Triple Helix Knowledge Interactions: A study of Institutional, Virtual and On-line Intermediaries

Abstract

Moving from a triple helix perspective, through quadruple and quintuple toward N-Tuple helices, the emphasis placed on the utility of knowledge and the effectiveness of knowledge transfer by the world's leading economies only increases. Similarly, at an organisational level the shift toward knowledge sharing and open innovation reflects this also. Therefore, the importance of understanding the interactions between the respective stakeholders and the specific mechanism and structures being developed to facilitate and manage this activity, is imperative too. This will better enable us to maximise the potential offered to companies, universities and societies from knowledge sharing and exchange and this study focuses on one particular type of organisation operating within this intersection – intermediaries who facilitate knowledge or technology transfer. Firstly we identify a range of structural models that stakeholders from around the world have adopted to build their knowledge and technology transfer offerings. These range across institutional: through faculty-based; arms-length; peripheral; regional-virtual and virtual-online. The article discusses the relative merits of each structure before focussing in on one new and emergent mode – the virtual online platform. We then explore different on-line platforms before deriving a simple typology that begins to characterise their respective service offerings and major differentiating characteristics. Finally, the article showcases five specific offering, representing the respective typologies, before discussing their relative strengths and weaknesses and their fit with the wider structural offerings, presented in the earlier sections of the paper. The article makes a number of contributions. By identifying the respective structural configurations of intermediaries, researchers may compare and contrast each format and University senior managers can likewise consider the respective options before they select and launch their own knowledge or technology transfer office. Also by exploring and comparing the virtual online platforms, actors in the triple helix can understand how this new type of intermediation fits within the existing typologies.

1.0 Introduction

Knowledge is considered as an essential component of any world-leading economy's resource-base, where creation, application and exploitation of new knowledge can lead to sustained competitive advantage. These go beyond the economic rents offered by the extraction of mineral resources or the price-based advantage levered by low-cost labour (Drucker, 1993). This is not a new concept, but as the pressures of globalisation increase, the imperative to ensure societies are able to create, transfer, adopt and utilise the knowledge created in our universities increases accordingly (Miller et al., 2014). The fundamental problem of knowledge transfer however doesn't change: knowledge is complex; is hard to package; is often intrinsically linked to the knower and thus, is 'sticky', with the characteristics of adoption 'slippery' (Markusen, 1994). However, knowledge is important and cannot be overlooked and to this end, economies have invested considerable funds in trying to develop national systems of innovation or so called, knowledge-ecosystems (concieved by OECD, 1997 and reinforced in, OECD, 2011).

Since the late 1990s, evolutionary models of knowledge transfer (KT) have been explored, with various societal level models for knowledge transfer being presented (Etzkowitz and Leydesdorff, 2000, Stevens and Bagby, 2001 etc. etc.), the most enduring of which is the 'triple helix' model of university-government-industry presented by Etzkowitz (2002) and subsequently developed by Carayannis and Campbell (2009) and latterly Leydesdorf (Leydesdorff, 2012). If we consider the direction of movement from the triple helix, to the quadruple, quintuple etc. etc. the challenge is obvious – with each revision of the model brings forward a more granular description of society and thus, focuses more on the different end-users of the knowledge, whether this be society as a whole, consumers or specific pockets of society, such as the creative industries (Colapinto & Porlezza, 2012). Contrasting this with the direction of travel in innovation research, where the move toward open innovation and collaborative models is evident, the alignment between triple helix progression and open innovation is clear – the unconstrained and open sharing of knowledge between collaborating partners is seen as the 'holy grail' by both disciplines (Chesbrough,

2003). With the research in these two fields aligned, what must be explored is the barriers that inhibit; the modes of engagement that foster; and the structures that operationalise knowledge transfer at a national, regional and organisational level (From Agrawal, 2001 to, Galán-Muros and Plewa, 2016).

This paper aims to explore the interactions within the classical triple helix, particularly, university-industry links and focuses in on the structural characteristics and relative services offered by intermediaries, all of whom have one common aim - to facilitate the transfer of knowledge between the three helices for the benefit of all stakeholders. Thus, our study was motivated by one underpinning research questions:

For knowledge transfer intermediaries (KTIs), what types exist, how are they structured, what are their functions and how are they evolving?

The study makes two distinct contributions. The first is in presenting a better understanding of the respective organisational structures that intermediaries from around the world have developed, to manage the activity of knowledge transfer. This is achieved by comparing a range of simplistic structural models discovered during a small-scale, short-duration survey undertaken in 2012-2013. The second contribution is to explore the most recent addition to these structural models – virtual, on-line platforms for knowledge transfer. Again, this is done by comparing respective models from around the world during surveys undertaken in 2015/6, before deriving a simple typology. To further illustrate the relative differences for each typology, short descriptions, collected during semi-structured interviews with the founders or representatives of one of each type of online platform, are presented in this paper.

The remainder of the paper is therefore structured thus: initially we explore the relevant literature that frames the problems faced by knowledge transfer intermediaries, before focussing on the literature relating to virtual platforms. Secondly, we present the respective methodology used to identify and collect results in our studies, before presenting the results and discussing their relative differentiators and respective merits. We close the paper with conclusions, reflections and suggestions for further work.

