national and regional innovation systems of economic development. Therefore, universities are increasingly seeking to become more entrepreneurial to remain competitive and sustainable (Matos and Vairinhos 2017). The impact of the university, as an entrepreneurial entity, has been observed in economic growth and social change within their regions (Guerrero et al. 2015) in the form of new business creation, knowledge transfer and an influx of well-educated people (Etzkowitz and Klofsten 2005).

In the university context, intellectual capital (IC), can be described as intellectual material that has been formalized, captured and leveraged to produce higher valued assets (Steward 1997). The concept of value, rather than wealth creation, is more appropriate in this context because although value can include wealth, the outputs of a university are mainly intangible (Dumay and Guthrie 2012). Indeed, IC constitutes the largest proportion of the universities' assets, and as such, systematic monitoring and assessment (Osinski et al. 2017) could therefore contribute to economic improvement and better accomplishment of strategic objectives, as well as prioritizing scarce resources (Bornemann and Wiedenhofer 2014). The tripartite classification of IC includes human capital, relational capital and structural or organizational capital (Habersam and Piber 2003). The process undertaken by a university for valorising their knowledge assets and IC, is supported by technology transfer offices (TTOs) (Vinig and Lips 2015). Within the entrepreneurial university, the benefits of implementing and leveraging IC can be divided into two categories. The first pertains to the potential of IC to function as a management tool to help develop and allocate resources, create strategy, monitor the development of the university's results, and facilitate decision-making (Secundo et al. 2015). This enables the university to be more flexible and adaptive to the external environment, and in turn results in a more sustainable organization. The second relates to the potential of IC to function as a communication and reporting tool linking the institution to stakeholders and as a way to attract financial, human and technological resources (Secundo et al. 2015a).

The performance of TTOs is generally assessed by measuring efficiency and effectiveness (Hulsbeck and Lehmann 2013). Efficiency is defined as the conversion of inputs (such as invention disclosures) to outputs (such as patents, licenses, spin-out companies and income generated), and as such these tangible indicators are measured quantitatively (Thursby et al. 2001; Thursby and Kemp 2002; Thursby and Thursby 2003, 2004; Siegel et al. 2003a). Efficiency of TTOs can be measured in numerous ways, and in literature data envelopment analysis (DEA) has been regarded as a proper approach (Thursby and Kemp 1998; Thursby and Thursby 2002; Powers 2003; Siegel and Phan 2004; Anderson et al. 2007; Kim et al. 2008). There is, however, a clear and widespread dissatisfaction with many of the metrics currently used (Carayannis et al. 2014) because these methods are based on the return on investment (ROI) concept. The concept of ROI only measures short-term benefits, rather than the long-term gains brought by research and has been criticized by researchers as a "restraint on innovation" (Faulkner 1996). Measuring performance based solely on efficiency has, recently, been critiqued because using income generated by technology transfer does not measure real performance, as it does not provide, nor is it based on, the potential for technology transfer based on university research (Vinig and Lips 2015).

Effectiveness is defined as the degree to which something is successful in producing a desired result (such as the outputs anticipated by efficiency) and, in essence, is measured qualitatively through intangible indicators. Research has focused on measuring the efficiency of TTOs, and then determining

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causality by investigating antecedent characteristics, organizational or best practices, or other variables. Therefore, by enhancing these determinants of effectiveness, consequently the efficiency of TTOs will then be enhanced. Research has shown that the effectiveness of the TTO is influenced by many variables such as organizational structure, faculty involvement and the technology readiness level of disclosed inventions (Phan and Siegel 2006). Many of these determinants of effectiveness are embodied in the tripartite classification of IC, and as such it's assumed that the concept of IC can be leveraged as a tool to enhance effectiveness of the TTO and therefore improve the efficiency of technology transfer. The tool we created thus measures the access a TTO perceives to have to the IC of the university, to determine the efficiency of the TTO in a qualitative and intangible way. Previous research (Secundo et al. 2017) has shown that increased access to university IC improves the efficiency of TTOs.

For universities seeking to remain sustainable through the incorporation of entrepreneurial activities, such as promoting academic entrepreneurship, IC must be effectively managed and leveraged to support the TTO. What this means, practically, is that the university can strategically intervene to improve the performance of its TTO thereby resulting in increased success at academic entrepreneurship. This can be achieved through leveraging IC in developing the necessary policies to create an enabling environment for the TTO. As an example, human resources relate to the skills and expertise TTOs need to be successful at academic entrepreneurship. Often, within the HC of the university these skills are available. The university may, therefore, leverage its HC to increase the human resources of the TTO. This can be achieved through incentives, policies, different organisational structures, or closer collaborations between departments. Thus, the performance metric, because it is based on IC, allows the university insights into areas where it may strategically intervene. These interventions, will improve the performance of the TTO and increase success at academic entrepreneurship. This in turn, will aid the university in its pursuit of entrepreneurialism, competitiveness and sustainability.

Literature started to demonstrate through empirical research and theoretical work, the relation between intellectual capital management (ICM), competitiveness and sustainability (Lozano 2011) and to highlight trends, issues and problems related with the application, diffusion of IC concepts and conceptual innovation (Cavicchi 2017; Matos and Vairinhos 2017). In line with this overarching trend, the aim of this chapter, therefore, is to illustrate how access to IC may be visualized and monitored, using a tool (Secundo et al., 2016), to inform strategic decisions towards improved technology transfer. Managing IC in this way, leads to enhanced effectiveness at technology transfer office and therefore develops the university in a sustainable manner.

The chapter is organized into a literature review of university IC and technology transfer discussing the relationship between the IC indicators and determinants of effectiveness, the performance of TTOs and how IC may be leveraged in the measurement thereof, and visualizations of IC. This is followed by a discussion of the tool created, and how it was applied in the methodology section. The results are represented in various visual representation or heatmaps and discussed, after which the chapter concludes.

5.3.2 Literature Review

University Intellectual Capital (IC) and Technology Transfer

IC in a university is, ultimately, the set of intangible and knowledge assets that drive the mechanisms of value creation according to the targets defined by stakeholders of the internal and external environment (Redford and Fayolle 2014). As alluded before, IC in its tripartite classification, is partly the subject matter of the process of technology transfer. Human capital comprises value deriving from the expertise,

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knowledge, and experiences of researchers, professors, technical staff, Ph.D. students and administrative staff. In technology transfer, the human capital embodied in the idea/invention that was disclosed, by researchers or students at the university, is valorized by TTO. Relational capital comprises the intangible resources capable of generating value linked to the university's internal and external relations, as such during the process of technology transfer the TTO maximizes these relationships to identify funders, investors, experts, partners and clients. Structural capital refers to the intangible resources that are found in the organization itself. This includes, amongst others, the databases, the intellectual property (IP), the research projects, the research infrastructure, the research and education processes and routines, the university culture, and the governance principles. IP of course, is the basis of most commercial technology transfer licenses, and is therefore one of the income generating aspects of TTOs (Secundo et al. 2015).

Research has shown the following determinants of effectiveness of technology transfer, which correspond with the tripartite classification of IC as follows:

- Human capital (HC)
  - Human resource management practices in the TTO (Libecap et al. 2005)
  - Developing the expertise to manage their licensing portfolio as a set of options, as this type of management has implications for the selection, training and development of TTO personnel (Chapple et al. 2005)
  - Providing more education to overcome informational and cultural barriers (Siegel et al. 2004)
  - Increasing marketing expertise in the TTO (Phan and Siegel 2006)
- Relational capital (RC)
  - Personal relationships and social networks involving scientists (Curi et al. 2012)
  - Formal and informal networking between scientists, TTO staff and industry (Kim et al. 2008; Siegel et al. 2003a)
  - Understanding of the firms' needs that can potentially commercialize their technologies (Siegel et al. 2003b; Anderson et al. 2007)
- Structural capital (SC)
  - Organizational characteristics such as the existence of a medical school or being a private or a public university (Libecap et al. 2005; Thursby et al. 2001)
  - The age (Carlsson and Frith, 2002) and size (Thursby et al. 2001) of the TTO
  - The royalty shares to faculty (Friedman and Silberman 2003; Lach and Schankerman 2004; Debackere and Veugelers 2005)
  - The IP policy of the institution (Siegel et al. 2007)
  - Incentive compensation (Curi et al. 2012)
  - A clear, transparent and consistent vision for technology transfer (Libecap et al. 2005)
  - Devoting additional resources to technology transfer (Siegel et al. 2004)
  - Being less aggressive in exercising intellectual property rights (Siegel et al. 2004)
  - Formulation and implementation of a technology transfer strategy (Libecap et al. 2005)
  - Organizational design and structure (Bercovitz et al. 2001)
  - Strategic goals and priorities for technology transfer (Libecap et al. 2005)
  - Rewarding technology transfer activities (Siegel et al. 2004)

As such, in the context of university technology transfer, IC has a dual nature. On the one hand, IC is the subject matter which is transferred by the TTO and on the other hand, IC is the

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determinant of the effectiveness of this transfer. Thus, to provide insights into what interventions may be made to improve the efficiency of the TTO, access to IC needs to be studied and understood. We believe that IC in the context of the TTO can support handling and managing university sustainability and competitiveness. This is captured by the research question, does the TTO have the access to the determinants of effectiveness, as embodied in the tripartite classification of IC, to ensure and enhance the efficiency of the TTO? An efficient TTO has many benefits for the university, including spurring business innovation, fostering competitiveness, promoting economic and social development through academic entrepreneurship (Secundo et al. 2015a), and finally it can contribute to the sustainable development of university (Matos and Vairinhos 2017).

Performance of TTOs

The efficiency and effectiveness of the TTO comprise its performance, and yet a TTO can be efficient but not be effective. Effectiveness relates to the success at achieving a desired result, and let's say that desired result is generating increased income. A TTO may, therefore, be efficient at converting an input (invention disclosures) to an output (patents) and yet not be effective as patents in themselves do not generate income. However, a TTO cannot be effective and not efficient, as such the lesser (efficiency) is incorporated in the greater (effectiveness). According to Resende et al. (2013), there is no generally accepted method to verify systematically the performance of an institution's TTO. Little is known about the performance of the TTO, if it is adequate, if it can be improved, if improvements are possible, or how to intervene to improve efficiency and effectiveness. TTO performance measurements are emergent in nature with many aspects of technology transfer not being adequately addressed, such as intangible assets (effectiveness, impact, efficiency) and thus there is a need for more fine-grained TTO performance measures (Miller et al. 2016).

Besides DEA methodology, other tools and methodologies for the performance measurement of TTOs have been developed in the literature (Thursby and Kemp 2002; Phan and Siegel 2006; Anderson et al. 2007); some of which focused on management and development strategies of the key intangible assets of universities (Arena et al. 2009). The suggestion of utilizing IC in this manner is grounded in three main arguments; (i) IC represents the main mission and performance of the entrepreneurial university (or a university actively engaging in technology transfer), (ii) the identification of IC which can improve the value creation process results in a higher degree of competition moving the university towards being more entrepreneurial, and (iii) to ensure successful university-industry cooperation transparency is needed, and IC is already widely adopted by industry in assessing performance (Secundo et al. 2015).

