Knowledge Transfer in University Quadruple Helix Ecosystems: An Absorptive Capacity Perspective.

Abstract

Increased understanding of knowledge transfer (KT) from Universities to the wider regional knowledge ecosystem offers opportunities for increased regional innovation and commercialisation. The aim of this paper is to improve the understanding of the KT phenomena in an open innovation context where multiple diverse stakeholders are interacting. An absorptive capacity-based conceptual framework is proposed, using *a priori* constructs which portrays the multidimensional process of KT between universities and its constituent stakeholders in pursuit of open innovation and commercialisation. Given the lack of overarching theory in the field, an exploratory, inductive theory building methodology was adopted using semi-structured interviews, document analysis and longitudinal observation data over a three year period. The findings identify various factors, namely human centric factors, organisational factors, knowledge characteristics, power relationships and network characteristics which mediate both the willingness of stakeholders to engage in KT and the effectiveness of knowledge acquisition, assimilation, transformation and exploitation. This research has implications for policy makers and practitioners by identifying the need to implement interventions to overcome the barriers to KT effectiveness between quadruple stakeholders to be able to more fully develop an open innovation ecosystem.

1.0 Introduction

This paper focuses on the role knowledge plays in commercialisation, within a University knowledge ecosystem context and explores how to improve the effectiveness of knowledge transfer (KT) from universities. Traditionally, university KT and Knowledge Exchange

comprised of the 'pushing' or brokering of discipline-specific research outputs and/or the provision of more generalised education and skills development (Etzkowitz and Klofsten, 2005; Urbano and Guerrero, 2013). However, in recent years, universities have been required to take on a more entrepreneurial role as core actors within regional innovation ecosystems resulting in new and diverse opportunities for KT (Ambros et al, 2008; Etzkowitz, 2008; Arnkil et al, 2010; Hewitt-Dundas, 2012). Whilst this triple helix 'ecosystem' approach is purported to be one of the core elements of regional economic growth, within a knowledge-based economy (Nambisan and Sawhney, 2007; Urbano and Guerrero, 2013) a number of studies suggest that this largely normative KT process has not and is not delivering the expected levels of commercialisation in terms of GDP and increased jobs (Asheim and Coenen, 2005; Lawler, 2011). Cooke (2005), Arnkil et al (2010) and Kenney and Mowery (2014) suggest that from an open innovation perspective, the normative and primarily closed innovation through Triple Helix-based KT process adds to the 'internalisation' or isolation of knowledge rather than enabling more widespread opportunities for knowledge as a source of innovation. More recently user-driven innovation models have emerged, which add a fourth stakeholder group to the triple helix model. This approach recognises the increased role that end-users and therefore society are playing in regional and project-based innovations. These end-users in essence create the 'pull' or demand for innovation which can lead to opportunities for open innovation (Arknil et al., 2010; Carayannis and Rakhmatullin, 2014).

Alexander et al. (2012) suggests that the changing role of universities within a complex open innovation ecosystem of diverse stakeholders poses considerable challenges for effective KT. However, this is currently an underexplored area which is in need of improved understanding and conceptualisation as to how knowledge can be effectively transferred within an open innovation context (Holi et al., 2008; Chesbrough, 2011; Carayannis and Rakhmatullin, 2014).

The aim of this paper is to improve the understanding of the KT phenomena in an open innovation context where multiple diverse stakeholders are interacting. To achieve this aim, an *ex ante* framework, derived from literature on KT between multiple stakeholders and triple helix based innovation is proposed. It is then applied to an in-depth case study. The case study aims to stimulate co-creational commercialisation outputs in the quadruple helix context. Based on the empirical findings, the initial framework has been revised and an *ex post* framework presented to aid understanding and conceptualisation of the actual KT processes which take place within an open innovation context.

2.0 Knowledge Transfer within an Open Innovation System

Universities are increasingly viewed as a hub of new knowledge (Leydesdorff, 2011). In recent years they have been expected to take on a more entrepreneurial role in KT within the regional knowledge ecosystem (Etzkowitz and Leydesdorff, 2000; Urbano and Guerrero, 2013) whereby they are considered a core conduit for regional KT and innovation through their engagement in commercialisation activities (Van Looy et al., 2011).

Arnkil et al., (2010) suggest that the presence of a university and supporting regional innovation strategy (RIS) does not guarantee that KT will take place, rather it attempts to create conducive conditions for KT and more radical innovation and commercialisation within the regional innovation ecosystem (Leydesdorff, 2012). Indeed, despite numerous governmental reports and initiatives over the past decade encouraging collaborations between triple helix stakeholders (e.g. Lambert Review, 2003; DTI, 2004; Sainsbury 2007; Wilson, 2012), key KT challenges in this context remain.

KT within the Triple Helix is conceptualised as boundary spanning across academia, Industry and regional Government (Etzkowitz et al., 2000; Etzkowitz and Klofsten, 2005). However, with the emergence of the knowledge economy, and a network based knowledge ecosystem leading to quadruple helix structures, KT is deemed to be a both an entrepreneurial process (Dakin and Lindsey, 1991) and a valorisation process (Leloux et al., 2009) in the context of open innovation ecosystems.