2.0 Literature

The Triple-Helix model developed in the mid-1990s by Etzkowitz and Leydesdorff (1995) has since undergone an evolution and split itself into two lines of research: Carayannis and Campbell (2009) turned to Quadruple Helix for innovation ecosystem creation, whereas Etzkowitz continued to work on original Triple Helix introducing the Triple Helix Systems of Innovation (Ranga and Etzkowitz, 2013) as an analytical framework that merges the key features of Triple Helix and innovation system view, bringing in the systems theory as a set of components, relationships and functions. One of the five relationship types between components is knowledge transfer one (Ranga and Etzkowitz, 2013). At the same time, an institutional perspective of Triple Helix research sees universities as the increasingly prominent innovation actor (Etzkowitz et al., 2005), carrying out so called 'third mission' (Etzkowitz et al., 2000) of transferring academic research results and technology to the industry.

General Trends in Knowledge Transfer Research

Knowledge transfer has been explored for from various perspectives, (from Agrawal, 2001, to Galán-Muros and Plewa, 2016); with many of these studies adopting a macro or policy level of abstraction (e.g. Carayannis and Campbell, 2009, Bozeman et al., 2013). The general theme within the policy literature is that across the world there is polarised performance in knowledge transfer, with certain regions and nations significantly outperforming others (Howard, 2005, D'Este and Neely, 2007, Holi et al., 2008, Bedward et al., 2003, Lowe and Quick, 2005). To try to examine this relative underperformance recent studies have begun to explore the meso-level, including the triple helix and innovation systems in particular countries (Etzkowitz et al., 2005, Smith and Leydesdorff, 2014) and micro-level factors (Perkmann et al., 2013, Alexander et al., 2015) such as academic motivations and the competencies and skills of knowledge transfer managers (Cranefield and Yoong, 2007, Lockett et al., 2008, Alexander and Martin, 2013).

A small number of 'meso- level' studies also suggest that there are other reasons contributing to this problem, that dervive from internal organisational tensions

existing between the different demands placed on KTOs, subject faculties and on individual academics (Sharifi and Liu, 2010, Syed-Ikhsan and Rowland, 2004).

From this literature a common reoccurring theme, also reported in the policy literature, relates to the perceived bureaucracy and inflexibility of university processes and their administrators (PACEC, 2009, PACEC, 2012). Whilst it not surprising that organisations as large and as complex as universities will have management systems and organisational processes that are complex, this is potentially amplified by their historical reliance on public funding. A number of studies, focusssed at a 'macro-level' (eg Oliver, 1991; Lee, 1998; Pache and Santos 2010; McAdam et al., 2012; Bozeman, 2013) identify that a major contributor to the problem of percieved burocracy and inflexibility results from the plethora of internal and external stakeholders, each with an interest in the growth of knowledge transfer, but in turn with a range of different expectations.

One potential solution to the macro, meso and micro-level problems is for a specific department or service to take responsibility for the process of knowledge transfer, but with this comes other problems.

Pervasive Problems in Knowledge Transfer: why intermediaries are needed?

Firstly, knowledge itself is complex. It is, by its very nature, difficult to comprehend, viewed by many as intrinsically embedded in the "knower" and as such cannot be "commoditised" or "traded" as part of a transaction between two parties. One solution to this problem is to utilise personnel rotation (Kane et al., 2005), thus moving people and therefore moving knowledge. Personnel rotation however, in certain academic institutions is fraught with its own difficulties (Kimble et al., 2010) and thus the Cartesian split is generally overlooked and knowledge is believed to be largely transferrable.

Secondly, one important aspect of knowledge transfer that must not be overlooked is the requirement for reciprocity. Knowledge does not merely 'flow' from a university to a company. It is a messy process or iterative action and as a minimum there is a feedback or reciprocal loop which enables important aspects

of diffusion and adoption to be understood by the knowledge creators. This then inform their revision and iteration of the offerings to ensure future outcomes are realised by the end-users (Alexander and Childe, 2012).

Thirdly, knowledge transfer involves multiple internal and external stakeholders. In terms of the respective motivations of the external project partners, universities are more oriented to searching for new ideas and fundamental knowledge, while companies are more profit and practice-oriented (Prigge, 2005). That is in part, why a collaboration between academia and business can be difficult to establish and manage. This is illustrated by different business languages the parties speak, and also the time horizons for knowledge creation, transfer and adoption. The company needs a fast tempo to ensure they make money, whist the university's own intrinsic tempo is often regulated by other institutional departments (Bedward et al., 2003) and day-to-day practices (Plewa et al., 2005, Muscio and Pozzali, 2013, Barnes et al., 2002).

From an institutional stakeholder perspective, there are also multiple actors (for example a university might mobilise their IP management specialists, their insurers, their contracts team etc.; a company - its lawyers, accountants or consultants etc.), which in turn spans various intra-organisational boundaries.

Additionally, a lack of resources on both sides inhibits university-industry knowledge transfer (Hughes, 2010), but also hinders the actual search for partners and awareness of collaboration opportunities (Muscio and Pozzali, 2013) forming a 'connection' barrier in the knowledge transfer process (Galán-Muros and Plewa, 2016). Browsing through other organizations' websites to find a likely partner isn't an efficient strategy and that is why tools, which help guide the search or build a connection could be highly valuable in solving the connection problem.

Thus, an intermediary able to speak both business and academia languages and capable of smoothing the differences between the two worlds is often required to make collaboration happen (Cranefield and Yoong, 2007). These intermediaries

must also be able to manage the process of transfer of knowledge from university to industry and vice-versa; they must be aware of the various definitions and attributes of knowledge; be able to respond to this multi-level, multi-actor complexity and undertake all this in a timely manner. Therefore, with such a varied role to play there are various types of knowledge transfer intermediaries operating.