IC, being inherently qualitative, is not only difficult to define but also difficult to measure objectively, and it is this complexity of defining and conceptualizing IC that has become one of the impediments for its acceptance especially, in the public-sector organizations. However, the tool created (Secundo et al. 2016) and recently improved (de Beer et al. 2017) seeks to overcome these challenges and will be discussed in detail in the methodology section.

Visualization of IC

A central concern within the domain of IC is the rendering of the invisible as visible, or perceiving the intangible as tangible through the explication of IC. Significant attention in research continues to be devoted to the visualization of IC within organizations and the relationships actors within the organization have to IC (Cuganesan & Dumay, 2009). The main frameworks that attempt to make visible the way that IC elements interact to create value are the IC-Navigator (Fernstrom et al., 2004), strategy maps (Kaplan and Norton, 2004), value creation maps (Marr and Chatzkel, 2004), and causal performance maps (Abernethy et al., 2005). Heat maps are a two-dimensional

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representation of data in which values are represented by colours, and allows the viewer to understand complex data sets. A noticeable, visual feature is the high information density possible with heatmaps (Pryke et al., 2007). Unlike most other visual representations, all the information from the original data is presented, and is only limited by the amount of colours visible to the human eye. Colours generally range from intense red, through to orange, yellow and intense green, whereby red represents the least values and green the greatest values. A simple heat map provides an immediate visual summary of information, such as activity, value, performance or access. We propose the use of a heat map to visualise the access a TTO perceives to have to university IC determinants of effectiveness, to render a visual representation of the efficiency of the TTO.

5.3.3 Methodology

Research Tool

The self-assessment tool (Secundo et al. 2016) encompasses the determinants of effectiveness through the measurement of IC within six efficiency areas (Human resources, Technology, Networking, University-Industry links, IP policy and strategy, Organization design and structure) on an ordinal 5-point Likert scale, with each indicator individually weighted by expert opinion (de Beer et al. 2017).

Accordingly, the TTO performs a self-assessment of the perceived access it has to university IC on a scale of 1 (least) to 5 (most) and each score is individually weighted. The final score is then calculated for the access to the determinants of effectiveness, and is therefore a reflection of the efficiency of TTO. This score then classifies the TTO at a certain maturity level using the Maturity Model created by Secundo et al. (2016), and elaborated on by de Beer et al. (2017). The relationships between these efficiency areas and university IC are illustrated in Figure 5.3.1 below.

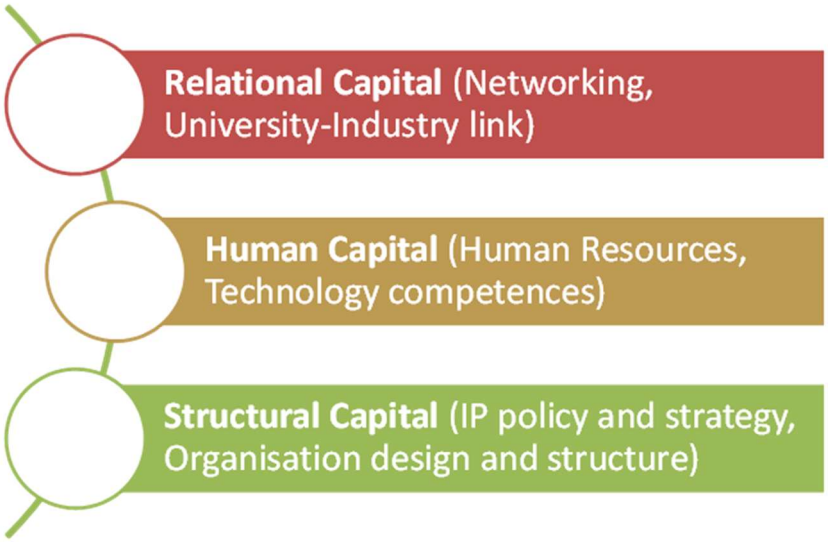

Figure 5.3.1: Correlations between determinants of effectiveness and intellectual capital components

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Data collection

The tool was translated into a survey instrument using Dillman's (2011) tailored design method, which is a set of procedures for conducting successful, self-administrated surveys that produce both high quality information and high response rates. In addition, we followed Couper's (2008) directions for designing web surveys in order to provide a well-designed and effective survey instrument using eSurveycreator. All surveys were administrated electronically between the beginning of June 2016 and end of October 2016 to the email addresses of TTO staff. Data on TTOs and their staff were collected using the websites of individual universities.

A personalized invitation letter to participate in the survey including a link to access the survey was sent to the TTO staff. The participation was entirely voluntary and a summary of the research findings was offered to participants who agreed to a follow-up interview. According to Guerrero and Urbano (2012) the benefit of conducting research in an international context lies in the comparison of universities from different countries with similar economic and social conditions. This comparison provides a real-world opportunity to learn about entrepreneurial academics, policymakers and practitioners (Guerrero and Urbano 2012). For the purposes of allowing the cross-cultural generalization of our findings, we sent the survey to 234 TTOs in the UK (116) and Europe (118).

All the indicators were measured through adequately modified scales previously tested and used by other researchers. The indicators, as embodied in their corresponding IC classifications, were rewritten as a statement, and respondents were asked to indicate the level of their agreement with 24 statements on a five-point Likert scale, ranking from "strongly disagree" to "strongly agree" (Kalar and Antoncic 2015). Guidelines offered by Anderson and Gerbing (1991) on data collection were used in our research to compensate for the subjectivity that arises from qualitative assessment (Murphy and Saal 1990).

In total, 54 TTOs responded, 20 from the UK and 34 from Europe. The survey thus had a response rate of 23% in total, 17% from the UK and 29% from Europe. Of these 54 responses, 19 TTOs chose to remain anonymous. The remaining 35 responses were then weighted (de Beer et al. 2017) and each answer was then converted to a percentage to illustrate the percentage of perceived access to university IC.

The final weighted score given to each TTO, was then linked to a certain maturity level 1 to 8, according to the maturity model created (de Beer et al. 2017). According to the maturity model, a TTO with a maturity level 1 is seen as at the awareness stage, where the university is aware of the importance and benefits of technology transfer. At maturity level 2 the TTO is at the early defined stage, where the university has defined a vision and mission for technology transfer, and then transitions to maturity level 3, the late defined stage where technology transfer activities are undertaken reactively. At maturity level 4, the early managed stage, staff and students engage with the TTO which leads to a transition to maturity level 5, the late managed stage, where the TTO proactively undertakes technology transfer activities. At maturity level 6, also known as the early integrated stage, engagement between the TTO, staff and industry happens cohesively leading to a transition to maturity level 7, the late integrated stage where the TTO is wholly integrated at all levels. Finally, at maturity level 8, the sustained stage the TTO has reached optimal efficiency, effectiveness and maturity.

These maturity levels and the corresponding percentage of access to IC was then used to create a heat map of access that each TTO has to university IC.

5.3.4 Results and Discussion

The results of the percentage access each of the 35 TTOs have to human capital (HC), relational capital (RC) and structural capital (SC) are given in Figure 5.3.2 below, together with their corresponding maturity levels (1 to 8) sorted in

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descending order. The heat map illustrates the relationship between percentage access to IC vs the maturity level of the TTO. The greater access to IC is shown in green, and as access declines the colour ranges from yellow, to orange to red. It is clear from this representation that the most mature TTOs also have the greater access to IC.

TTO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Maturity Level	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3
%RC	90	83	83	80	80	80	77	73	63	97	93	80	80	80	77	77	73	70	70	70	70	70	67	67	67	67	60	60	60	57	73	63	57	47	37
%SC	78	82	89	86	76	74	67	75	80	54	57	60	55	53	63	57	74	74	66	64	57	56	76	68	62	55	75	68	59	60	46	47	49	54	55
%HC	70	67	62	62	68	60	78	58	67	63	43	78	68	57	65	62	60	52	52	60	63	63	53	43	57	63	52	63	43	63	62	57	42	45	33

Legend	
Colour	% Access
75	75% or more
40	40% or more
0	Less than 40%

Figure 5.3.2: The correlation between percentage access to IC and maturity level of the TTO

The heat map above shows that increased access to IC (the high prevalence of green), and therefore the determinants of the effectiveness of technology transfer, has a relationship with increased maturity. TTOs with a higher maturity (level 5) reflect an increased efficiency of the TTO.

As a next step, this information can now be filtered according to certain indicators, which will inform where access to IC needs to be increased to enhance the effectiveness of the TTO and therefore increase the efficiency. We will illustrate this application of the visual representation of access to IC through two examples

Example 1: Mission statement

As stated before, effectiveness is success at achieving a desired result, and for most universities this desired result is reflected in their mission statement for the TTO. One of the determinants of effectiveness is a clear, transparent and consistent vision for technology transfer (Libecap et al. 2005) as embodied in the SC of the university. Therefore, during the interview phase we determined the mission statement of each of the 35 TTOs. From the interviews, it was identified that mission statements (MS) had a combination of three categories: commercialization (C), impact (I) and relationship-building (R). These three categories are supported by different activities. Commercialization is supported through IP protection, licencing and spin-off company creation. Impact is supported through research outputs, knowledge transfer, and regional development. Relationship-building is supported through research contracts, specialized consulting to industry and collaboration for development of research. Accordingly, even though the mission statement is part of the SC of the university, access to other areas of IC would be needed to support each mission statement as seen in the heat map below (Figure 5.3.3). It is important to note that 3 of the TTOs did not have a clearly defined mission statement (N).

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TTO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MS	C	C	C	C	C	C	C	C	C	C	C	C	I	I	I	I	I	I	N	N	N	R	R	R	R	R	R	R	R	R	R	R	R	R	R
%RC	93	90	83	83	80	80	77	73	70	67	60	47	80	77	70	70	63	57	77	70	37	97	80	80	80	73	73	70	67	67	67	63	60	60	57
%SC	57	78	82	89	86	76	63	46	74	62	75	54	53	57	64	57	47	49	67	56	55	54	74	60	55	75	74	66	76	68	55	80	68	59	60
%HC	43	70	67	62	62	68	65	62	52	57	52	45	57	62	60	63	57	42	78	63	33	63	60	78	68	58	60	52	53	43	63	67	63	43	63

Legend	
Colour	% Access
75	75% or more
40	40% or more
0	Less than 40%

Figure 5.3.3: Impact of the mission statement (MS) on access to IC needed

A TTO with a commercial mission statement needs to liaise with, and identify, industry partners to ensure the outputs anticipated with commercialisation, and as such the RC of the university is extremely important to ensure university-industry links and networks are established and leveraged. TTOs with a commercial mission statement therefore require access to RC, which seems to indicate that RC is the most important determinant of effectiveness in such TTOs, as evidenced by the high percentage of access such TTOs have to RC (Figure 5.3.3). Impact-focussed TTOs have a greater mission than commercialisation as impacts are needed to be seen in regional development, not only in a once-off transaction with one industry partner. The heat map seems to indicate that these TTOs require access to all levels of IC equally, which indicates that IC as a whole is important for their efficiency. When the mission of the TTO is to build relationships, it stands to reason that access to RC would be needed, but the heat map also shows, that TTOs who wish to build relationships, seem to require access SC to enable this mission. SC allows the TTO to freely engage with all partners it chooses to build relationships with.