3.0 Conceptualising Knowledge Transfer between multiple stakeholders using an Absorptive Capacity lens

KT has been explored in a wide variety of practice based contexts however, there is a lack of an overarching or unified theory within the field (Chesbrough, 2011) reflecting its relative immaturity (Mitton et al, 2007; Arnkil et al., 2010; Carayannis and Rakhmatullin, 2014). Hence there is a need for improved conceptualisation. We suggest building on the conceptualisation of Su et al. (2013) who identify that an absorptive capacity lens can be used within an inductive theory building study to explore the process of KT. Absorptive Capacity has been used to explore why some organisations transfer knowledge more successfully than others, particularly in regards to University based KT within an open innovation ecosystem (Easterby-Smith et al., 2008; McAdam et al., 2010). Furthermore, Absorptive Capacity is seen as playing a crucial role in intra and inter-organisational knowledge transfer (Zahra and George, 2002; Lane et al., 2006). Hence following Su et al. (2013) Absorptive Capacity is put forward as a core construct in an initial *ex ante* theoretical framework.

Absorptive Capacity is defined as the ability to recognize, assimilate and apply new external knowledge to advance commercialisation and competitiveness (Cohen and Levinthal, 1990) and is viewed as a knowledge-based capability (Zahra and George, 2002). Knowledge sources

and recipients (i.e. stakeholders within an open innovation ecosystem) may vary in their Absorptive Capacity levels and hence this may impact KT effectiveness between organisations (Cohen and Levinthal, 1990; Zahra and George, 2002; Todorova and Dursin, 2007; Su et al., 2013). In particular, Easterby-Smith et al., (2008) and McAdam et al., (2010) identify that Absorptive Capacity has become a useful construct to understand why some organisations develop more innovative products and are more successful at innovation activities than others (Easterby-Smith et al., 2008; McAdam et al., 2010). There is a paucity of studies using absorptive capacity constructs to explore KT processes within a quadruple helix knowledge ecosystem where an open innovation climate of inflows and outflows of knowledge coexist (Arnkil et al., 2010; McAdam et al., 2012). Hence there is an opportunity to at least partially address this knowledge gap and facilitate theoretical development and refinement through using absorptive capacity as a lens to explore the process of KT from universities to its respective stakeholders within an open innovation ecosystem (Easterby-Smith et al., 2008; McAdam et al., 2010).

4.0 *Ex Ante* Model Development

An *ex ante* model was developed using *a priori* concepts as suggested by Bendassolli (2013) from the extant literature. Figure 1 presents the *ex ante* model which uses an absorptive capacity lens to portray the process of knowledge acquisition, assimilation, transformation and exploitation (Zahra and George, 2002). Figure 1 suggest that KT from universities for commercialisation traditionally happens within a complex network of triple helix stakeholder interactions however, a knowledge validation decision needs to take place or what Zahra and George (2002) deem an 'activation trigger' to begin the process of KT. The KT literature identifies a number of influencing factors which can impact the effectiveness of KT. These can be grouped into the characteristics of the knowledge source and recipient, properties of

knowledge, network characteristics and organisation context (Szulanski, 1996; Gupta and Govindarajan, 2000; Rothaermel et al., 2007; Matzler and Meuller, 2011).

[Insert figure 1 around here]

Once 'buy in' has been achieved absorptive capacity is needed to recognise the value of new knowledge, acquire, assimilate, transform and apply that knowledge to commercial ends (Cohen and Levinthal, 1990; Zahra and George, 2002). Similar to the knowledge validation decision, figure 1 identifies that capability development is mediated by various factors which are said to have varying impact on how knowledge flows between stakeholders at each KT stage (Zahra and George, 2002). Whilst a number of barriers and enablers to KT have been identified forming this conceptual model, the lack of overarching theoretical conceptualisation (Chesbrough, 2011) stresses the need for exploratory and inductive theory building to gain further understanding of the process of KT (Holi et al., 2008). This is particularly important when moving from a triple helix to a Quadruple Helix context in progressing towards effective mechanisms for open innovation and commercialisation (Sharifi and Liu, 2010; Alexander et al., 2012).

Based on the conceptual framework shown in figure 1, and the move from triple helix to quadruple helix structures within regional innovation systems, identifying a new stakeholder group, namely end users, three main questions have been identified. These were the cornerstones of the empirical phase of our research, where we explored in-depth the applicability of the framework in an open innovation quadruple helix context.

RQ1) What factors enable or prevent university KT effectiveness in relation to the absorptive capacity constructs of knowledge acquisition, assimilation, transformation and exploitation?

RQ2) What role do quadruple helix stakeholder relationships play in progressing KT through the absorptive capacity constructs of knowledge acquisition, assimilation, transformation and exploitation in the context of open innovation and commercialisation?

