‘Engineered’ University-Industry Collaboration: A social capital perspective

ABSTRACT

While there is an extensive body of knowledge on University-Industry Collaboration (UIC) for technology transfer, two salient gaps remain. First, studies on UIC have predominately focused on situations when the relationship is established based on perceived complementary needs between collaborators. However, research on ‘engineered’ UIC, or when the collaboration has been triggered and coordinated by a third-party, is still scarce. Second, we lack proper understanding into the micro-foundations of technology transfer process using the lens of social capital (SC). This is a necessary inquiry given the prevailing conception of technology transfer as a socio-technical process. We address these two gaps by investigating the idiosyncrasy of SC in five case studies of the Faraday Partnership Initiative, a UK public-sponsored program designed to enhance cross-sector technology transfer. As key contributions, we develop a conceptual framework that explains how social capital facilitates technology transfer in engineered UIC. We also advance the debate on academic engagement and commercialization by elaborating how knowledge produced by academics can be transformed into useable forms of technology by distinguishing between technology translation and transfer. The former emerged as a critical element of the latter.

Keywords

University-industry; partnership; social capital dimensions, technology transfer; technology translation

INTRODUCTION

The number of collaborations between industry and universities (UIC hereafter) has increased dramatically over the last two decades (Mirc et al., 2017), and this trend seems to be accelerating (Scandura, 2016, Villani et al., 2017). One of the main reasons behind this mounting interest is the capacity of UIC to promote the process of technology transfer (Perkmann et al., 2013). Through this process, firms seek to generate, internalize, and commercialize technology (Hemmert et al., 2014), while universities strive to increase the usability of their abstract knowledge (Ankrah and Al-Tabbaa, 2015) and to find new resources for research and training (Bstieler et al., 2015).

Recent research posits that UIC is actually path dependent (Heimeriks and Boschma, 2014, Thune and Gulbrandsen, 2014); the development process and final shape of the collaboration are significantly influenced by initial conditions, suggesting three distinct types: 'embedded', 'emergent', and 'engineered' (Doz et al., 2000, Ring et al., 2005). Embedded describes a situation where collaborators have previous experience and enjoy a high level of trust, yet they do not have mutual dependence or share a common interest (Salerno et al., 2008). Therefore, the rationale of collaboration is based on 'hoped' potential value and assumed reciprocal commitment, rather than concrete collective targets and obligations. Conversely, organizations can formulate emergent relationships when they perceive a need for joining their resources in order to proactively seize an opportunity or reactively respond to a change in the external environment (Ring et al., 2005). Finally, if the collaboration was initiated by an external party, it can be categorized as engineered (Doz et al., 2000). Here, potential collaborators would have some common objectives and overlapping interest to form an alliance, but they are not strong enough to self-initiate the collaboration process. In this case, a triggering entity is necessary to create 'a perception of the need for the collaboration' (Ring et al. 2005, p. 251). A review of the literature shows that most research hitherto has investigated the first two types of UIC (e.g., Roessner, 2000, Siegel et al., 2003a, Bradley et al., 2013, Bozeman et al., 2015), which shows a limitation in our knowledge regarding the third type. In particular, as knowledge transfer is a socio-technical process that demands common ground and social interaction between different actors from collaborating partners (Siegel et al., 2003b, Miller et al., 2016), there is a need to explore the extent to which the intervention of an external body (e.g., public funding institutions that initiates the collaboration) can expedite or obfuscate the effectiveness of the technology transfer process by affecting the coordination and interaction dynamic across individuals who are involved with the collaboration. In this article, we aim to address this gap using the social capital framework.

Social capital can play a key role in technology transfer across organizations (Perkmann et al., 2013), given its reported capacity to enhance inter-organizational relationship performance (Maurer et al., 2011), boost team creativity and co-innovation (Elfenbein and Zenger, 2014) and reduce transaction costs (Roden and Lawson, 2014). However, despite the few studies that looked at social capital in UIC context (e.g., Santoro and Chakrabarti, 2002, Schartinger et al., 2002), research so far has adopted a narrow perspective when examining this concept, thus it has failed to capture the complexity of its dimensions, namely structural, relational and cognitive (Nahapiet and Ghoshal, 1998), and their embedded interconnection. Specifically, efforts have been made to study these dimensions as distinct variables. For instance, researchers have investigated the role of relational dimension (for example using trust) on innovation and knowledge creation (e.g., Carayannis et al., 2000, Thune, 2007), but without considering the effect of the other two facets. Also, Murray (2004) relied merely on the structural dimension (in terms of connections networks between firms and academic scientists) to explore the value of social capital in the case of collaboration between scientists and firms. Similarly, Datta and Saad (2008) focused primarily on the structural dimension, employing social networks to investigate the use of social capital as a resource that firms can exploit when searching for prospective partners. We acknowledge, though, that a stream of research has emerged which examines the factors that influence the various aspects of social capital dimensions within UIC setting, for instance, trust formation (e.g., Bstieler et al., 2015, Hemmert et al., 2014), proximity and geographical distance (Hong and Su, 2013), and mutual understanding and shared language (Gertner et al., 2011). While these studies provide valuable insight into UIC-based social capital, we know much less about how the interaction between the three dimensions affects technology transfer across universities and industries when the collaboration is elicited externally.