Example 2: Organizational structure

The university plays an important role in defining the mission statement of its TTO, setting the TTO's objectives, assigning the funds for TTO activities and defining the relationships with other university structures i.e. defining governance structures (Huyghe et al. 2014). Organizational design and structure (Bercovitz et al. 2001) is another determinant of effectiveness as embodied in the SC of the university. Thus, during the interviews we also identified the university's governance and corresponding organization of the TTO. Brescia et al. (2016) presents three knowledge transfer organizational models (internal, external, and mix) and six configurations of these models. The external TTO organizational model comprises three configurations: The E-SINGLE organizational structure refers to one external TTO (fully-owned company) serving one university; the E-MULTI refers to two or more external TTOs (companies) with different functions which serve the same university, these functions may include IP portfolio management, business incubation services, spin-out company holding firm etc.; the E-JOINT organizational structure refers to one, often regional, TTO co-owned by more than one university and serving all equally to take advantage of the network of competences and of specific expertise. The internal TTO organizational model comprises two configurations: The I-SINGLE organizational structure refers to one internal office serving as a TTO, or staff within an office performing TTO activities related to academic entrepreneurship such as patenting, licensing, legal agreements, sponsored research contracts, and entrepreneurship support; the I-MULTI organizational structure refers to two or more offices in the university working together, such as legal, marketing, grants and funding, or research and development. The I-MULTI can also refer to a

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distributed TTO organizational structure in which the TTO has representatives at Faculty or School level, or so-called IP Scouts, which serves as the first point of contact for staff (Schoen et al. 2014). The MIX organizational structure refers to a combination of one internal office (irrespective of organization) and one external office (irrespective of organization).

For ease of comparison, we have grouped these organizational structures (OS) into three broad categories: internal (I), external (E) or mix (M), as we show the heat map in Figure 5.3.4 below.

TTO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
OS	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	I	I	I	I	I	I	I	I	I	I	E
%RC	97	93	83	83	80	80	80	80	80	80	77	77	73	70	70	70	67	67	63	60	60	57	47	37	77	73	73	70	70	67	67	63	60	57	90
%SC	54	57	82	89	86	76	74	60	55	53	67	63	74	66	64	56	62	55	80	75	59	49	54	55	57	75	46	74	57	76	68	47	68	60	78
%HC	63	43	67	62	62	68	60	78	68	57	78	65	60	52	60	63	57	63	67	52	43	42	45	33	62	58	62	52	63	53	43	57	63	63	70

Legend	
Colour	% Access
75	75% or more
40	40% or more
0	Less than 40%

Figure 5.3.4: The impact of the organizational structure (OS) of the TTO to access to IC

An internalized structure is when a TTO is viewed equivalently to a department or office within the university, but functions independently from other departments. These internal offices have a low degree of autonomy and report at various levels within the university. An externalized structure is where a TTO company is established physically outside of, but wholly owned by, the university. These external offices have a high degree of autonomy, often being governed solely by an external board. The mix structure is where the TTO is held internally as a central office, but supported by other offices (marketing, legal etc.) and/or IP scouts (faculty level technology transfer officers) or both. It seems the mix structure is the most preferred organizational structure of the TTOs studied, and indeed has the greatest access to IC. Due to the fact that the mix structure is supported by other offices and/or due to its proximity to faculty it naturally would have greater access to IC in terms of RC (with researchers, staff and students) and SC (collaboration between other offices within the university). The internal structure allows for access to RC due to proximity, but it does not access SC and HC so easily. This may be due to the fact that a mix structure is more flexible (SC) and benefits from being a multi-office (HC). Only one external structure is represented in our sample and as such no deductions can be made.

5.3.5 Conclusions

As alluded to in the introduction of this chapter, the research question we seek to answer is: does the TTO have the access to the determinants of effectiveness, as embodied in the tripartite classification of IC, to ensure and enhance the efficiency of the TTO? We proposed the use of a tool (Secundo et al. 2016) to capture the access a TTO has to IC, and the use of heat maps to visualize this access and to inform strategic decisions towards improved technology transfer and university sustainability.

The two examples above illustrate how the heat maps, and indeed visual representations of access to IC, may be used to understand the performance of the TTO. As we have shown in Figure 5.3.2, access to determinants of effectiveness of TTOs as embodied in the tripartite classification of IC enhances the maturity level of the TTO and therefore improves the efficiency of technology transfer. However, in order to strategically intervene and improve the efficiency of the TTO, it needs to be understood what IC it needs access to. We have illustrated in

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example 1, that the mission statement of the TTO influences which IC it needs access to, and in order to achieve its mission (and therefore be efficient) different TTOs would need access to different IC. Similarly, we have illustrated in example 2 that the organizational structure of the TTO influences which IC it has access to, irrespective of the mission or performance of the TTO. This shows that, the structure of the TTO may need to be adjusted to allow access to certain IC to enable it to achieve its mission and therefore be seen as effective and efficient. The aim of this book is to explore the relationship between IC management and the sustainable development of organizations, and we believe that understanding the performance of the TTO through the visualization of IC will aid management to leverage IC in a way that will allow for sustainable development of the university.

The tool is based on a self-assessment, which is influenced by subjectivity, and as such the scores are not an objective reflection of the access a TTO has to IC. However, this limitation may be overcome by allowing each full-time employee of the TTO to complete the self-assessment to find an average. It is recommended that this tool is further tested through case studies. Future work may furthermore include testing this tool in universities in developing countries.

Implications for practice regards the visual representation that the heat map allows management at both university and TTO level, to have a clearer understanding of the performance of the TTO and how IC may be leveraged to improve it. Visualizing the access to university IC in this way also allows for comparison of various factors which may allow increased access to IC, such as the TTO typology, or increased efficiency, such as the mission statement of the TTO.

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Conclusion: Chapter 5

The visual representation of the access a TTO has to intellectual capital is the culmination of the findings of this study. The book chapter included here in Chapter 5, describes the (improved) self-assessment tool and intellectual capital (intangible and non-monetary indicators) used. The improved maturity model is discussed, and the links between maturity and access to intellectual capital are established. This proves that access to intellectual capital is essential for efficient university technology transfer.

The visualisation, in the form of heat maps, allows university management to see where strategic intervention is needed. It also allows the TTO management to explain the need for specific resources and advocate for the leveraging of institutional intellectual capital. The use of intellectual capital in this way is a new and emerging field. As discussed in Chapter 3, this research contributes to the third stage of intellectual capital research, showing how intellectual capital can be used in practice to improve the efficiency of TTOs.

The final chapter will conclude the contributions of this study. The research gaps addressed and novel contributions will be highlighted, as well as what this study means for future research in this field.

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CHAPTER 6: Conclusion

The contribution of these published articles to improving university technology transfer

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Conclusion

Introduction: Chapter 6

The final objective of this study was to publish articles to act as a guideline to aid TTOs and university management to intervene and improve efficiency. As stated several times over in this portfolio, TTOs learn through experimentation and failure, and by sharing these experiences with other TTOs. A large part of this sharing of experiences was encapsulated in Chapter 4, in sharing best practices. But these experiences can also be shared through publication and presentation. For this reason this study actively published and presented its findings as widely as possible.

Table 1.1 (from Chapter 1, page 21) has been included again as Table 1.1 on page 125 to provide a high-level overview of the six objectives of this study, and their corresponding outcomes and references to the works either submitted, accepted or published. This table also shows how these objectives align with the three levels of intervention to improve the efficiency of university technology transfer at internal, interoffice and intra-organisation level.

The aim of this study was to improve the efficiency of university technology transfer in South Africa. Research had shown that this might be achieved at the three levels mentioned. At the internal level, a TTO might activate steps to improve, if the performance of the TTO was well understood. The performance of TTOs is generally measured by inputs (such as R&D funding, and disclosed ideas) converted into outputs (patents, licences and spin-off companies created). However, collecting this kind of tangible data in developing countries such as South Africa proved to be a problem due to lack of data. Given that the filing of patents and creation of spin-off companies are expensive processes, and that most TTOs in developing countries are not well-resourced, it explains this paucity of data.

Moving on from this, literature was reviewed to understand the efficiency of TTOs. It appeared that there is a set of determinants of effectiveness, which in turn govern the efficiency of TTOs. However, no current methods use these determinants of effectiveness to measure the performance of TTOs. Given that these determinants are intangible and non-monetary indicators, and the lack of data on tangible indicators in South Africa, it was decided that a new performance measurement tool would need to be created. This led to the first objective of this study:

1. Create a self-assessment tool using intangible indicators of efficient technology transfer.

The outcome of this objective was a self-assessment tool, and given the qualitative nature of the indicators, the methodology employed was a survey. The survey measures, through self-assessment on a Likert scale, the presence of, or access to, the intangible indicators. This self-assessment tool is presented in the article in Chapter 2 titled: 'Measuring University Technology Transfer Efficiency: A Maturity Level approach'. The indicators were weighted and a score calculated which would be an indication of the efficiency of the TTO. However, this score would not provide the TTO with the insight needed to understand its performance. It was therefore necessary that the data collected with the self-assessment tool be translated to a meaningful analysis of the performance of the TTO which led to the second objective of this study:

2. Translate the data collected with this tool to understand the performance of the TTO.

Table 1.1: High-level overview of objectives and layout of study, with outcomes

Level of intervention	Objective	Chapter	Method	References	Status
Internal	Create a self-assessment tool using intangible indicators of efficient technology transfer	**Chapter 2**	Qualitative, survey	Secundo, G., De Beer, C. & Passiante, G. (2016). Measuring university technology transfer efficiency: a maturity level approach. Measuring Business Excellence, Vol. 20 No. 3, pp. 42-54.	**Published**
	Translate the data collected with this tool to understand the performance of the TTO		Project Management Process Maturity Model		
	Validate and verify the tool	**Chapter 3**	Live testing, expert interview	Secundo, G., De Beer, C., Schutte, C. S. & Passiante, G. (2017). Mobilising intellectual capital to improve European universities' competitiveness: the technology transfer offices' role. Journal of Intellectual Capital, Vol. 18 No. 3, pp. 607-624.	**Published**
			Case study, expert interview	Secundo, G., De Beer, C., Schutte, C. S. & Passiante, G. (2017). Leveraging Intellectual Capital to assess the Technology Transfer Office: a South African University case. Accepted with revisions (Journal of Intellectual Capital)	**Accepted**
Interoffice	Create a mechanism for sharing best practice between TTOs based on their efficiency and maturity level	**Chapter 4**	Expert interview, reiteration	De Beer, C., Secundo, G., Passiante, G., & Schutte, C. S. (2017). A mechanism for sharing best practices between university technology transfer offices. Knowledge Management Research & Practice, Vol. 15 No. 4, pp. 523-532.	**Published**
Intra-organisation	Visualise the performance of the TTO in a way that is relatable at all levels of university management	**Chapter 5**	Heat Maps	Secundo, G., De Beer, C., Schutte, C. S. & Passiante, G. (2017). A Visual Representation of Technology Transfer Office Intellectual Capital Access. Submitted to Springer Books.	**Accepted**
All	Publish articles to act as a guideline to aid TTOs and university management to intervene and improve efficiency	**Chapter 6**	Conference proceedings, journal publications, book chapter	European Conference on Knowledge Management conference paper entitled: Assessing University Technology Transfer Efficiency in South Africa: A Maturity Level Approach / International Forum on Knowledge Asset Dynamics conference paper entitled: Technology Transfer Office type for increased access to University Intellectual Capital: Recommendations from Europe and UK (Appendix A) / International Conference on Entrepreneurship, Innovation and Regional Development conference paper entitled: A Novel Technology Transfer Office Typology Based on Lessons Learnt from the UK (Appendix B)	**Published**

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The outcome of this objective was a maturity model, based on a project management process maturity model. Given that technology transfer is a process, consisting of a series of projects (disclosed ideas/inventions) that need to be managed, this seemed like the perfect fit. The Berkeley PM^2 model was chosen as it highlights strengths and weaknesses within the performance that may be leveraged or improved upon. Therefore, the scores were translated to a series of maturity levels with specific definitions that would give insight into the performance of the TTO. This maturity model is presented in the article in Chapter 2 titled: 'Measuring University Technology Transfer Efficiency: A Maturity Level approach'.