RQ3) How can KT theory and practice be progressed through empirical findings demonstrating the relevance and further development of a absorptive capacity lens to depict the multidimensional nature of the process of KT amongst multiple stakeholders.

5.0 Research Methodology

In order to scrutinise the conceptual model based on *a priori* concepts (Bendassolli, 2013), an interpretivist, qualitative methodology was employed in order to inductively build theory in an under researched context. To facilitate in-depth, nuanced understanding in order to refine the conceptual model, one intrinsic case study (Stake, 2000) of a University was undertaken. Fromhold-Eisebith and Weker (2013) identify that the idiosyncratic nature of universities and their complex processes is best explored through single intrinsic case studies. Data was collected longitudinally over a period of 3 years, through in-depth semi-structured interviews (Yin, 2011) and observational analysis of KT meetings which happened monthly and comprised of internal and external stakeholders involved in the case university's KT activities. Appendix one presents the profile of the interviewees and their respective codes. In addition, publically available documents were analysed relating to KT from universities and regional quadruple helix stakeholder collaborations, in order to gain a holistic view of the area under study (Eisenhardt, 1989; Yin, 2011). These documents included governmental strategies and white papers focused on collaborative KT between universities and quadruple helix stakeholders for the purposes of innovation.

6.0 Results and Discussion

Based on the empirical findings, Figure 2 presents the *ex post* model of KT from universities from an absorptive capacity lens. This model presents the dynamic interaction between the quadruple helix stakeholders within the case study and thus aids refinement of the enablers and challenges of KT within an open innovation context.

6.1 Quadruple helix stakeholder knowledge transfer with the aim of commercialising university research

Figure 2 shows that the commercialisation of knowledge from the case university is increasingly becoming a collaborative process whereby universities, industry, government and end users were increasingly engaging in KT to help commercialise knowledge in an open innovation process (Alexander and Martin, 2013; Kenney and Mowery, 2014).

[Insert figure 2 around here]

It was noted by a KTO4 and recent policy documentation (RIS, 2014; DETI, 2014) that there was increasing pressure and financial incentives for the University to take a more central role within a quadruple helix open innovation ecosystem. Government dictated performance measures include, engagement in joint supervision projects, such as Knowledge Transfer Partnerships (KTPs), collaborative research and contract research. Moreover, engagement in co-creational KT to increase technology commercialisation effectiveness in the market place was now deemed to be core to regional and national innovation strategy (McAdam et al., 2012; Wilson, 2012; RIS, 2014). From the data it was identified that a number of enablers and challenges existed in relation to KT between stakeholders with the emergence of more open innovation processes. These are represented as latent factors within figure 2 and largely mirror the core enablers and barriers of KT identified from literature within the *ex ante* model which illustrates the ongoing importance of these factors when engaging in more open innovation

practices. Each of the core enablers and barriers are summarised in table 1 and will be discussed in the sections which follow.

[Insert table 1 around here]

6.2 Enablers and Challenges for effective Knowledge Transfer

Whilst the core enablers and challenges within the case study appeared to align with prior literature, figure 2 differs from the *ex ante* model to show the interdependent nature of the latent factors which mediate both engagement in KT and the effectiveness of KT. It was found that a combination of those factors may have either a positive or negative impact on knowledge acquisition, assimilation, transformation and exploitation. Prior research often fails to represent the dynamic nature of factors which mediate the flow of knowledge between stakeholders (Volberda et al., 2010; McAdam et al., 2010), with Lee (2010) noting that KT is often taken for granted with less known about how absorptive capacity is created and developed.

6.2.1 Human-centric Characteristics

A number of personal characteristics and skills were found to affect stakeholders from engaging in KT and sharing (hence affecting knowledge validation, as shown in figure 2) and were also found to impact the effectiveness of knowledge acquisition, assimilation, transformation and exploitation when engaging with other stakeholders in the pursuit of open innovation and technology commercialisation. Concurring with prior literature, human-centric characteristics of stakeholders such as the ability to network and individual attitudes and traits were found to affect absorptive capacity (Cohen and Levinthal, 1990; Zahra and George, 2002; Walter et al., 2006; D'Este and Patel, 2007).

The networking capability of academic entrepreneurs within the case university was identified as a mediator of collaborative open innovation processes. Concurring with past research, it was

identified that some academics have a lack of expertise which prevents them from engaging in effective networking and KT with industry (Lockett et al., 2003; Mosey and Wright, 2007). *"Everyone have their own personal mechanisms for networking and I suppose academic scientists are not exactly known for their interpersonal skills... I don't think there is anything that can be done"* (PI12). However, the importance of engaging in KT with industry and end users was identified as being useful in enhancing technology commercialisation (Audretsch and Feldman, 2003; McAdam et al., 2010). Stakeholder relationships were utilised to help understand and transform knowledge, aiding potential absorptive capacity (Zahra and George, 2002; Adams et al., 2006; McAdam et al., 2010). Furthermore the transformation of knowledge and consequently commercialisation (i.e. realised absorptive capacity, Zahra and George, 2002) was more successful when academic entrepreneurs had two-way flows of knowledge with industry networks and interaction with end users who helped to build awareness and interest in the innovations (Mitten et al., 2007; Livange et al., 2009).