Types of intermediaries in Knowledge Transfer

Considering the wider phenomenon of intermediation, the research is divided from different perspectives and using different units of analysis. A number of studies focus on analysing and classifying innovation intermediaries (Howells, 2006, Lopez-Vega and Vanhaverbeke, 2009, Hossain, 2012) from an innovation and non-sector specific perspective, whilst other are sector specific and focus directly on university to industry knowledge transfer (Seigel et al., 2003, Alexander and Martin, 2013, Sharifi and Liu, 2010, Yusuf, 2008, Galbraith and McAdam, 2013). Again at a macro-level knowledge transfer intermediaries are evident in the literature from the National Innovation Systems, Triple Helix concepts, institutional disciplines and also network theories (Watkins et al., 2015, Dalziel, 2010, Klerkx and Leeuwis, 2008, Westergren and Holmström, 2012, Levén et al., 2014).

In terms of categorising these university intermediary organisations, Wright et al (2008) divide them into two groups: internal intermediaries (as university knowledge and technology transfer offices) and external intermediate organizations (as Collective Research Centres, regional development agencies, etc.). Lopez-Vega & Vanhaverbeke (2009), looking at innovation intermediaries (but not specifically in the university context), define four archetypes of innovation intermediaries by their value proposition: innovation consultants, innovation traders, innovation incubators and innovation mediators. Howells (2006), again looking at general inter-organizational mediators, analyse intermediaries from the perspective of the functions they perform. They define ten functions: foresight and diagnostics, scanning and information processing, knowledge processing and combination/recombination, gatekeeping and brokering, testing and

validation, accreditation, validation and regulation, protecting the results, commercialisation and evaluation of outcomes.

One particular stream of the literature on open innovation and crowdsourcing platforms (Frey et al., 2011, Marjanovic et al., 2012) creates a foundation for the emerging topic on university-industry collaborative online platforms (Søndergaard et al., 2015). To begin to synthesis a common view of intermediaries we have partly integrated and adopted university definitions in Table 1 and explain their differences below, within the university knowledge transfer context.

Table 1 - A summary of innovation intermediaries for the context of university-industry knowledge transfer

Internal vs External for university (Wright et al., 2008)	*Intermediaries by value proposition (Lopez-Vega &* Vanhaverbeke, 2009)	*Intermediaries by functions (Howells, 2006), (Lopez-Vega &* Vanhaverbeke, 2009)
Internal (External) university-industry KTIs	Innovation mediators	Creates spaces for knowledge processing, generation and combination; intermediaries between science policy and industry; demand articulation; testing and validation
	Innovation incubators	Knowledge processing and combination/recombination, Testing and validation, training, evaluation of outcomes
External (Internal) university-industry KTIs	Innovation consultants	Scanning and information processing, Protecting the results, Commercialisation, foresight and diagnostics
	Innovation traders	Gatekeeping and brokering; scanning and information processing, foresight and diagnostics, Commercialisation

Innovation mediators, manage a collaborative environment and could be either internal (such as university-based Living Labs) or external - independent external organizations (as publically funded Labs) or corporate initiatives targeting particular company' interests in collaboration (for example, Connect and Develop by P&G (Huston & Sakkab, 2006)). However, they can all be combined

in one group, defined by their main function – providing an environment (physical or digital) for collaboration between companies, universities and government.

Innovation incubators could be also university-based (as start-up or business acceleration programmes launched by university), independent public/private initiatives (for example FinTech Innovation Labs) or corporate innovation incubators (for example the Samsung Accelerator), but again, they share the main functions – transforming knowledge into innovation utilizing the expertise of academia and business. At the same time, independent (external) companies normally represent ***innovation consultants*** assisting corporates in detecting technological and innovation opportunities, technological foresight, advising on technology acquisition. Finally, ***innovation traders*** (such as NineSigma, InnoCentive, etc.) represent purely external intermediaries for university-industry knowledge transfer, which play the role of gatekeepers and brokers in between challenge holders (companies) and solution providers (universities).

Despite the fact that the literature examines many aspects of mediation in cooperation of universities and business, the theory is very fragmented and is lagging behind the practical development of knowledge transfer intermediaries (especially the emerging online ones) in university-industry relationships (Søndergaard et al., 2015). Our aim therefore is to explore and try to make sense of both the structural and virtual intermediaries within the knowledge transfer environment.

3.0 Methodology

To explore the research aim there were two distinct phases of data collection. The first occurred in 2012/13 and focussed on the structural dimensions, the second in 2015/16 and focussed on online platforms.

Phase 1 – Physical Structural Dimensions

This phase of data collection utilises supplementary data gained during a snap-shot survey of knowledge transfer organisations in 2013 and data collected

during a longitudinal survey of two particular knowledge transfer offices between 2012 and 2013. The original focus of the snap-shot survey was to explore new and innovative mechanisms, offered by universities that focussed directly on open innovation. Thus 18 institutions were identified who advertise their open innovation schemes, with 12 responding to our research questionnaire. The questionnaire combined structured, closed questions and also open-ended exploratory questions. The respondent institutions are represented in table 2. Two of these institutions were also taking part in another, longitudinal survey, comparing their wider knowledge transfer offerings. Whilst the results of these surveys are published elsewhere (reference withheld for peer review), careful analysis of the results highlighted that not only were these institutions offering a range of services, but they were also employing a range of structures to enable this. It is these structural variations that we present as examples in the first part of this paper.