Two novel tools were therefore created to support this novel approach to understanding the performance of the TTO in Chapter 2. Chapter 3 focused on the validation and verification of these tools, and is consequently centred on the third objective of this study:

3. Validate and verify the tool.

Throughout Chapter 3 various methods are used to provide evidence of the validity of the results and the accuracy of the results for both the self-assessment tool and the maturity model. First, the self-assessment tool and maturity model were put through live-testing. In this case the self-assessment tool was sent out in survey format to TTOs, the results calculated, and then discussed with the TTO in an interview format using the maturity model as a guide. In this way the TTO could confirm both the accuracy of the self-assessment tool and the maturity model. The results of this first live-test are given in the article in Chapter 3 titled: 'Mobilising Intellectual Capital to Improve European Universities; Competitiveness: The Technology Transfer Office's Role'.

Next, the self-assessment tool and maturity model were applied to a case study of one university in South Africa. The same steps were followed as with the live-testing and interviews described above to confirm the accuracy of the results. Furthermore, traditional benchmarking tools were used (albeit with a lack of data on all indicators) and the results compared. This served to provide evidence of the validity of the results. The outcomes of objective 3 were to provide evidence of the validity and of the results and to verify the results, and these are given in the second article in Chapter 3 titled: 'Leveraging Intellectual Capital to Assess the Technology Transfer Office: A South African University Case'.

Now that the novel approach (both tool and model) were validated and verified, the TTO could start using this tool to understand its performance and identify weaknesses that could be improved upon. This would lead to an internal level of intervention as anticipated in Table 1.1.

During the interview phase, the self-assessment tool and maturity model were described in detail to allow for further improvements to them through iterations. Also, as alluded to by the sixth objective of this study, the work was widely presented at a variety of conferences. This allowed for further testing by peer groups and experts from a broad spectrum of backgrounds. Furthermore, as shown in the two articles in Chapter 3, the link between the intangible indicators and intellectual capital was explored. As a result, an improved self-assessment tool and maturity model were created as discussed in Chapter 4.

The second level of intervention, as seen in Table 1.1, is interoffice. This means that different TTOs share best practices with one another to improve their efficiency. Following on from this, the fourth objective of this study was:

4. Create a mechanism for sharing best practice between TTOs based on their efficiency and maturity level.

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Given the proven link between the intangible indicators and intellectual capital, and the variety of improvements made to the self-assessment tool and maturity model, it was clear that the novel approach had evolved beyond performance measurement. As discussed at length in Chapter 4, there are many challenges in sharing best practices between TTOs, which could be addressed through the application of the novel approach. The article in Chapter 4 titled: 'A Mechanism for Sharing Best Practices Between University Technology Transfer Offices' details exactly how this can be achieved.

Principally, the self-assessment tool and maturity model allow the TTO to understand its performance in an intangible way. They highlight the absence of certain determinants of effectiveness, and also a lack of access to certain aspects of intellectual capital (human, relational or structural). The TTO therefore, not only understands how to improve its own performance internally, but also has a characterisation of itself. Similarly, another TTO, using the self-assessment tool and maturity model would be able to characterise itself on the same basis, using the same indicators. This means that two TTOs from completely different countries, structures and backgrounds can now understand their performance and their characteristics in the same way. The TTOs are therefore more comparable, and best practices can be shared more effectively on this basis.

Therefore, the TTO can now enact the second level of intervention, and enable the sharing of best practices interoffice. However, there is a third level of intervention, as detailed in Table 1.1, intra-organisation. The university can strategically intervene to improve the efficiency of its TTO, if the university also understands and characterises the TTO in this manner. Understanding the performance of the TTO as a unique entity (instead of the one-size-fits-all approach of traditional benchmarking) allows for more effective, targeted intervention. Given the complexity of technology transfer, and the fact that it is a fairly new development at universities in South Africa, a fifth objective was included in this study:

5. Visualise the performance of the TTO in a way that is relatable at all levels of university management.

At an internal level, the self-assessment tool is very useful for the TTO as it can (in conjunction with the maturity model) show weaknesses for the TTO to improve upon. At an interoffice level, the maturity model is very useful for TTOs as it allows for characterisation on the same basis, and therefore sharing of best practices. However, at an intra-organisation level, this information needs to be presentable in a way that allows university management to intervene. Given the strong correlation with intellectual capital, the data collected with the tool was reorganised to reflect access to intellectual capital in its human, relational and structural dimensions. Chapter 5 discusses how, moving from two conference papers, the link between efficient university technology transfer and access to intellectual capital was established. It also discusses how university management can intervene to create an enabling environment for access to intellectual capital through the organisational structure of the TTO and the mission statement of the TTO.

The book chapter in Chapter 5 titled: 'A Visual Representation of Technology Transfer Office Intellectual Capital Access' presents a series of heat maps. Heat maps were chosen as the best visual representation of access to intellectual capital, as they would guide university management to intervene strategically and effectively. The book chapter also makes some recommendations as to how the university might intervene to improve the efficiency of its TTO. The figure below has been included to highlight how Chapters 2, 3, 4 and 5 have achieved their objectives through the anticipated outcomes.

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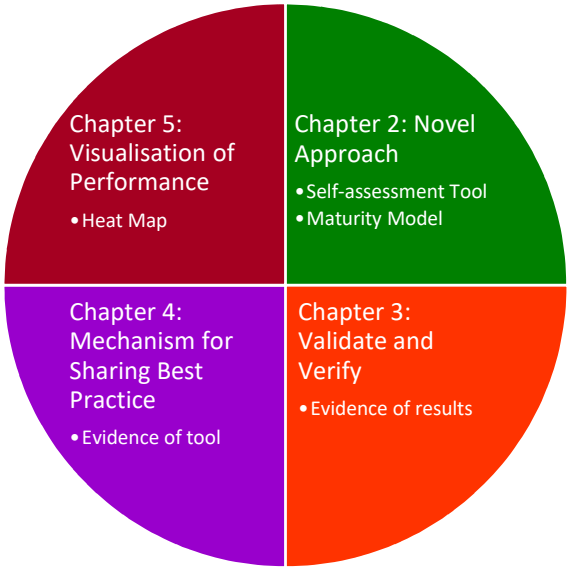

Figure 1.2: Contextual guide

Table 1.1 highlights a sixth objective that would improve the efficiency of university technology transfer at all three levels, which is:

6. Publish articles to act as a guideline to TTOs and university management to intervene and improve efficiency.

The outcome of this objective is this PhD portfolio which discusses two published articles, two accepted articles and one submitted book chapter. The conference papers presented are included in Table 1.1, and two of these papers have been included in the appendices. Ultimately TTOs improve through sharing knowledge, experience and failures with one another and so the dissemination of the data collected in this study was regarded as of paramount importance.

6.1 How is the research gap addressed?

Several research gaps were identified at the beginning of this study. First, the paucity of tangible data for traditional benchmarking in developing countries was found. A review of literature showed that intangible and non-monetary indicators were determinants of effectiveness, yet were not utilised to understand the performance of TTOs. This research gap was addressed through the creation of the self-assessment tool based on determinants of effectiveness. These included intangible and non-monetary indicators, which were later collectively referred to as intellectual capital indicators.

Secondly, the lack of mechanisms to effectively share best practices between TTOs to improve their efficiency was observed. A review of literature showed that TTOs primarily improve their performance by sharing experiences, both failures and successes, and that this was achieved through publication and presentation at conferences. However, when it came to sharing best practices directly, this was not done effectively (especially in the developed to developing country context). This was addressed through the creation of the maturity model to characterise the TTO. The maturity model allows TTOs to be comparable, contextualised on the same basis, and characterised using the same indicators. Therefore, the challenges in sharing best practices, as shown in literature, are addressed.

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A final research gap was identified throughout the study, as the link between determinants of effectiveness and intellectual capital became clearer. Universities are not actively managing and leveraging their intellectual capital, and the study has shown the importance of this in improving the efficiency of technology transfer. Therefore, this study contributed to the third stage of intellectual capital research in using it as a tool to improve university technology transfer. The gap in the research surrounding the strategic use of intellectual capital by universities was addressed through the creation of the visual representation to allow university management to leverage intellectual capital more effectively.

6.2 Why is this study a unique contribution?

Aside from the novel tools created, and the use of novel indicators which had until now not been applied in assessing the performance of TTOs, this study contributes to a paradigm shift. It is a shift from seeing performance only as efficiency, but as an all-encompassing effectiveness. It is a moving away from measuring performance using tangible and monetary indicators alone, to including intangible and non-monetary indicators. As a result, the performance of a TTO can be understood in a more practical way, and weaknesses can be more clearly identified and improved upon. Furthermore, the novel tools created allow for intervention at internal, interoffice and intra-organisation level. Thus, any stakeholder within the innovation ecosystem can understand the performance of the TTO, and how to improve it.

This study advocates assessing the performance of TTOs aligned with the mission statement of the TTO and viewing success accordingly. Up to now, the performance of the TTO, using traditional benchmarking, did not allow for TTOs with mission statements other than a commercial one, as traditional benchmarking is based on the return on investment concept. The novel tools allow for the performance of the TTO to be determined in which the mission statement could be impact-focused or have a relationship-building (university-industry) focus.