Whilst it was evident that engagement with industry and end users had improved in recent years, cultural differences were still identified as a core barrier to effective KT (Goh, 2002; Easterby-Smith et al., 2008). However, the KTO staff perceived their role to be boundary spanning (Carlile, 2004) whereby they helped bridge interactions between academic entrepreneurs and industry, alleviating variances between cultures and processes (McAdam et al., 2010).

Within the case study, it was noted that intrinsic mind-sets and attitudes of individual stakeholders affected their willingness to engage in KT (Lucas and Ogilvie, 2006). It was recognised by all interviewees that within universities, academics are often working in academic silos, therefore there is a need for them to be opportunistic and to actively chat with

external stakeholders to help the university fulfil their role as part of an open innovation ecosystem. PI5 notes "*It is really up to us to engage with it and make an effort to meet different people and that is where the opportunities for collaboration arise"*. However, through the interviews and observation, it was unravelled that these mind-sets and attitudes to collaborate with industry and end users were largely a function of the organisational context, whereby organisational processes and mechanisms often shaped knowledge sharing behaviours (Szulanski, 1996; Bhagat et al., 2002; Laursen and Salter, 2006; Yeoh, 2009; Argote, 2012).

6.2.2 Organisational factors

It was evident that organisational factors played a key role in affecting knowledge absorption, sharing and transfer between the various stakeholders (see figure 2 and table 1). Organisational procedures and mechanisms were found to mediate stakeholder engagement and impact the effectiveness of KT (Urbano and Guerrero, 2013). For example, the emergence of a dedicated KTO identified the commitment of the university to develop internal procedures which enable academic entrepreneurs to engage in KT through open innovation activities. However, concurring with Locket et al., (2005) and Miller et al., (2014), the academic remit of teaching and producing high quality research publications was found to deter some academics from collaborating with external stakeholders. *"They keep expecting more and more from us, I do not know how they expect us to teach, produce 3 and 4 star publications and have time to network with industry and engage in commercialisation when over 50% of the time it does not result in something fruitful"* (PI2). However, internal promotional mechanisms did appear to be changing with one academic (PI9) highlighting that they had received their senior lectureship by engaging in KT activities reflecting the universities efforts to change practices to embrace their entrepreneurial obligations in striving towards meeting government objectives (Bhagat et al., 2002; Lucas, 2006).

6.2.3 Knowledge characteristics

The characteristics of the knowledge being transferred was found to influence its ability to be acquired, absorbed and exploited. Consistent with past research on KT (Siegel et al., 2003; Wright et al., 2009) the main type of knowledge being transferred during open innovation processes was business-related knowledge. This ranged from sales, marketing, finance, legal and experiential business knowledge; which has tacit and 'sticky' elements and is therefore often hard to acquire, transfer and absorb (Szulanski, 2002; Gourley, 2006). Hence the opportunity to increase collaboration of industry and end users at earlier stages of technology commercialisation processes was suggested as beneficial by the interviewees. It was recognised by the majority of the academics that having a good technology with a patent and protected IP was not enough *"Having IP is almost immaterial because if you are a good sales person you can have dreadful IP but still sell"* (PI11). This type of knowledge was thought to be based on personal attitudes, abilities and experience; therefore was difficult to acquire and absorb (Dyer and Singh, 1998; Nonaka and von Krough, 2009). Therefore it was identified that there was a need for academics to engage in open innovation processes with industry to help bridge this knowledge gap (Gassmann et al., 2010; McAdam et al., 2010). KTO staff were aware of academics deficiencies in knowledge *"I know that whilst academics may be very good in their own research area and the specific areas they specialise in. Not very many of them have actually formed and sustained relationships with industry"* (KTO3).

Furthermore, a scenario was identified by PI6 where they were engaging in open innovation with industry via mechanisms such as email and telephone. *"We tried to do it remotely so we never actually met the people involved ...the project was full with problems ... our experience was that face to face communication is superior"* (PI6). Thus it was noted that complex or 'sticky' knowledge, such as that required for innovation was said to require rich

communication channels such as face to face communication to facilitate transfer and absorption (Szulanski, 2002; Yeoh, 2009; Alexander and Childe, 2012).

In prior studies, open communication has been found to reduce knowledge asymmetry (Vandekeckhove and Dentchev, 2005) which is essential when multiple diverse stakeholders are interacting in an open innovation context. However, the case study showed that with an increasing number of stakeholder's becoming involved in commercialisation processes, it was becoming increasingly difficult to negotiate and compromise on stakeholder objectives which are often diverse. Recent government policies (Wilson, 2012; RIS, 2014; DETI, 2014) identify the 'ideal' of co-creational KT in an open innovation quadruple helix ecosystem however, as noted previously, inherent organisation factors were found to constrain full engagement between universities, industry and end users.