Table 2 – The comparators institutions providing structural examples for Phase 1

REFERENCE		**AUS 1**	**UK 1**	**AUS 2**	**UK 2**	**NZ 1**
Country		Australia	England	Australia	Scotland	NZ
World QS League Table (2011/12)*		26	30	49	59	82
Institution Size (XL/L/M/S)*		Large	Large	X Large	Large	Large
Age (H/M/E/Y/N)*		Mature	Historic	Mature	Historic	Historic
Research Intensity (VH/HI/MD/LO)*		Very high	Very High	Very high	Very High	Very High
NOR 1	**UK 3**	**UK 4**	**AUS 3**	**FR 1**	**GER1**	**GER2**
Norway	England	England	Australia	France	Germany	Germany
121	168	207	400+	400+	400+	400+
Medium	Large	Large	Large	Large	Medium	Large
Young	Established	Mature	Established	Historic	Historic	Mature
Very High	Very High	High	High	Very High	Medium	Medium

* The QS University League Tables – accessed@ www.topuniversities.com/university-rankings/world-university-rankings in June 2012

Phase 2 – Virtual Online Platforms

Having identified that one emergent structural configuration was virtual online platforms the second phase of the data collection process focussed on virtual platforms and was undertaken during 2015/16.

Firstly, we analysed 15[*] online platforms in total, by collecting secondary data by searching webpages and public documents to establish their aims, target audience, requisite functionality and service offerings. Based on this preliminary analysis, five distinct types of intermediary online platforms were identified, namely: education-focussed platforms; platforms for knowledge or technology (via IP sales etc.); crowdsourcing platforms; networking platforms and innovation marketing platforms (see Table 3). Primary data was then collected for one example of each type of platform using semi-structured interviews following a proforma, with each interview respondent selected as their role of Chief Executive or Director of the company owning the platform. This data was then augmented, where possible, with interviews with a small number of their users.

Finally, targeted supplementary data was collected, which included additional secondary data (press releases, web-sites and platform users' public feedback). In total, seven interviews were conducted in February-April 2016. The duration of the interviews varied from 30 minutes to 70 minutes. Interviews were conducted via Skype or in person. The interviews were recorded. The interview guide consisted of 10-15 open-ended questions, tailored to the specific focus of each platform and/or respondent, which in turn was informed by the secondary data.

Finally, in order to test the interpretation of the results we applied a member check technique. We asked our interviewees to read and comment our results and we revised the paper in accordance with their comments.

[*] It is important to note that a large number of open innovation online platforms exist at present (e.g. InnoCentive, Yet2.com, NineSigma). However, we have limited the scope of our research only to those online platforms, which explicitly target knowledge transfer between universities and businesses.

Table 3 - Five types of online knowledge transfer intermediaries.

Platform type	*Platform Functions*	*Platform examples*
1. Education-focused platforms	Enabling project-based learning and students working on the real company problems	www.edusourced.com www.coursera.org
2. Knowledge, technology and IP transfer focused	Enabling easier search for required knowledge, technology or IPR	www.in-part.com www.easyaccessip.com www.praxisunico.org.uk www.globalipexchange.co.uk
3. Crowdsourcing platforms	Collection and assessment of ideas and solutions for companies from students and university researchers	www.challengeacademy.eu www.nimblebee.eu www.marblar.com
4. Network building platforms	Mapping a network of valuable actors, enabling easy search for capabilities, competences and individuals, connecting individuals with complimentary assets	www.uiin.org www.bridgelight.co.uk www.uidp.org www.connect.innovateuk.org www.konfer.online
5. Innovation marketing platforms	Disseminating information about university innovation, provision of statistics analysis (clicks, downloads)	www.leadingedgeonly.com a number of open science platforms (e.g. www.sciworthy.com)

4.0 Results

Our research identified a number of intermediary architectures that have been used to structure and to manage the activity of knowledge transfer.

These include universities who manage their respective knowledge transfer activity within faculty-based, discipline-specific offices; or universities that centralise this activity, creating institutional knowledge transfer offices which serve all, or the majority of the faculties accordingly. Another group of universities choose to provide a ‘special purpose vehicle’ or subsidiary company operating at ‘arms-length’ and acting as a conduit for knowledge and intellectual property.

Furthermore, other universities choose to create virtual entities, where the sharing of resources and intellectual property happens across a number of universities. Finally, there were a small number of universities that choose to 'contract-out' their knowledge transfer and applied research to entirely separate legal entities, some operating under complex framework agreements to enable for royalty and income redistribution, or others who offer a range of services across their online platforms. Within these, there are virtual platforms who utilise online presences to manage the transfer of knowledge.

4.1 Knowledge transfer intermediaries located within their institutions

Of the twelve knowledge transfer offices reviewed, four had adopted the models shown in figure 1. They had not chosen to separate their respective knowledge transfer intermediary from their main institution. Staff employed in the knowledge transfer office were the institution's own staff and their overarching management and leadership was provided by the senior administrative manager (e.g. the Registrar, Chief Operating Officer etc.).

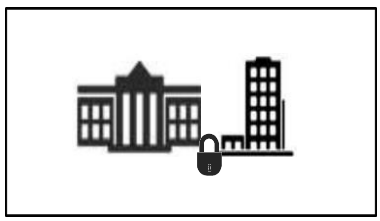

Figure 1 University with an internal department as a Knowledge Transfer Intermediary.

All financial resources were taken from central institutional funds and any IP ownership, income and royalty earnings was owned by the institution.

4.2 Knowledge transfer intermediaries located within arms-length institutions

Of the knowledge transfer intermediaries reviewed four had adopted the models shown in figure 2. Each institution had established a special purpose legal entity, which was a wholly-owned subsidiary of the university.

They each had given this entity differing degrees of operational remit and autonomy as part of its memorandums and articles. The subsidiaries were controlled by a board of directors, often consisting of a number of senior

administrative officers from the parent institution. In addition, some had membership from senior institutional academics, others with membership drawn from the local industrial community.