More importantly, this study aims to overcome the bounded rationality which exists in university technology transfer, and to engage the university at all levels. This can be achieved through leveraging institutional intellectual capital, and moving from an intellectual property policy mindset to an intellectual capital policy mindset. The novel approach of leveraging intellectual capital in the improvement of university technology transfer, opens the door for a whole new field of research within intellectual capital and university policymaking. It is the opinion of this study that through directed, strategic intervention the university may create an enabling environment for access to intellectual capital.

6.3 Recommended future research

Currently very little research is available on the performance of TTOs in developing countries. With the use of the novel approach described in this study, developing countries can now be researched as the metrics are more easily measurable. Thus, one avenue of future research will include the performance of TTOs in developing countries and a deeper understanding of the challenges and complexities of university technology transfer.

If this line of research is pursued, the sharing of knowledge between developed and developing country's TTOs will be able to increase. Given that a mechanism has been established within the novel approach to share best practices, this will further enable the sharing of knowledge. It follows that another area of research can revolve around the collection and sharing of best practices. Of course, at this point the mechanism has not yet been thoroughly tested, and so the feasibility of the use of

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this mechanism will need to be assessed, as well as the effectiveness with which best practices are shared.

Additionally, there is a variety of research questions within the application, leveraging and management of intellectual capital in the university technology transfer context. Specifically one question revolves around the development of an intellectual capital policy regarding this. The visual representation will also need to be tested in various case studies, and using different filters as each university's context demands.

Final Remarks

The aim of this study was to improve the efficiency of university technology transfer in South Africa. In order to achieve this aim, six objectives were identified with a series of outcomes. Each of these has been thoroughly discussed in Chapters 2, 3, 4 and 5. Through the creation of the self-assessment tool and maturity model, objectives 1 and 2 were addressed. These started to address the improvement of university technology transfer at the internal level. The self-assessment tool and maturity model were validated and verified using a case study in South Africa. This addressed objective 3, but also showed the applicability of the tool in the South African context.

The self-assessment tool and maturity model, now validated and verified, were also improved and applied to the challenge of sharing best practice. Even though this still needs to be tested empirically, this would theoretically be able to act as a mechanism for sharing best practices, thereby addressing the fourth objective. Additionally, the improvement of university technology transfer can potentially now also be addressed at the interoffice level.

In addition, as this study has proven the link between access to intellectual capital and the efficiency of university technology transfer, another means to improve efficiency has been identified. The heat maps, based on intellectual capital access, answer objective 5, and also address the intra-organisation level of intervention to improve efficiency.

Finally, the last objective of this study was to share its findings, and this has been achieved as evidenced through this portfolio.

In conclusion, in addressing the six objectives of this study, the tools to address the aim have been created. Evidence has been provided of a novel approach that can be used to understand the performance of the TTO, share best practice between TTOs, and visualise the performance of the TTO to allow intra-organisational intervention. Thus, the improvement of university technology transfer in South Africa is possible.

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Appendix A:

The two articles in Chapter 3 found that access to intellectual capital was essential for improving the efficiency of university technology transfer. This access can be viewed in two ways: First, that the organisational structure of the TTO allows access to intellectual capital. Secondly, that the TTO has access to the intellectual capital it most needs for efficiency.

These dual ideas of access were investigated in the form of two conference papers. The first paper was presented at IFKAD (International Forum on Knowledge Asset Dynamics) and discusses the importance of the organisational structure of the TTO.

Technology Transfer Office type for increased access to University Intellectual Capital: Recommendations from Europe and UK

Christle de Beer*

Giustina Secundo

Corne S.L. Schutte

Giuseppina Passiante

** Corresponding author*

Structured Abstract

Purpose – As many developing countries are embarking on establishing technology transfer practices within their universities, the study of successful technology transfer office (TTO) typologies in developed countries may serve as a frame of reference. The Maturity Model (MM) created by Secundo et al., (2016a) has proven that intangible indicators may be used to assess and improve the efficiency of academic entrepreneurship. Intellectual capital (IC) in a university is a set of intangible and knowledge assets, thus, it can be postulated that increased access to IC would lead to improved efficiency at academic entrepreneurship. TTO typologies exist in literature and this study aims to determine which type of TTO enables better access to IC.

Design/methodology/approach – The self-assessment tool and MM created by Secundo et al., (2016a) measures the efficiency of academic entrepreneurship through intangible indicators grouped into six areas: human resources, intellectual property policy and strategy, networking, university-industry links, technology, and organization design and structure. Data was collected from 18 universities in Europe and 6 universities in the United Kingdom. It is assumed that efficient TTOs, as measured by the MM, would have maximum access to IC. Therefore, these TTOs may inform which TTO type would be best suited for developing countries.

Originality/value – This methodology provides a new approach and perspective on utilizing IC to improve academic entrepreneurship. An indication of the level of access that the TTO has to IC, through its efficiency at academic entrepreneurship, is given. Furthermore, information on the type of TTO informs decisions around the organizational structure which new TTOs in developing countries may take.

Practical implications – The results from this study can be used by university management in developing countries to determine the organizational structure of the TTO which would be best suited to their needs. It is proposed that a TTO type which maximizes access to and utilization of IC would lead to improved efficiency in academic entrepreneurship.

Keywords – Intellectual Capital (IC), Technology Transfer Office (TTO), Academic Entrepreneurship, Typology, Efficiency

Paper type: Academic Research Paper

This paper was presented on 9 June 2017, at the International Forum for Knowledge Asset Dynamics (IFKAD) in St. Petersburg, Russia.

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Introduction

In the last few decades, the economies of developed countries have become increasingly knowledge dependent (Brinkley and Lee, 2006), and therefore dependent on intangible assets and knowledge producers. Knowledge and intangible assets have become the engines of productivity and long-term economic growth (Schiuma and Lerro, 2008). To remain competitive, developing countries need to redesign themselves using innovation (Job and Sanghamitra, 2010), and indeed a trend has emerged in moving from a developing nation status to a developed nation status, that a transformation from a resource-based economy to a knowledge-based economy is needed (Romano et al., 2014). In a knowledge-based economy, the university becomes the key stakeholder in the national innovation system (Secundo et al., forthcoming), which is a network of institutions in the public and private sectors, whose activities and interactions initiate, import, modify and diffuse new technologies (Kloppers et al., 2006). By implementing lessons learned from universities in the USA, UK, and Australia over the last 20-30 years, developing countries have tried to follow the example of developed countries. As such, developing countries have been trying to build viable national innovation systems, establish good university-industry collaboration, formalize the intellectual property (IP) rights of universities and establish technology transfer offices (TTOs) (Attia, 2015).

Since universities in developed countries first established TTOs in the 1980s and 1990s (Lockett et al., 2015), technology transfer has changed dramatically and has since come to be known as academic entrepreneurship (Siegel and Wright, 2015a). Initially, technology transfer referred to the capacity of a university for managing and valorising their knowledge assets or intellectual capital (IC) (Vinig and Lips, 2015). But has since evolved into academic entrepreneurship to include technology development, dissemination, and commercialization activities such as university licensing, patenting and start-up creation. As such, there is a substantial body of literature from developed countries regarding academic entrepreneurship (or so-called technology transfer) and insights into increasing the efficiency thereof (Rasmussen, 2008). There is, however, little evidence regarding the effectiveness of TTOs in promoting academic entrepreneurship (Siegel and Wright, 2015b). It is also highly debatable how far models applied to elite universities in improving academic entrepreneurship are applicable to other universities (Wright et al., 2008). Furthermore, the application of these data to the developing country context has not been very successful (Kloppers et al., 2006).

Intangible assets and IC constitute the largest proportion of universities' assets (Sánchez et al., 2009), yet the concept of IC is still very much in its infancy in developing countries (Firer and Stainbank, 2003). For the university, there are benefits to implementing and leveraging IC which fall into two categories: (1) IC has the potential to function as a management tool to help develop and allocate resources, create strategy, monitor the development of the university's results, and facilitate decision-making and (2) IC has the potential to function as a communication and reporting tool linking the institution to stakeholders and as a way to attract resources – financial, human and technological (Marr and Chatzkel, 2004). IC, therefore, has a dual nature in the university context during academic entrepreneurship: to be valorised through the TTO, and, to be managed by the TTO for the benefit of the university.

With this dual potential of IC in mind, Secundo et al. (2016a) created a self-assessment tool and accompanying Maturity Model (MM), which leverages IC to assess and improve the efficiency of academic entrepreneurship. Specifically, the self-assessment tool measures various intangible indicators grouped into six efficiency areas namely: human resources, technology, IP policy and strategy, organization design and structure,

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networking, and university-industry links. These six efficiency areas incorporate the tripartite classification of IC, which structures IC with regard to three elements: human capital, structural capital or organizational capital and relational capital (Secundo et al., 2015). Thus, through the application of this tool, a determination can be made with regards to how IC is valorised through the TTO (i.e. efficiency of academic entrepreneurship) and also how the university may manage IC to improve the efficiency. This leads to the assumption that a highly efficient TTO would have maximum access to IC, which then leads to the research question of this paper: Which TTO organizational structure would be the most suitable to enable access to IC in developing countries?

The remainder of this paper will discuss university IC and TTOs in more detail and the variety of TTO typologies found in the literature. The MM was employed as the methodology of this study and it will be discussed as well as the findings, after which this paper will conclude with a discussion of the results and recommendations for developing countries.

Literature Review

The aim of this section is to discuss relevant literature about university IC and TTOs, with a specific focus on the various TTO typologies in literature.

University Intellectual Capital (IC) and Technology Transfer Offices (TTOs)

Recently the role of the university has been evolving from its original goal (teaching) and secondary goal (research) toward embracing a third goal, that is closer connections with society (Secundo et al., 2016b; Secundo et al., in press). Three ways in which the university relates to external environments are encapsulated in academic entrepreneurship and innovation, continuing education, and social engagement (E3M, 2010). To enable the university to relate in this way, the IC of the university needs to be managed and measured comprehensively taking in consideration the collective involvement of all the University's stakeholders (Secundo et al., 2016b). IC in a university is, ultimately, the set of intangible and knowledge assets that drive the mechanisms of value creation according to the targets defined by stakeholders of the internal and external environment (Redford and Fayolle, 2014). IC can furthermore be divided into three categories, based on the tripartite classification of IC, into human capital (HC), structural or organizational capital (SC), and relational capital (RC) (Habersam and Piber, 2003).

As there are a variety of universities (research, public, private, teaching etc.) there are also a variety of managerial approaches in terms of the management of IC and IP, depending on the national law and internal policies of the university (Secundo et al., 2015). This furthermore influences the efficiency of the university at leveraging its IC and ultimately promoting academic entrepreneurship. The role of TTOs is, in part, to ensure the effective management and valorisation of IC, yet TTOs face many challenges in this endeavor. Universities often do not have a culture that is conducive to academic entrepreneurship, nor do they possess the complementary assets to be successful therein (Siegel and Wright, 2015a). A survey on TTOs in the USA found that over 50% lose money on their academic entrepreneurship operations while only 16% are self-sustaining (Abrams et al., 2009). Similarly, in TTOs across Europe, just 10% of TTOs secure 80% of all licensing deals, and the top 2% of TTOs across 6 countries capture 40% of licensing revenue (Granieri and Frederick, 2015). Seeing as TTOs are central to a process as complex as academic entrepreneurship, it is important to know how efficient a TTO is at conducting its missions, and it is crucial to know if a type of TTO exists that leads to increased efficiency (Resende et al., 2013). Bearing in mind how technology transfer has evolved into academic entrepreneurship, individual universities also need to consider whether to pursue academic entrepreneurship (Siegel and Wright, 2015a).