6.2.4 Power relationships

It was noted throughout the research period that KT between multiple diverse stakeholders in pursuit of open innovation was complex and often difficult. Consistent with prior research (Easteby-Smith et al., 2008; McAdam et al., 2012), this source of conflict was often the result of varying aims and objectives governing KT. From the case study findings (and as shown in figure 2 and table 1) it was found that power relationships had an effect on both stakeholder willingness to engage in KT and the effectiveness of KT, which will have a consequential impact on commercialisation success.

University remit was a reoccurring theme, whereby the need to publish often conflicted with the priorities and objectives of industry during collaborative innovation projects (Van Looy et al., 2011; Hewitt-Dundas, 2012). The KTO staff recognised this issue when trying to bridge

KT between industry and academics; "*well academic publications run directly counter to the commercialisation task. That is one of the great ironies at the heart of the academic research system!"* (KTO3). However, it was identified that IP applications can be sough quite quickly thus it was thought that two way communication was needed to eliminate potential conflict between stakeholders (Nadler et al., 2003; Van Wijlk et al., 2008).

It was suggested by several academics and KTO staff that government do not fully understand the challenges involved in KT between universities, industry and end users in the pursuit of innovation;*"...the nature of the stuff coming out of the universities labs at that stage is a very fragile concept and you can't directly take those things and in 6 months time be employing 100 people ... You are looking at ideas and discoveries which on the day that they are disclosed to us that no one can put their hand on their heart that that is worth investing in or not... They think it (referring to Government) is perhaps an automatic one rather than a kind of hand holding, steering, developing, mentoring type one"* (KTO4). GOV2 admitted that there are a lot of bureaucracy governing quadruple stakeholder collaborations however, that this was driven by disappointing results from previous programmes and innovation strategies. It appeared that the KTO and Government were both trying to exert their power to influence how quadruple interactions should progress. However, drawing upon Mitchell et al. (1997) and Frooman, (1999) the more dominant stakeholder appeared to be government since they had the power to withhold/withdraw funding which potentially could affect the KT activities.

6.2.5 Network characteristics

As noted, with the emergence of the quadruple helix, there is increased pressure for more networked relationships between universities and their stakeholders (Arnkil et al., 2010; Carayannis et al, 2012). Within the case study it was identified that KT between universities,

government, industry and end users was aided through the case university's KTO. The KTO staff considered their role to be invaluable in helping eliminate any cultural or language problems between diverse knowledge groups. Therefore the KTO appeared to be 'boundary spanners' and played an important role in aiding KT (Zahra and George, 2002; Tortoriello and Krackhardt, 2010).

The ability to effectively engage in KT was also found to be mediated by the need to build trust between stakeholders; however, this was considered to be challenging when dealing with diverse stakeholders, many of which interact in an ad-hoc manner (McAdam et al., 2012; Miller et al., 2014). Indeed, concurring with Levin and Cross (2004) and Szulanski et al. (2004) it was stressed that a lack of trust could potentially hinder knowledge sharing and transfer within open innovation commercialisation activities since it prevents knowledge openness. *"I think it's important as a model for whatever academic community or social community who undertake with no hidden agendas, just for sheer joy of finding out what other people do and then having a one to one or whatever conversation with them that you are not going to steal their ideas. The trust has to be built before partnerships can foster"* (PI14). The ability to build personal relationships was found to be essential to use not only as a source of prior knowledge but helped convert ideas into products and services. Thus building relationships and actively maintaining those relationships was found to facilitate access to knowledge (Miller et al., 2011).

6.2.6 Learning from knowledge transfer

In contrast to figure 1, the feedback loop in figure 2 presents a continuous cyclical process where it was observed that KT and learning is cumulative and path dependent (Cohen and Levinthal, 1990; Lane et al., 2006). However, it was found that learning mechanisms within the case university required further development. Whilst it was evident that academics reflected

on past commercialisation failures, there appeared to be a lack of internal systems and procedures which captured knowledge from past unsuccessful commercialisation efforts so that lessons could be learned for future KT efforts (Cohen and Levinthal, 1990; Easterby-Smith et al., 2008). Thus in the case study, single loop learning appeared to still prevail at the university level (Argyris and Schon, 1978) which could be considered a core barrier to KT since, the case university did not appear to alter their processes or policies as a result of 'lesson's learned' through prior KT with stakeholder in the pursuit of innovation.

7.0 Conclusions and recommendations for further research

Empirical studies on KT and absorptive capacity to date show serious shortcomings signalling the need for further conceptualisation and development (Holi et al. 2008; Chesbrough, 2011; Carayannis and Rakhmatullin, 2014). Indeed, in an open innovation context, where multiple diverse stakeholders are interacting, new challenges emerge (Chesbrough et al., 2006) identifying the need for improved knowledge and understanding of the processes of KT between multiple stakeholders. Within this article we aimed to contribute to this discourse by exploring how knowledge can be effectively transferred between universities and their constitute stakeholders within an open innovation quadruple helix context. The proposed model identifies a number of interdependent factors can enable or restrain KT effectiveness, namely human centric factors, knowledge characteristics, organisational factors, power relationships and network characteristics. These factors were found to both determine the initial decision to engage in KT and mediated the acquisition, assimilation, transformation and exploitation of knowledge when multiple stakeholders are engaging in commercialisation activities.