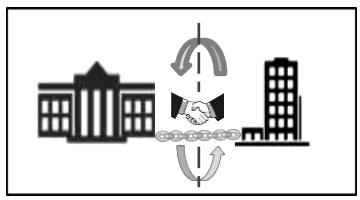

Figure 2 University with an arms-length subsidiary as a Knowledge Transfer Intermediary.

In terms of staff employment there was a mix of secondees from the parent institution or directly employed staff, likewise there was a mix of parent-services utilised in each (For example – one had its own legal officer, whilst others used the parents legal office, one had its own accountant whilst others used their parent accounting facilities etc.). In terms of ownership of Intellectual Property each subsidiary acted on behalf of the patent and therefore did not own any IP that they traded or shared. Funding was provided by the host institution under a range of transfer pricing agreements.

4.3 Knowledge transfer intermediaries based outside of their institutions

Two knowledge transfer organisations stood out as different, both from Germany. These knowledge transfer organisations where legal entities in their own right and were only linked to institutions through regional economic policy and thus, had memorandums and articles linking them, by agreement, to their local host university.

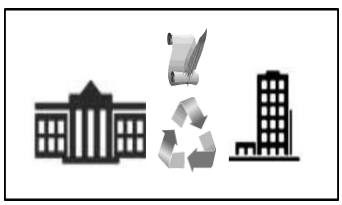

Figure 3 University with a separate Knowledge Transfer Intermediary.

Staff employed in the knowledge transfer intermediary organisations were directly employed, and the KTIs employed senior academic staff from the host universities directly through proportional contracts. In terms of intellectual property ownership, much of the university intellectual property was licensed for resale to the KTI, but significant amounts of IP were created directly by the

knowledge transfer organisations themselves – either through development of institutional IP under license or by undertaking contract research and consultancy on behalf of the host institution. Contracts also existed to locate Post Graduate Research students and programmes of Industrial Doctorates directly under the supervision of the knowledge transfer intermediary.

4.4 Knowledge transfer intermediaries operating on a virtual platform

One particular example arising from France (FR1) also offered a different perspective to models explained previously. Figure 4 represents a regional knowledge transfer approach. Each institution in a geographic region signed up to an agreement to create joint ventures that in turn receive financial support and seconded staff from each institution to create a vehicle for knowledge transfer. Each virtual organisation has a specialist sectoral focus – for example agriculture, marine, high-technology, automobile and these organisation mirror the regional focus for science parks, incubation facilities and business support. Intellectual Property is retained by the originator and knowledge creation is not undertaken within the organisations themselves.

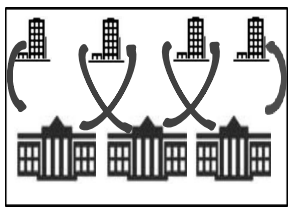

Figure 4 Regional universities creating virtual discipline-specific Knowledge Transfer Intermediaries.

Finally, one interesting structural configuration from Australia (AUZ2) was the provision of collaboration opportunities via a virtual online platform. The institution has linked with a range of other academic institutions (as above) but instead of developing a physical space where their academics could collaborate and develop new ideas with commercial partner, they had created a virtual, online presence. This mode of the intermediary could be named as a transitional model compared to our mode 5 – fully independent online knowledge transfer intermediaries.

4.5 Knowledge transfer intermediaries operating as independent online platforms

Whilst the Australian example was relatively unique, since the original survey was carried out in 2012/13 there have been a range of online platforms developed to operate in the knowledge transfer space. Based on the analysis of the secondary data devoted to web-based platforms serving university-industry relationships in 2015/6, we identified five archetypes of online knowledge transfer intermediaries. Overall, the virtual online platforms structure wise represent the fifth mode of Knowledge Transfer Intermediary – completely independent, mainly commercial organizations aiming at bridging universities and companies by supplying both sides with information and services for partner search (see Figure 5). Here below we take a closer look at each subtype of the online intermediary through the prism of one particular platform analysed in-depth.

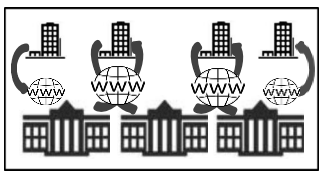

Figure 5 MODE 5 – Universities worldwide utilising services of online knowledge transfer services (platforms)

Education-based platforms are those online intermediaries, which enable students to 'learn by doing' – running a project for a company (as EduSourced) or taking a course designed by company (as those offered by Coursera). The USA-based EduSourced platform analysed by us in detail provides a digital space allowing centralised and efficient management and monitoring of company-student collaborative projects. In addition to actual involvement into project-based learning, by using the platform students become familiar with project management tools. The projects are funded by a company and run by a team of students, often with faculty oversight, in collaboration with a company manager. According to the interview with the EduSourced CEO, there are cases, when after working for the company the students were hired by the client organisation. The main benefits of EduSourced for companies are an easy access to low-cost skilled students (potential employees) and digital tools with corporate-friendly interface, which enable the management of difficult projects in a fast moving environment. According to EduSourced CEO, the demand and

interest in EduSourced is growing and the current team ambition is to expand its presence globally.