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Technology Transfer Office (TTO) Typologies

A TTO can be considered, according to Tahvanainen & Hermans (2011) as a process catalyst, a knowledge converter and, an impact amplifier. The vast amount of literature surrounding TTO typologies has recently been reviewed by Brescia et al., (2016) and a synthesis of this review is included in Table 1 below.

Table 1: Synthesis of typologies found in literature (Adapted from Brescia et al., 2016)

Office	Organizational Structure	Reference
Knowledge Transfer Office (KTO)	Centralized - knowledge transfer activities within a single, central unit	Litan and Mitchell (2007)
University Liaison Offices (LO)	Decentralized - knowledge transfer activities distributed among several units	Jones-Evans et al., (1999)
Licensing Offices	Centralized and Decentralized	Link and Siegel (2005)
Knowledge Transfer Office (KTO)	• The functional or unitary model • The multidivisional model • The holding company • The Matrix model	Bercovitz and Feldmann (2001)
Knowledge Transfer Office (KTO)	Semi-centralized - involves a divisional assignment where a multi-business unit or division committee oversees.	Carlsson et al., (2008)
Technology Transfer Office (TTO)	Hybrid TTO model – a combination of the traditional hierarchical structure, in which a TTO is established at the central level of the university, complemented by decentralized TTOs at the level of the research groups and departments.	Huyghe et al., (2014)
Technology Transfer Office (TTO)	Specialized (discipline specific) and Decentralized	Debackere and Veugelers (2005)
Industry Liaison Office (ILO)	Internal model - where the ILO is fully integrated into the university's administrative structure External model - where the ILO operates outside the university as a corporation that is either non-profit or for-profit	Fisher and Atkinson-Grosjean 2002
Knowledge Transfer Office (KTO)	Traditional - organized as an integral department within a university's administrative structure Not-for-profit - functions as an independent non-profit unit or as part of a separately constituted research foundation outside the university's administrative structure For-profit private venture - has an independent CEO and a board	Markman et al., (2005)
Knowledge Transfer Office (KTO)	Network form – interconnected group of KTOs	(Powell 1990)
Knowledge Transfer Office (KTO)	Regionally based, sector-specific	Chapple et al., (2005)

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Office	Organizational Structure	Reference
Knowledge Transfer Office (KTO)	A single KTO that serves a consortium of several public research organizations in a region A single office, funded by the national government or a philanthropic institution, that serves as a KTO for several public research institutes	Young (2007)
Technology Transfer Office (TTO)	(1) classical TTO (2) autonomous TTO (3) discipline-integrated Technology Transfer Alliance (4) discipline-specialized Technology Transfer Alliance	Schoen et al., (2014)

The optimal design of a TTO depends on the university it serves, on its institutional history, and evolves over time. Brescia et al., (2016) presents three knowledge transfer organizational models (internal, external, and mix) and six configurations of these models. The external TTO organizational model comprises three configurations (Figure 1). The E-SINGLE organizational structure refers to one external TTO (fully-owned company) serving one university. The E-MULTI refers to two or more external TTOs (companies) with different functions which serve the same university, these functions may include IP portfolio management, business incubation services, spin-out company holding firm etc. The E-JOINT organizational structure refers to one, often regional, TTO co-owned by more than one university and serving all equally to take advantage of the network of competences and of specific expertise. The internal TTO organizational model comprises two configurations (Figure 2). The I-SINGLE organizational structure refers to one internal office serving as a TTO, or staff within an office performing TTO activities related to academic entrepreneurship such as patenting, licensing, legal agreements, sponsored research contracts, and entrepreneurship support.

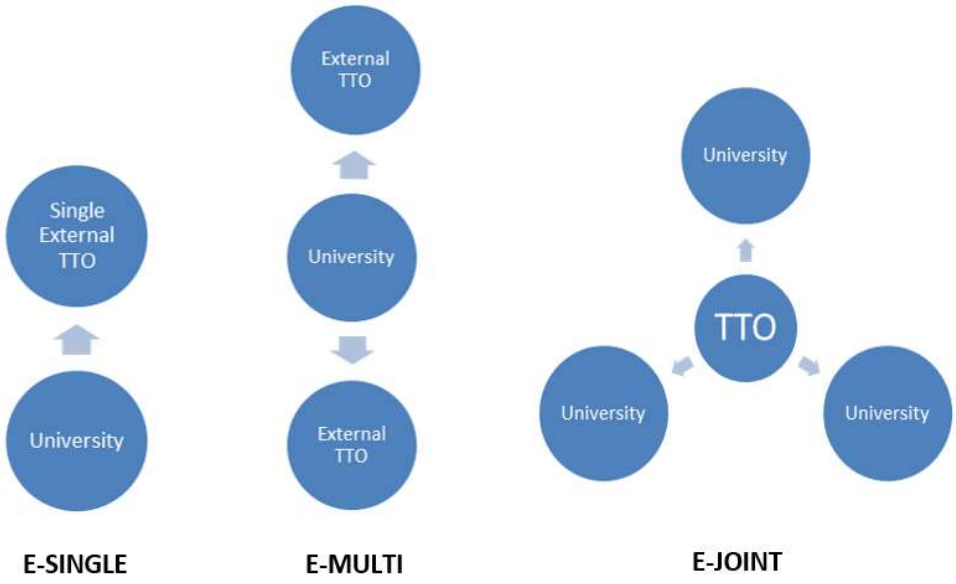

Figure 1: Three external configurations (Adapted from Brescia et al., 2016)

The I-MULTI organizational structure refers to two or more offices in the university working together, such as legal, marketing, grants and funding, or research and development. The I-

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MULTI can also refer to a distributed TTO organizational structure in which the TTO has representatives at Faculty or School level, or so-called IP Scouts, which serves as the first point of contact for staff.

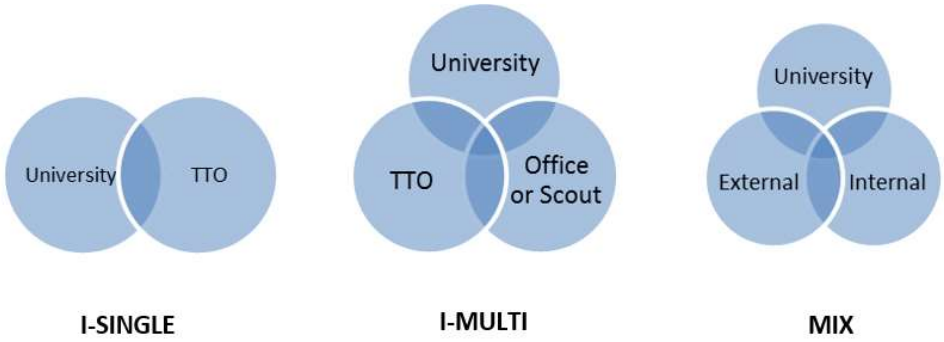

Figure 2: Two internal configurations and the mix organizational structure (Adapted from Brescia et al., 2016)

The MIX organizational structure refers to a combination of one internal office (irrespective of organization) and one external office (irrespective of organization) (Figure 2). For the purpose of this study the TTO typology proposed by Brescia et al., (2016) will be taken in consideration. Indeed, the aim of this study is to determine which type of TTO enables better access to IC and recommendations will be made as to the most efficient organizational structure. This will be determined based on the maturity levels of the TTOs investigated, and their corresponding access to IC.

Methodology

The self-assessment tool and MM created by Secundo et al., (2016a) was used as a research framework for this study to determine the efficiency of TTOs, and through interviews with these TTOs identify the type of TTO as per Brescia et al's., (2016) definition, to answer the research question: Which TTO organizational structure would be the most suitable to enable access to IC in developing countries?

Maturity Model (MM)

As mentioned before, the self-assessment tool measures the efficiency of a TTO through various IC indicators on an ordinal 5 point Likert scale, and each category (HC, SC or RC) is weighted using the fuzzy analytical hierarchy process (AHP), and a final score is calculated for the efficiency of a TTO. This score then classifies the TTO at a certain maturity level using the MM created by Secundo et al., (2016a), which indicates which category of IC needs strategic interventions to increase the efficiency of the TTO at academic entrepreneurship. This is possible because the MM is based on the Berkley (PM)2 Model (Kwak and William, 2000) which breaks down processes and practices into efficiency areas based on best practice and literature reviews. The level of maturity ranges from 1 (low) to 5 (high) and allows for the determination of strengths and weaknesses, and can, therefore, enable the TTO to selectively focus on weak practices to achieve a higher maturity. The levels of maturity are the Awareness stage (1), Defined stage (2), Managed stage (3), Integrated stage (4) and Sustained stage (5). Each level is furthermore described in terms of the key processes and practices needed for optimal efficiency.

Data collection and analysis

Through internet searches, universities with a TTO (or similar unit) in the EU (118) and UK (116) were identified and contacted by email requesting participation in this study. A total of 54 TTOs responded from Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, France, Greece, Italy, Netherlands, Sweden, Switzerland and the UK. Participation in the study was voluntary and some TTOs chose to keep their

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answers anonymous. For the purposes of this study, 24 of the 54 responses were used, due to number of participants who were willing to be interviewed regarding their TTO. Each of the 24 TTOs was classified during the interview according to Brescia's et al (2016) Typology.

Findings

To determine how efficient a TTO is at valorising IC, and therefore how efficient a TTO is at academic entrepreneurship, the self-assessment tool was used by 24 TTOs. The final score was calculated and a maturity level assigned to each TTO. A TTO with a maturity level of 4 would be considered highly efficient at academic entrepreneurship. The 24 TTOs were then interviewed to classify the type of TTO and to determine if one type of TTO exists which enables access to university IC as evidenced by highly efficient academic entrepreneurship. The results are given in Table 2 below. The maturity levels are based on the score of the self-assessment which defines the levels as: Awareness stage (1) = 14,2; Defined stage (2) = 15 – 33; Managed stage (3) = 34 – 51; Integrated stage (4) = 52 – 70; and Sustained stage (5) = 71. Table 2 is divided into three sections, the first includes TTOs at the Managed stage, the second includes TTOs which are close to moving up to the Integrated stage (49 – 51) and the last includes TTOs at the Integrated stage.