It was identified that an open innovation context presents significant challenges for KT where diverse stakeholder groups, each with organisational-specific traditions, experiences and

idiosyncratic practices create specific challenges impacting KT effectiveness (Mitton et al., 2007; Fromhold-Eisebith and Weker, 2013). In particular, the impact of power relationships were found to significantly impact KT, where a dominant stakeholder can exert their power which impinges upon the balance of the quadruple helix and has the potential to affect KT behaviours. A defining feature of an effective quadruple helix is mutual interdependence between all stakeholders (Leydesdorff, 2012; Carayannis et al., 2012) however, it was evident in the case study that the different stakeholders often tried to exert their salience (Frooman, 1999; Miller et al, 2014) creating an imbalance of power. This contest for power had the ability to affected KT willingness, behaviours and effectiveness at all stages. Therefore there is a need to more fully identify and address power relationships in open innovation projects involving diverse stakeholders.

The empirical findings identified that the KTO played a key boundary spanning role in helping mediate relationships between the diverse stakeholders and helping progress KT through the absorptive capacity constructs of knowledge acquisition, assimilation, transformation and exploitation in the context of open innovation and commercialisation. Thus it is suggested that KT between diverse stakeholders demands intermediaries to help eliminate the barriers of KT (Howells, 2006; Mitton et al., 2007) and champion the value of KT.

Furthermore, the case study findings identified that that move from a triple helix to a quadruple helix ecosystem did appear to be beneficial to aid collaborative innovation efforts, with the role of industry and end users being viewed as important in helping progress from potential absorptive capacity to realised absorptive capacity. However, it was identified that the case university was still yet to fully embrace the concept of open innovation due to the overarching priorities of the academic remit of teaching, research and producing high quality publications

which was limiting KT between the university and their constitute stakeholders (Hewitt-Dundas, 2010; Miller et al., 2014). For universities to fully embrace their core role in a quadruple helix ecosystem, more supportive organisational mechanisms facilitating academics to build relationships with industry and end users is needed.

Increased pressure from government for more collaborative open innovation processes between quadruple helix stakeholders (Ahonen and Hämäläinen, 2012; Leydesdorff, 2012), raises questions as to how KT can be effectively managed with an increased number of diverse stakeholders expected to mutually collaborate. Within this study, our model is useful since it helps conceptualises of the multidimensional nature of the process of KT and proposes that absorptive capacity is a meaningful construct to identify the flows of knowledge between diverse stakeholder groups in pursuit of open innovation practices. Within this research, a single case study approached was followed in order to explore the applicability of a priori concepts (Bendassolli, 2013). Single case study approaches do not lend themselves to empirical generalisation across different contexts (Yin, 2012) however, the proposed model and absorptive capacity constructs can be reinterpreted and reconstructed in varying contexts thus facilitating theoretical generalisation (Eisenhardt, 1989). It is suggested that future research should develop the proposed model into testable propositions to be used in other contexts where multiple stakeholders are engaging in KT thus facilitating empirical generalisation and development of the KT field. In addition, future research should also explore mechanisms and platforms which may help balance power relationships in an open innovation context which will help aid KT effectiveness and commercialisation success.

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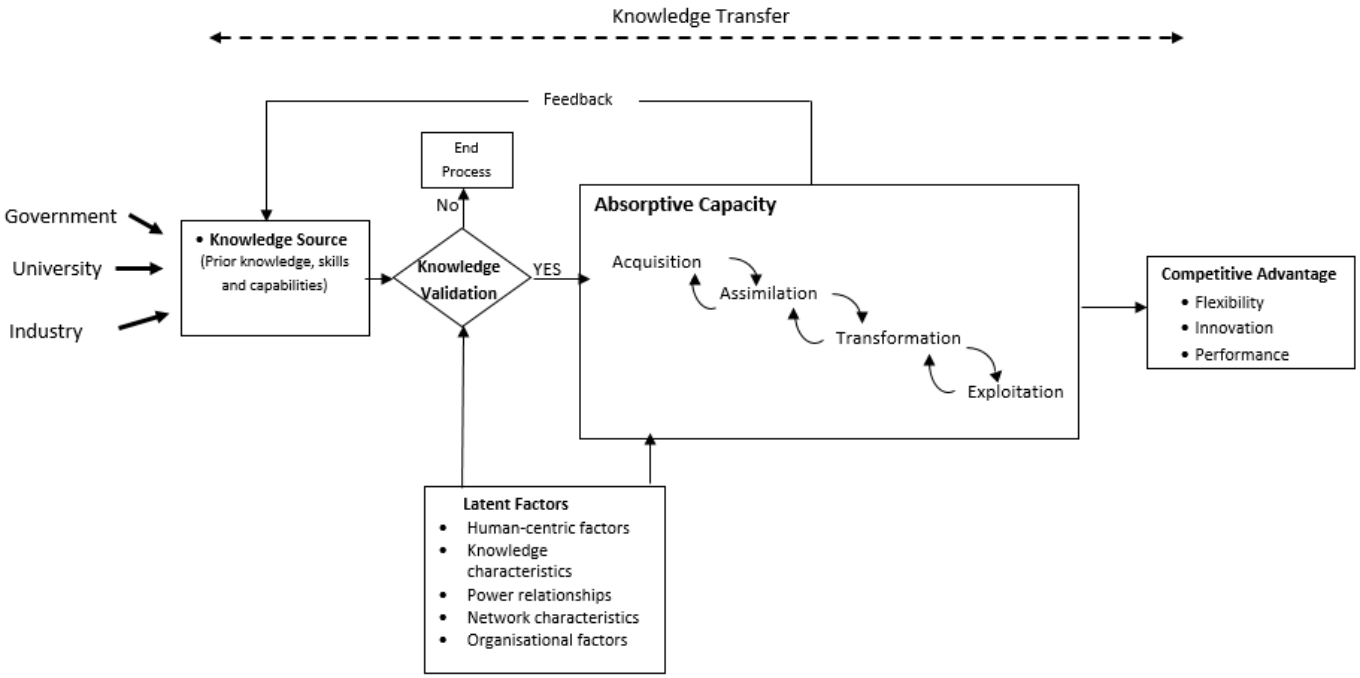