Online platforms that aim to **transfer knowledge from universities to companies** exist in many forms. These ranged from the transfer of very tangible assets (as patents and licensing – i.e. easyaccessip.com or globalipexchange.co.uk) to a larger number of forms of knowledge sharing through establishing connection (e.g. In-part.com). The UK-based IN-PART analysed by us in-depth particularly introduces university technology and/or opportunities for collaboration to a curated network of users from industry. Opportunities range from very early-stage research with potential commercial application, to ready-to-licence technologies. Their approach is exclusively to company executives, with the goal of connecting them to the university to further discus an opportunity. If the company is not interested, IN-PART collects qualitative market feedback on the technology or solution, and shares this with the respective university TTO. This is also reported within regular Impact Reports, which also contain quantitative user interest metrics, and helps universities to better understand the commercial value of their solutions, and at the same time get a better picture of current industry needs. If a company is interested in the university opportunity, IN-PART personally introduces parties directly. For companies, the platform helps in reducing resources used to scout for new university technology or commercial research ideas, as they no longer need to browse individual university websites; instead receiving opportunities tailored to their interests via email. When one of the platform users, a university representative, was asked to describe an ideal online platform, they admitted that university-industry relationships are all about people. The actual connection often happens offline, because it could be challenging to understand online if the parties are able to collaborate or not. However, the IN-PART tool provides an initial point of contact.

The platforms generally applying **crowdsourcing principles** collect ideas or problem solutions from any individual or any team globally, while the crowdsourcing platforms for university-industry collaboration aim specifically at sourcing ideas from students and university researchers to solve business

challenges (e.g. nimblebee.eu or marblar.com) or also to jointly solve scientific challenges (e.g. challengeacademy.eu). The Belgium-based NimbleBee is a crowdsourcing platform, where the main concept is to engage students to solve industry challenges. These industry-led projects are undertaken within their university programme (as part of the curriculum) and take the form of a competition, where the best results are validated by the end-user. According to the NimbleBee programme manager, when comparing the quality of the outputs across other crowdsourcing initiatives open to the public, NimbleBee scores higher in terms of client satisfaction and quality, which is largely thanks to its embeddedness into university curriculum. From a few month programme and for a relatively small fee the companies (sponsors) get a new design-concepts validated by end-users for relatively low costs and they also get access to jointly trained and developed potential employees (talents). The whole process happens via the closed and secure web-based platform. This keeps the development process protected from competitors and efficient, since it avoids the costs of all the actors (university teachers, students, corporates and end-users) travelling to meet each other, as has been the case in previous, similar projects. The universities in turn get a free access to real industrial challenges, receive direct inputs from industry in the curriculum development and get their students trained with real industrial experience and monetary reward.

Network building platforms source social capital across a network and play a vitally important role in establishing valuable collaborations. Acknowledging this, a number of tools have appeared, and, in addition to the commonly used social media platforms such as Facebook, Twitter and LinkedIn that are applicable for any kind of collaboration, the platforms specifically designed to bridge experts from academia and business have been developed. Among those are University-Industry Interaction Network (UIIN.org), which in addition to online social network features provides both companies and university representative a chance to meet in person annually at the conference and discuss collaboration related issues. Another connector is the University-Industry Demonstration Partnership organization, which uses its website (UIDP.org) and the dedicated community on LinkedIn to build a network of academics and practitioners and assist in facilitating their collaboration on the project-level (UIDP, 2016). Another rapidly

developing online tool for building a network is a UK-based start-up Bridgelight. This platform builds a map of the actors with complementary assets (knowledge, technology, expertise) and common interests, based on the analytical algorithm that aggregates and examines all of the data available online, combining it with additional, specific data provided by participating organizations themselves. The platform's main function is to dynamically interrogate the network map, refocussing it around keywords that could represent challenges, or funding calls or any other common opportunity for collaboration. Unlike manual projects to map and analyse a capability network (typically costing organisations £50k-£250k, taking 3-6 months and delivering a static picture), the Bridgelight platform provides a live asset that can grow and maintain itself on an ongoing basis. As the platform analyses a university's skills, competencies and track record (including the UK Government Gateway to Research database), it is able to help companies in searching for university partners and likewise, for universities vice-versa. The Bridgelight map helps to identify the challenges that industry faces, who is working on these challenges and thus makes a partner / collaborator search both easier and more targeted.

Innovation marketing platforms use a number of tools that help to disseminate information about academic research online and make it more accessible and understandable by business – in essence, to make science more open. Friesike et al. (2015) provide a comprehensive overview of the initiatives supporting open science, including online tools, such as Atlas Twiki Portal – an open-access platform that provides access to the results of the CERN lab. Another example is Sciworthy, which delivers easy-to-understand scientific news. A platform specifically dedicated to marketing university research has been developed by the UK-based start-up called Leading Edge Only (LEO). Using the principles of online marketing, LEO provides a space for scientific discoveries to be presented, generates and analyses statistics concerning interest in particular technologies or ideas by tracking clicks and number of kits downloaded. For thirty universities that LEO has on board, it prepares a brief digital profile of the university assets (ready for market prototype, just an idea or even a research methodology), publishes it on the platform and supply the corporates interested in the relevant innovation with these profiles via emails, compensating the lack of

marketing skills among university employees. For companies, LEO provides an access to description of university assets (knowledge, ideas or technologies) formulated in industry-oriented language. LEO also collects the challenges that industry search solutions for and provide universities an access to these challenges, so university researchers can better understand the industry needs and possibly address them in their research.

5.0 Discussion

The research undertaken within this study has identified five different structural configurations for knowledge transfer intermediaries, set against an existing categorisation of only two (internal vs. external cf. Lopez-Vega and Vanhaverbeke, 2009). Whilst we cannot ascertain from the data the primary motivations for establishing these architectures, some offer particular benefits and can overcome some of the problems identified earlier in this paper even though still having some disadvantages (we provide a summary in Table 4).