Table 2: Results of 24 TTOs in the EU and UK sorted ascendingly according to score

Country	Score and (Maturity Level)	Type of TTO
Austria	34.8 (3)	I-MULTI
Greece	36.6 (3)	I-SINGLE
Italy	37.2 (3)	I-MULTI
UK VI	42.2 (3)	I-MULTI
Czech Republic II	42.6 (3)	I-SINGLE
Belgium II	43 (3)	I-SINGLE
UK II	43.2 (3)	I-MULTI
UK V	48 (3)	I-SINGLE
Czech Republic I	48.2 (3)	I-MULTI
Netherlands	49.2 (3)	MIX
Czech Republic III	49.6 (3)	I-MULTI
Denmark	50 (3)	I-SINGLE
Belgium I	50.6 (3)	I-MULTI
UK III	50.8 (3)	I-MULTI
Bulgaria	51.8 (4)	E-JOINT
Estonia	52 (4)	I-MULTI
Belgium III	52.8 (4)	I-SINGLE
Czech Republic IV	53 (4)	I-MULTI
Belgium IV	53.6 (4)	E-JOINT
France	55.2 (4)	E-JOINT
Sweden	56.8 (4)	MIX
Switzerland	60 (4)	E-JOINT

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UK IV	60.4 (4)	E-MULTI
UK I	61 (4)	E-SINGLE

Discussion

The results in Table 2 show 3 categories of TTO maturity, those at level 3, those in the transitional phase, and those at level 4. As postulated at the beginning of this paper, TTOs with high maturity levels should have maximum access to IC. Therefore, we consider those at maturity level 4 as well as those at the transitional phase in determining which organizational structure is most suitable to enable access to IC. Based on the typology suggested by Brescia et al., (2016), all the organizational structures are noted in these high performing TTOs as identified from the interviews with 24 TTOs. The most prevalent, of course, is the external model, in either its single, multi or joint configuration as illustrated in Figure 1. These organizational structures support our postulation in part, in that an external TTO which would be a registered, fully functioning, company. Therefore, an external organizational structure would have its own IC, and maximum access thereto as these offices are typically small and closely organized to ensure optimal performance.

Similarly prevalent, especially amongst the transitional phase TTOs, is a mixed or internal multi-office model as illustrated in Figure 2. From the results in Table 2, a multi-office (I-MULTI or MIX) organizational model is preferred, which fully supports our postulation because these organizational structures have maximum access to IC. Through the addition of another office within the university to the TTO organizational structure, the TTO has increased access to university IC, specifically HC and SC. Similarly, when the TTO is in a distributed structure, due to the proximity to the researchers or staff of the university, the TTO has increased access to university IC, specifically, HC and RC. In the MIX organizational structure an equal increase in access to IC is noted, except in this case, it is a mixture of university IC and external TTO IC. External TTOs have more freedom in terms of employing staff with specialist skills, which increases their HC. Additionally, external TTOs can engage freely with industry partners, which increases RC. The internal TTO then provides access to the university SC, and as such the MIX organizational structure has increased to IC in all three categories of classification.

Conclusion and Recommendations

The aim of this study was to determine which TTO organizational structure would be the most suitable to enable access to IC in developing countries. As alluded to in the discussion section above, the MIX organizational structure is, in the opinion of this study, the most preferred structure for a new TTO in a developing country. Of course, when establishing a TTO for the first time it may be costly to start with the MIX organizational structure, and as such, it is recommended that developing countries start with an internal multi-office TTO, until sufficient capacity, skills, and funding is established. From there, adding an external TTO which works closely with the internal TTO should move the TTO to a higher maturity level. In certain countries, an external TTO may not be necessary, if the internal TTO has strong university-industry links, or there is no legal requirement preventing the university from engaging directly in commercialization activities.

Theoretically, this study contributes to the performance measurement of academic entrepreneurship research. Often-used metrics, for example counting patents, have little to do with overall performance as patenting is only a

This paper was presented on 9 June 2017, at the International Forum for Knowledge Asset Dynamics (IFKAD) in St. Petersburg, Russia.

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small part of academic entrepreneurship and its measurability (e.g. invention disclosures, number of patent applications, domestic patents granted) (Larsen, 2011). While patenting and licensing have been widely explored in the literature, their de facto status of representing academic entrepreneurship is an example of bounded rationality (Tello et al., 2011). This study puts into evidence another metric, IC, which has heretofore not been considered as a representation of academic entrepreneurship. Moreover, on a practical level, this study provides some guidance to university management in developing countries on the various TTO organizational structures currently in use, and their relative performance. The efficiency is measured based on IC, and different efficiency measures such as data envelopment analysis may indicate a different performance level. As stated before, individual universities need to consider whether to pursue academic entrepreneurship and if so, if their goal will be a commercial gain or social impact.

The limitation of this study is the small number of TTOs involved in the data collection, and that no data has been collected from developing countries. Future work should look towards testing these recommendations more extensively.

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Appendix B:

The two articles in Chapter 3 found that access to intellectual capital was essential for improving the efficiency of university technology transfer. This access can be viewed in two ways: First, that the organisational structure of the TTO allows access to intellectual capital. Secondly, that the TTO has access to the intellectual capital it most needs for efficiency.

These dual ideas of access were investigated in the form of two conference papers. The second of these was presented at ICEIRD (International Conference on Entrepreneurship, Innovation and Regional Development) and discusses the importance of the vision/mission statement of the university for technology transfer.

A Novel Technology Transfer Office Typology Based on Lessons Learnt From the UK

Christle de Beer [1], Felicia. M. Fai [2,] Corne S.L Schutte [1]

[1] Department of Industrial Engineering, Stellenbosch University, Stellenbosch, South Africa, *18867790@sun.ac.za*, *corne@sun.ac.za*

[2] School of Management, Bath University, Bath, England, *f.m.fai@bath.ac.uk*

Developing countries are increasingly establishing technology transfer offices (TTOs) recognising that these can play a potentially significant role in facilitating the successful transfer of technologies and knowledge between universities and industry. However, many TTOs in developing countries operate inefficiently and seek to learn from developed world practices. Whilst research on the characteristics of TTOs and their performance is growing there is still much to understand even in developed nation TTOs. We contribute to this area by using novel primary data gathered from UK universities to create a typology of technology transfer offices (TTOs) based on the combination of their mission statement, governance structure and maturity. Using the conceptual Maturity Model of TTO efficiency developed by Secundo et al (2016), an online questionnaire was developed and sent to 116 universities in the UK. Eight of the 20 respondent universities were interviewed about their range and types of practices. We found correlations between the maturity level of the TTOs mission statements and their governance structures. We suggest this emerging typology may assist TTOs in developing countries to be more efficient by appropriately aligning their mission statement, governance structure and maturity.

Keywords

Developing Countries, Efficiency, Mission Statement, Technology Transfer Office, Typology

Introduction

Developing countries strive for developed nation status. A critical step is to transform from a resource-based to a knowledge-based economy (KBE) [1]. A KBE requires the establishment of a national innovation system (NIS) in which a network of institutions in the public and private sectors, interact to develop, import, modify and diffuse new technologies [2]. Appropriately configured and effectively organised NIS's can help reduce poverty and improve income distribution in developing nations [3]. A key element within NIS is the establishment of good university–industry linkages [4] which facilitate technology transfer (TT) from the science base to industrial application as evidenced by the successful commercial TT from university to industry in the USA, UK and Australia over the last 20-30 years [5]. Developing countries have attempted to emulate these countries by typically formalizing the Intellectual Property Rights (IPR) of universities and creating

This paper was presented on 31 August 2017, at the International Conference for Entrepreneurship, Innovation and Regional Development (ICEIRD) in Thessaloniki, Greece.

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Technology Transfer Offices (TTOs) [6]. Yet TTOs in developing countries take a reactive (case by case basis) rather than a proactive (strategic and well-defined) approach to TT and several studies reveal many TTOs operate inefficiently [6,7,8,9]. Whilst it has been suggested shared experiences between TTO leads to learning and improved efficiency in their TT processes [7], we believe improved efficiency in turn, correlates with the antecedent characteristics of TTOs. Understanding antecedents becomes particularly important in the case of developing countries, where even well understood technologies are often adopted with limited success [10]. We investigate this among a small sample of 8 UK university TTOs using a novel tool previously developed by one of us [10] and data gathered from semi-structured interviews from which the antecedents of organisational governance and mission statements were identified. We find some limited support for our propositions.

Literature Review

Mission Statements

The academic literature on mission statements is limited, but identifies three core purposes of mission statements; as a guide to decision making, as a communication tool, and as a tool in directing the formulation and implementation of strategic planning [11]. It has been suggested [12] that during the establishment phase of TTO's (which many developing countries are in) understanding and defining the purpose and intent of a TTO is an important, but not simple, task. However, given TTOs operate in different environments, one might expect them to develop differentiated missions and therefore mission statements. The university plays an important role in defining the mission statement of its TTO, setting the TTO's objectives, assigning the funds for TTO activities and defining the relationships with other university structures [13] i.e. defining governance structures.

Organisational Governance Between Universities and Their TTOs

In the USA, the enactment of the 1980 Bayh-Dole Act, formalized the IPRs of universities. Consequently, the original mission of TTOs was to derive economic benefits for the university from TT and this is reflected in their core activities i.e.: intellectual property (IP) protection support, research support and spin-off support. As such, early studies considered TTOs to be centralized and hierarchical structures, embedded at the central level of the university [13]. As TTOs have been adopted by other American universities and universities in nations beyond the US, greater variance in the governance structure has been identified with respect to the degree of autonomy granted to TTOs. This is reflected in the variety of ways in which TTOs are organized e.g. an internal centralized office, an internal decentralized office, an external non-profit research foundation, or a for-profit venture [14]. Furthermore, hybridizations of these organizational structures have been suggested to enhance the efficiency of the TTO. However, given that the goal of TTOs can be identified as knowledge transfer, an analysis of the organizational structures of TTOs requires a model of their core activities [13]. Recent research therefore includes the degree of discipline specialization, degree of task specialization, and degree of exclusivity highlighting the emergence of various regional TTOs or technology transfer alliances [15]. However, none of these typologies consider the mission statement as a factor influencing the organizational governance of the TTO and how alignment between these correlates with TTO efficiency.

TTO Efficiency

Seeing as TTOs are central to a process as complex as TT, it is important to know how efficient a TTO is at conducting its missions [8]. The efficiency of a TTO is often considered as the conversion rate of inputs (research funding) to outputs (patents, licenses and spin-off

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companies) [16, 17, 18]. Yet, TTOs face many challenges in this endeavour, such as an unconducive university culture and a lack of complementary assets [8]. A survey on TTOs in the USA found that over 50% lose money on their TT operations while only 16% are self-sustaining [6]. Similarly, in TTOs across Europe, just 10% of TTOs secure 80% of all licensing deals, and the top 2% of TTOs across 6 countries capture 40% of licensing revenue [7]. In the case of developing countries' university TTOs, despite the adoption of new IPR legislation, this has not resulted in an efficient approach to technology transfer in these standard output terms. We follow the principles of others [19] in defining TTO efficiency on other grounds and detail this in the methodological section that follows. Importantly, we suggest that if the mission of the TTO is clearly defined and accordingly structured, it does lead to increased efficiency [12]. We now outline our data and methodology that is used to examine whether the combination of TTO mission statement and governance structure correlate with measures of TTO efficiency.