Figure 1: *Ex Ante* Absorptive Capacity based conceptual framework for knowledge transfer from universities

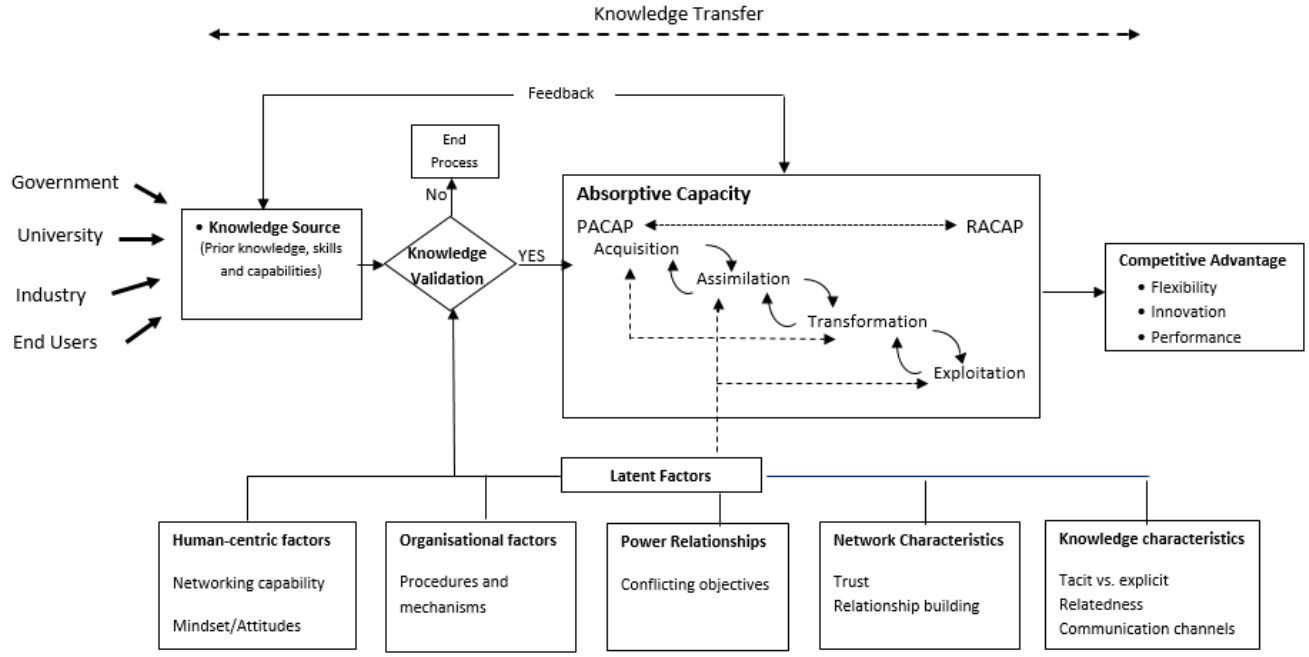

Figure 2: *Ex Post* Absorptive Capacity based conceptual framework for knowledge transfer from universities