Bureaucracy and institutional processes

In terms of the criticisms of bureaucracy and institutional process inefficiency, it would seem reasonable to assume that by creating an autonomous (separate KTI) or semi-autonomous (arms-length KTI) organisations there could realise a number of benefits. These could range from being able to set internal procedures and determine resourcing levels such that the tempo of commercial request be better adhered to. By employing specialist staff to address IP and legal aspects of the knowledge transfers then timeliness and efficiency is within the control of the knowledge transfer intermediary. By the very nature of the intermediary being small it presents an inherent level of agility that the intermediaries located within their institutions will struggle to achieve. In turn this effectively reduces the number of internal stakeholders, with the intermediary answering to its board of directors (and in the case of arm's-length to its shareholder/parent), rather than across a range of institutional professional services or faculty-based senior managers for example. The separate KTIs (detailed in mode 3 and virtual and online platforms of mode 4&5) compared to internal KTIs may also establish their own performance mechanisms and can select some that would typically not

reflect the host institutions respective governance. For example these could be timeliness to respond to enquiries, duration of negotiations, lead-time to sale for patents etc. as well as the harder income driven metrics, which will likely be imposed on the internal KTI. This may serve in matching performance measurements valued by each of the three actors of the Triple Helix – a common problem in assessing the performance of the university-industry knowledge transfer (Rossi & Rosli, 2013).

Proximity and resources

However, autonomous or separate KTIs (both, physical and digital) are also likely to have inherent problems too. The first is the relationship with the research institution (university) in terms of start-up funding. Totally independent KTIs (as Modes 3 and 5) are unlikely to be able to raise start-up capital from investors and so will likely require either policy-driven, public funding or a loan or other form of senior lending from their linked institutions (as in mode 3). The second major problem with particularly physical arms-length and separate knowledge transfer intermediaries (modes 2 and 3) is the ability to attract and to retain academic talent to work on ongoing projects. Whilst in the case of the German Institutes (mode 3) this is achieved by appointing senior academic staff on proportional contract, there is a tendency in the arms-length organisations for there to be a barrier perceived between the academic teams and the subsidiary. This is particularly likely in terms of establishing and maintaining knowledge reciprocity (the two-direction flow of knowledge - (Alexander and Childe, 2011)). At an organisational level, the online KTIs of mode 5, which involve students in solving industrial challenges, help universities in developing a more industry-oriented curriculum and improves the image of the university delivering a more substantial amount of industry collaboration and impact achieved. For companies such platforms help in identifying talented potential employees.

In terms of the internal knowledge transfer intermediaries, their proximity to the academics should be an advantage when maintaining knowledge reciprocity, as the knowledge transfer offices are merely a bridge (and not a separate legal entity).

Table 4 Five structural modes of the Knowledge Transfer Intermediaries (KTI): an overview

Structural mode	**Advantages**	**Disadvantages**
1. KTI located within their institutions	1) Proximity to academia: being well and continuously informed on the university needs, interests and strategy 2) Faculty-embedded KTI - being able to align the faculty needs with KT policies	1) Bureaucracy and institutional process inefficiency 2) Bias towards academia interests 3) Lack knowledge and understanding of the industry needs
2. KTI located within arms-length institutions	1) Being able to set some internal procedures – higher level of agility compare to mode 1	1) Low ability to attract and to retain academic talent
3. KTI based outside of their institutions	1) Being able to set all the internal procedures autonomously 2) Being able to set KPIs of the KT independently from the university/research institution	1) Unlikely to raise start-up capital from investors
4. KTI operating on a virtual platform	1) Proximity to academia: being well and continuously informed on the university needs, interests and strategy 2) Flexibility in KT process shifting across disciplines and regions	1) Possible lack of KT management skills among seconded academics
5. KTI operating as an online platform and fully independent organization	1) Operating purely in between universities and industry able to balance between the needs and priorities of both sides 2) Flexibility in KT process shifting across disciplines and countries 3) Saving resources for partner search	1) Unlikely to raise start-up capital from investors 2) Solving 'the connection' problem not always able to push KT further

It could be argued that a faculty setting for the internal knowledge transfer offices may increase this knowledge reciprocity further. However, due to closer proximity to university, there could appear bias towards academia interests as well as a lack knowledge and understanding of the industry needs.

One key potential benefit for the faculty-based and the virtual knowledge transfer intermediaries is the ability to recruit and align staff with the respective specialities of either the region (in terms of the virtual KTIs) or the faculty (for the internal KTIs). In the virtual KTI models specialist staff from the respective institutions are seconded to the virtual KTI, each bringing their own speciality. To some extent, these two discipline-dominant modes also go some way to address the problems with the types of knowledge – for example scientific knowledge vs. social science knowledge(Gertler, 2003). Virtual KTIs can establish themselves to focus on social science activity and can second staff from the host institutions across a region and focus on appropriate mechanisms for knowledge transfer, whilst other groups within the virtual KTI can focus on physical science and utilise the most appropriate mechanisms accordingly (Gittelman and Kogut, 2003). The possible disadvantage in that case could be the lack of knowledge transfer specific management skills and experience, since knowledge transfer activities are normally not the core responsibility of university scientists (Siegel et al., 2003). Virtual KTIs enable collaboration on the knowledge transfer across institutions within a region diminishing the importance of geographical proximity (studied precisely by Laursen et al., 2011 and D'Este et al, 2012). On the other hand, KTIs of mode 5 representing purely "external" intermediary (Wright et al., 2008) have the potential to go beyond regions enabling knowledge transfer across the globe.