Data and Methodology

University Technology Transfer Offices in the UK

We have used TTOs in the UK as the sample for this study. The US Bayh-Dole Act created a strong orientation towards the commercialisation of university created IP in US TTOs. Developing nations are technologically less advanced and their IPR systems less established than the US model, and therefore US TTOs are less relevant to developing nation TTOs. Contrastingly, whilst the UK has one of the world's leading research systems, it has no counterpart to the Bayh-Dole Act, as such UK TTOs were not established with the same commercial mission in mind as those in the USA. Moreover, in the UK public universities (there are very few private ones and these tend to be teaching focussed) have charity status and as such cannot engage in commercial activities directly [20]. The longevity of TT activity in the UK (since at least 1987) and the ways in which it contributes to UK economic growth, and the scale and activities of their TTOs are also more comparable to other countries making it a good frame of reference and basis of policy recommendations for developing nations. The UK government uses the Research Excellence Framework (REF) to assess and reward universities and departments that have achieved international scientific excellence. The REF utilises three criteria namely: research output, impact and environment. Within outputs, the originality, international significance and rigour of research outputs (e.g. publications) are assessed and carry a 65% weighting of the overall outcome. The vitality and sustainability of the research environment carries a 15% weighting. Lastly, impact carries a weighting of 20% and assesses the reach and significance of excellent research on the economy, society and/or culture (including impact on teaching, policy and practice). In this way, the 'impact' element of REF aims to build bridges between universities, business, and society [21] which are arguably a more relevant and broader set of objectives that TTOs from developing nations should be striving for. Universities in the UK are categorised as pre-1992 and post-1992 universities (including former polytechnics which were granted university status post 1992). The pre-1992 group are typically more research-focussed. Within the pre-1992 group, 24 universities known collectively as "the Russell Group," account for around 15% of all universities but 75% of all research income. Research has shown [20] that UK universities located in regions with higher levels of R&D and contributions to GDP appear to be more efficient at TT; these regions positively correlate with the Russell Group (RG) of universities.

Measuring TTO Efficiency

One of us has previously conceptualised a self-assessment tool out of the academic literatures to determine the efficiency of TT [10]. The tool captures the relative presence (5) to absence (0) of several intangible indicators in the areas of: human resources, IP strategy and policy,

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university-industry links, networks, technology, and organization design and structure. The 'human resources' of the TTO are identify their skill sets, 'IP strategy and policy' focusses on the institutional support given to TT activity, 'university-industry' links indicate the TTO's self-perception of their understanding of the needs of industry, whereas 'networks' indicate the extent of actual interaction between the parties involved. 'Technology' emphasizes the importance of the stage of development of the disclosed technology, as well as the academic merit of the discloser and finally 'organization design and structure' looks at the TTO features (e.g. size, age) and surrounding support functions (e.g. presence of a medical school, business school). Using these non-monetary and intangible indicators, the tool calculates an average score for the efficiency of TT which enables the TTO to be associated with a certain level of 'maturity' in a systematic way (See Table 1).

Table 1: Survey data collected from 8 TTOs in the UK

TTO	Human Resources	IP strat. & policy	Uni-Ind Links	Networks	Technology	Org. design & struct.	Maturity level (i.e. TT efficiency)
1 RG	5	4	5	4	2	3	4
2 RG	5	4	5	4	2	5	4
1 OU	3	4	4	5	1	2	3
2 OU	3	3	4	4	3	3	3
3 OU	4	2	4	4	2	3	3
4 OU	3	2	4	4	4	3	3
5 OU	4	4	4	3	3	4	4
6 OU	4	3	3	4	2	3	3
* RG denotes Russell Group Universities				*OU denotes other universities			

The self-assessment tool was converted into an online questionnaire, using ESurveyCreator, and sent to mid-level employees (identified by their job title: technology transfer manager, IP manager, business development manager, engagement manager etc.) at 116 universities in the UK in July 2016. These universities were sent reminders monthly till the deadline of 31 December 2016, in total 20 universities responded. These 20 were approached for a semi-structured interview and eight agreed. The semi-structured interviews enquired about their range and types of activities, the content of their mission statements and their governance relationship with the university.

Findings and Discussion

From the interviews, it was identified that mission statements had a combination of three categories: commercialization, impact and relationship-building. These three categories are supported by different activities. Commercialization is supported through IP protection, licencing and spin-off company creation. Impact is supported through research outputs, knowledge transfer, and regional development. Relationship-building is supported through research contracts, specialized consulting to industry and collaboration for development of research. The interviews also allowed us to identify the university's governance and corresponding organization of the TTO into three broad categories: internalised, externalised or hybrid. An internalised structure is when a TTO is viewed equivalently to a department or office within the university, but functions *independently* from other departments. These internal offices have a low degree of autonomy and report at various levels within the university. An externalised structure is where a TTO company is established physically outside of, but wholly owned by, the university. These external

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offices have a high degree of autonomy, often being governed solely by an external board. The hybrid structure is where the TTO is held internally as a central office, but supported by other offices (marketing, legal etc.) or IP scouts (faculty level technology transfer officers) or both. Due to the variety of offices involved in this hybrid structure, the autonomy of the TTO varies, but most often the central TTO has autonomy over the other offices, but reports internally.

These findings are combined with the outcomes of the self-administered questionnaire embodying the assessment of TTO maturity (numbers in bold in the table body) and represented in Table 2. Table 2 shows the emergence of a typology of TTOs: commercially-, impact- and relationship building-oriented TTOs, although given the small numbers, these must be interpreted tentatively.

Table 2: Emerging typology of TTOs

			Mission Statement	
		Commercial	Impact	Relationships
Governance structure	Internal	**3**(OU1)		**3** (OU6)
	Hybrid		**3**(OU2), **3**(OU3), **3**(OU4)	**4** (OU5)
	External	**4** (RG1), **4**(RG2)		

In terms of the TTOs which can be identified through their mission statements to be predominantly commercially oriented, these will also tend to be the most 'mature' in terms of the efficiency of TT. TTOs with a strong commercialisation orientation are likely to be externalised from the main university structure, much like in many US cases. This type of TTO is more likely to be adopted by a research-intensive university. TTOs which can be identified through their mission statements to be more concerned with having broader impact (on society, business and policy makers) will tend to be of moderate maturity i.e. moderately efficient at TT. They are more likely to be working in a hybrid governance structure, where they have moderate degrees of independence, but also work alongside other departments or functional divisions of the university.

We speculate that TTOs whose dominant mission is to commercialise university generated research are expected to have a direct impact on company level innovations and/or productivity or efficiency. One can expect that they are required to work closely with the private sector. This is reflected by the score of 5 in the university-industry linkages for RG1 and RG2 in Table 1 indicating both universities have an excellent understanding of the needs of industry and the related indicator of networks which indicates strong actual interaction with industry, not just understanding their needs. Additionally, these commercially oriented TTOs receive strong institutional support for TT (scores of 4 in Table 1). Commercially oriented TTOs also have high quality human resources to support their activities. In contrast, we speculate TTOs whose dominant mission is to ensure university generated research has impact (and influence), see private industry as only one of many stakeholders and most certainly do not regard it as the most important one. Impact-oriented TTOs are likely to try and influence government, NGOs, charities and society more generally. Indeed, they have strong interactions with stakeholders (indicated by a network score of 4 in Table 1), but their university-industry link scores (relative to the commercially oriented TTOs), are relatively less strong (scores of 4 versus 5 in Table 1).

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Interestingly, impact-oriented TTOs generally score more highly on 'technology' than commercially-oriented TTOs i.e. place more emphasis on the stage of development of the disclosed technology and the academic merit of the discloser. It may be that non-industry stakeholders have different attitudes to risk and so require technologies to be further down the pathway of development than private companies (quite possibly their own funding is from third parties, like tax-payers, charitable donors rather than from shareholders or retained profits), and also rely more on the academic reputation of the TTO's university as a broader indication of quality, reliability etc. This might explain in part why our impact oriented TTOs all adopt a hybrid governance relationship with their universities.

Conclusions

Our study is at a nascent stage. It is obvious that the sample size is a fundamental weakness of our study and that our findings needs to be interpreted with a good deal of caution. Our intention is to repeat this study with other TTOs across several EU nations thereby building up our sample and robustness of our findings. Nevertheless, that are some potential early lessons emerging for universities in developing nations attempting to establish their own TTOs.

Firstly, a clear mission statement is needed. Universities in developing countries need to decide what the main focus of their TTO will be, and accordingly which TT activities it will pursue. Depending on which activities the TTO undertakes, an appropriate measure of the success at pursuing these activities should be adopted. The Maturity Model [10] allows for the assessment of TTOs with different mission statements.

The second lesson learnt from TTOs in the UK, is that a clear mission statement needs to be paired with and appropriate governance structure for the TTO. As alluded to by the typology of TTOs in Table 2, an external structure enables a TTO with a commercial focus to be successful. Impact focussed TTOs should employ a hybrid structure, as this allows for an integrated and holistic approach to knowledge transfer within the university to strategically impact regional development. It is not possible to comment on relationship oriented TTOs due there being only 2 and each adopted a different governance structure and have different levels of maturity.

We conclude that when universities from developing countries attempt to establish a TTO it needs to consider the maturity of its TT activities and use the factors within this measure to determine if it might successfully adopt a predominantly commercial, impact (or relationship-building) mission. This should be clearly reflected in its mission statement as a signal to potential partners and the university should adopt a governance structure that enables the TTO to fulfil its primary mission.

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Appendix C: Declarations

With regard to Chapters 2 (24–37); 3 (65–58); 4 (89–98), and 5 (109–118), the nature and scope of my contributions were as follows:

Nature of contribution	Extent of contribution (%)
Writing published and unpublished work	70%
Data collection	100%
Data analysis	100%
Literature review	60%

The following co-authors contributed to Chapters 2 (24–37); 3 (65–58); 4 (89–98), and 5 (109– 118):

Name	E-mail address	Nature of contribution	Extent of contribution (%)
Giustina Secundo	Giusy.secundo@unisalento.it	Writing published and unpublished work	40%
Giuseppina Passiante	Giuseppina.passiante@unisalento.it	Supervision	10%

The following co-author contributed to Chapter 3 (65–58); 4 (89–98), and 5 (109–118):

Name	E-mail address	Nature of contribution	Extent of contribution (%)
Corne Schutte	corne@sun.ac.za	Supervision	10%

Declaration by co-authors:

The undersigned hereby confirm that:

1. the declaration above accurately reflects the nature and extent of the contributions of the candidate and the co-authors to Chapters 2 (24–37); 3 (65–58); 4 (89–98) and 5 (109–118);

2. no other authors contributed to Chapters 2 (24–37); 3 (65–58); 4 (89–98) and 5 (109–118) besides those specified above;

3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in Chapters 2 (24–37); 3 (65–58); 4 (89–98) and 5 (109–118) of this dissertation.

Signature	Institutional Affiliation	Date
Giustina Secundo	UniSalento	19/09/17
Giuseppina Passiante	UniSalento	19/09/17
Corne Schutte	Stellenbosch University	19/09/17