Table 1: Enablers and Barriers of Knowledge Transfer

Theme	Sub-Theme/Sub elements	Effect on KT	Findings
Human-Centric Factors	Networking Capability	Positive /Negative	• The ability to network was thought to be essential in aiding KT activities. However with all capabilities, the stakeholders, particularly the academics, varied in their abilities to network. • The unwillingness or ability to engage in networking was found to hinder KT activities.
	Skills and resources	Negative	• Many academics were lacking the skills, and time to network with industry. This meant they often had RACAP but then lacked the skills and resources to commercialise their technologies (hence lacking RACAP).
	Attitudes	Positive/Negative	• Being opportunistic was an enabler of KT. • University remit and organisational context was found to hinder engagement in KT.
Knowledge Characteristics	Knowledge Relatedness	Positive/Negative	• Synergy between knowledge sources is needed where there are sufficient knowledge similarity to aid absorption and internalisation but also a degree of diversity between a knowledge source and recipient to enhance their willingness to engage in knowledge transfer. • Diverse knowledge sources can be difficult to absorb and internalise.
	Type of knowledge	Negative	• The main type of knowledge sought was business related knowledge. This ranged from sales, marketing, finance, legal and experiential business knowledge; which is all inherently tacit and 'sticky' therefore often hard to acquire, transfer and absorb. • Some academics feel they have all the knowledge they need to commercialise a technology and do not need any help – 'not invented here syndrome. • KTO staff members thought that certain academics were not actively networking enough to gain the knowledge needed to help commercialise their technologies.
Power Relationships	University Remit	Negative	• The need to balance teaching, research and KT was a challenge. Academics stressed that it was usually impossible to do all three at the same time due to resource constraints. • There was a feeling amongst some of the Academics that the university doesn't support technology KT enough. • There was more of a push within the university towards teaching and research activities. This perceived lack of support or pressure could potential negatively influence certain Academics from engaging in KT for the purposed of open innovation.
	Incentives	Negative	• Perceived lack of incentives associated with KT negatively influenced both PIs willingness to engage in UTT and also affected their efforts within KT if they had decided to undertake commercialisation activities

	Conflicting Objectives	Negative	• The KTO, academics and Government all appeared to have varying objectives, with each trying to exert their power • While government programmes are beneficial to aiding KT activities the KTO and academics thought they were not flexible enough due to their time constraints of funding rounds • There was a lot of disharmony felt between the academics and the KTO in relation to technology assessments and KTO rules and procedures which de-motivated the academics from future engagement in KTO activities • It was felt that the KTO staff did not have the skills to properly assess technologies, that the KTO process was too slow and that there was not enough incentives to engage with KT activities
Network Characteristics	Role of KTO	Positive/ Negative	• They played the role of a broker and 'boundary spanner' by connecting academics with various networks and knowledge sources both internal and external to the university • However, the perceived value of this role varied with some academics thinking the KTO did not do enough
	Role of Government	Positive/ Negative	• The role government appeared to play was limited with respect to their interactions with the academic entrepreneurs, however with regards funding to enhance KT, their role was very important • However performance measurement were considered to be ambiguous and strict rules for funding mechanism were found to be restrictive; resulting in missed opportunities
	Role of University	Negative	• The case universities procedures, mechanisms and environment was found to potentially de-motivate some academic from engaging in knowledge transfer and collaborative innovation activities
	Relationship building	Positive	• The ability to build strong relationships with quadruple helix stakeholder facilitated knowledge transfer and exchange • Relationship building led to knowledge access • Allowed knowledge to be externally retained in networks (relative capacity)
	Trust	Positive/ Negative	• Trust mediated the willingness of stakeholder to engage in KT. • A lack of trust was found to prevents knowledge openness hence limited stakeholder engagement • Academic rivalry and research pressures resulted in some academics finding it hard to know who to trust within the university
Organisational Factors	Procedures/ Mechanisms	Positive/ Negative	• Dedicated KTO helped bridge KT and communication between quadruple helix stakeholders • University remit and lack of incentives to engage in open innovation and KT impacted upon academic entrepreneur's willingness and ability to engage in KT.

Appendix 1: Profile of Interviewees

Code	Job title
PI1	Academic entrepreneur/ Principal investigator
PI2	Academic entrepreneur/ Principal investigator
PI3	Academic entrepreneur/ Principal investigator
PI4	Academic entrepreneur/ Principal investigator
PI5	Academic entrepreneur/ Principal investigator
PI6	Academic entrepreneur/ Principal investigator
PI7	Academic entrepreneur/ Principal investigator
PI8	Academic entrepreneur/ Principal investigator
PI9	Academic entrepreneur/ Principal investigator
PI10	Academic entrepreneur/ Principal investigator
PI11	Academic entrepreneur/ Principal investigator
PI12	Academic entrepreneur/ Principal investigator
PI13	Academic entrepreneur/ Principal investigator
PI14	Academic entrepreneur/ Principal investigator
EC1	Enterprise co-ordinator
EC2	Enterprise co-ordinator
KTO1	Operational knowledge transfer office staff
KTO2	Operational knowledge transfer office staff
KTO3	Managerial knowledge transfer office staff
KTO4	Strategic knowledge transfer office staff
Gov1	Government knowledge transfer liaison staff
Gov2	Government knowledge transfer liaison staff
Gov3	Government knowledge transfer liaison staff
Gov4	Government knowledge transfer manager