In terms of the other benefits offered by mode 5 KTIs, all of our study group focus on the facilitation of university-industry collaboration in a virtual space, which in turn offer resource savings two both universities and industrial partners. It also enables new collaboration matching and network development to be more targeted (Albors et al., 2005). What is noticeable, and constitutes a function not expressly identified by Howells (2008) is that all the mode 5 intermediaries focus on the derivation and solution of problems. Two of the mode 5 platforms utilise this problem focus to create a project-based learning opportunity as a supplementary outcome. This aligns with the idea that a problem-orientated focus is an important tool to galvanise stakeholders with diverse organisational goals and motivations (Krajcik & Blumenfeld, 2006; Hung et al., 2008).

When considered from a policy perspective, all of the KTIs of mode 5 offered a way to disseminate university research results and attempted to help industry to learn and gain value for the businesses concerned, while the provision of industry feedback helps universities to better understand industry problems and the value that university research has for industry (Wilson, 2012). This aligns well with policy drivers and research onto the triple and quadruple helix models of interaction (Etzkowitz, 2002; Carayannis, 2014). However, compared to modes 2-3, mode 5 intermediaries our examples only (except possibly the NimbleBee case) only solve the 'connection problem' (Galán-Muros and Plewa,

2016) and do not enable the actual knowledge exchange to happen via the KTI. At the same time the more physical (modes 2-3) KTIs having both academics and industry representatives on staff which implies face-to-face meetings, networking between the actors and thus, enable the process of attrition to happen and as a result help to soften the sharp corners of differences in day-to-day practices (Plewa et al., 2005, Muscio and Pozzali, 2013, Barnes et al., 2002).

Therefore, our findings suggest that even though digital platforms for university-industry knowledge transfer represent a rapidly growing market breaking down the existing problem of search and connection of the knowledge transfer partners, the need in physical platforms for interpersonal interaction between two actors highly will likely remain. Those will be needed to solve or prevent second-order issues – the lack of partners' attrition, negotiation and continuous knowledge exchange (Perkmann and Walsh, 2008, Matthews and Norgaard, 1984).

6.0 Conclusions

In recent years, considerable attention from researchers and policy makers has focused on improving the knowledge flows back and forth between universities and industry, to create the innovations required to address some of the major challenges facing society today. Examples of these challenges are ageing populations, reduced funds for mass health and social care, scarcity of mineral resources and the ever-increasing demand from the developed world for goods and services that tax these resources. This research contributes to the growing debate on the strategic challenges of university-industry knowledge transfer and offers practical solutions on how to manage this activity by attempting to strategically align multiple stakeholder goals.

We suggest our research provides four core findings. Firstly, our study revealed five modes of organizational structures enabling university-industry knowledge transfer. Systematisation and visualisation of structural differences between various types of knowledge transfer offices allow a better understanding of reasons for functional differences that exist between the five types identified.

Secondly, the detailed analysis of each of the five structural types showed benefits and shortcomings of each type. The up-side of embedded or arm-length KTIs lie in the ability to mobilise the knowledge creators on an ongoing basis, enabling knowledge reciprocity and creating a cycle of knowledge creation and recombination. Access to funding is also a benefit. However, the down-side when KTI are close to their university, means they are a greater distance from their industrial partners – not just geographically but with a greater gap in expectations, speed of action, tempo and a lack of understanding of industry' needs. Arguably independent KTIs having a greater degree of freedom from university administration and should enable easier identification of industry demand for knowledge creation and technology development as well as speed up the IPR creation process. On the other hand, when a KT function is mainly outsourced, there is a risk of loss of reciprocity.

Thirdly, we note that distant, virtual platforms simplify and accelerate the partner search process, but our findings suggest that such KT tools do not yet solve the issue of partners' attrition and alignment of the working processes – all of this requires closer collaboration and direct person-to-person interaction.

Fourthly, we note the emergence of virtual infrastructure for knowledge transfer, aimed at supporting collaboration between the whole triad of university-business-government in the traditional Triple Helix, as well as aiming to increase uptake from society (as users or students) and deliver open innovation, as suggested by innovation eco-systems and the further theories of N-helices. This is contrary to the structural modes 1-4, who lack the ability to engage in anything other than typically dyadic relationships.

What it is not possible to conclude from this research at present, is the most beneficial architecture for knowledge transfer intermediaries. The limited examples considered at this time suggest that it could be a function of a number of constraints, such as access to start-up funding, type of knowledge being transferred or of a number of enablers such as regional policy and regional systems of innovation or even for stakeholder strategic objectives such as the desire for income creation within host institutions, amongst many other things. However, it is hoped that this research will help knowledge transfer staff and university managers visualise and align strategic priorities and challenges of university-industry knowledge transfer and then consider what architecture to adopt accordingly.

The researchers acknowledge many limitations within this research – but would urge the reader to recognise that the work is largely exploratory. There is firstly a lack of data – both in terms of reach and also in range. More longitudinal studies may lead to an understanding of a possible temporal dimension to knowledge transfer architecture. For example, perhaps an internal KTI is a starting point and with success, a degree of autonomy is offered, culminating in a separate organisation structure. Equally instead of a degree of success presenting autonomy, perhaps a degree of failure leads to the reduction of autonomy.

Therefore in terms of future research, a starting point would be to test these respective architectures to see if there are any additional variants in operation and then to identify what models are the most prevalent across different sectors, across different regions or perhaps across different institutional cultures. Also further detailed analysis should be undertaken of the every emerging online and virtual platforms, to ascertain if they are developing new value adding services and addressing the virtual collaboration problems noted earlier.

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