Therefore, we set our main research question as: How does social capital unfold and influence technology transfer process when established in engineered university-industry collaboration? Given the early stage of research on engineered UIC, we sought to answer this question by systematically analyzing data derived from five case studies of partnership that have been part of the Faraday Partnership Initiative. This is a government-sponsored initiative that was designed to enact a novel and fundamental change to the way technology transfer is carried out in the UK between research institutions and industry (Airto, 2001).

Our study makes two main contributions to the UIC-related literature. First, we develop a conceptual framework that explains how social capital affects technology transfer in engineered UIC. In particular, we unpack how social capital dimensions and their mutual interaction, while being influenced by technology translators and shared objectives imposed by the public funding body, support the technology transfer process. Second, we complement and advance the debate on academic engagement and commercialization (Perkmann et al., 2013) by elaborating how knowledge produced by academics can be transformed into useable forms of technology by firms. In this respect, we distinguish between technology translation and transfer where the former emerged as a critical element of the latter.

THEORETICAL BACKGROUND

University-industry collaboration: a review

In general, organizations have two basic options for developing technological know-how: 1) build the technology independently in-house (including the direct acquisition route), or (2) engage in inter-organizational relationship (Kamuriwo et al., 2017). However, as technological development projects are becoming excessively demanding, risky, and multidisciplinary (Ebersberger and Herstad, 2011, Salerno et al., 2008), organizations increasingly rely on the latter option for knowledge complementary and risk sharing purposes (Kamuriwo et al., 2017, Lipparini et al., 2014). Among the different forms of these relationships, the collaboration between university and industry emerged as a potentially powerful alternative for driving innovation and technology advancement by increasing the flow of knowledge across sectors and stimulating industrial R&D investments (Dill, 1995, Thune and Gulbrandsen, 2014). Through collaboration, university and industry collaborators typically exchange tacit knowledge and experience typical reside in their sectors (Fernández-Esquinas et al., 2016), in addition to a wide array of tangible and intangible resources, to attain individual objectives (e.g., technical problem solving, increase scientific productivity measured in quality and quantity of articles, technology commercialization, or generating of abstract knowledge) and common goals (i.e., create economic and social development by addressing societal concerns) (Galan-Muros and Davey, 2017, Al-Tabbaa and Ankrah, 2016).

Accordingly, technology transfer is regarded as a major element in the UIC (Bozeman et al., 2015), which involves numerous activities such as networking, curriculum co-design and delivery, personnel mobility, training, and collaborative R&D (Audretsch et al., 2014, Galan-Muros and Davey, 2017, Perkmann et al., 2013). However, there are other activities which are vital for the effectiveness of the technology transfer as part of the UIC process (Bruneel et al., 2010, Philbin, 2008), and can largely be categorized into two streams: pre-formation and post-formation.

The first stream, pre-formation, comprises activities (and their sub-activities) that are necessary for initiating and establishing the relationship in the first place (Ankrah and Al-Tabbaa, 2015). In principle, three key activities can be realized in this respect: partnership identification, which aims to establish the need and purpose of the collaboration, identify prospective partners (Fontana et al., 2006), and recognize prior individual/institutional relationships from past collaborative experience (Schartinger et al., 2001); partners assessment and selection, seeks to assess objectively the strategic interests of the potential partners, analyze their actual versus professed capabilities, and determine and organize appropriate portfolio of partners (Barnes et al., 2002); and partnership negotiation, which contains several sub-activities including co-defining the partnership's scope (including partnership purpose, mission/vision, and specific common goals/objectives), delineating the organizational structure of the partnership (Skute et al., 2017), determining partnership management and administration systems with clearly allocated responsibilities (Ankrah and Al-Tabbaa, 2015), defining work plan, milestones, and measures/indicators for success (including intellectual property aspects) (Peterson, 1995), and stating interim and/or final deliverables (Galan-Muros and Davey, 2017).

On the other hand, the post-formation stream reflects activities (and their sub-activities) that are necessary for the actual delivery of the collaboration and to ensure smooth execution of its processes (Djokovic and Souitaris, 2008), and accordingly, covers two key activities. First, coordinating, which concerns the sub-activities that address the management and organization aspects of the partnership implementation including project management (Barnes et al., 2002), trust-building and governance mechanisms (Hemmert et al., 2014), progress monitoring approaches, and routines for conflict management (Plewa et al., 2013a). Second, managing collaboration outputs activity involve sub-activities for organizing the utilization of UIC outputs (Gans et al., 2017). In general, UIC outcomes describe deliberate or emerged products, prototypes, services, or other intangible properties that yield from the collaboration, and are typically delivered to individual and institutional stakeholders in both short- and long-terms (Galan-Muros and Davey, 2017). Therefore, the outputs-related sub-activities relate to how co-developed knowledge can be disclosed (e.g., academic publication), licensing and patenting outputs that emerged directly or indirectly from the collaboration process (Plewa et al., 2013b). The sub-activities also involve actions toward the creation of new ventures, in a form of start-up or spin-out, by any of the UIC actors (Perkmann et al., 2013).

While both pre- and post-formation activities provide the foundation for effective UIC, the number and content of these activities depend primarily on the collaboration institutional setting (Scandura, 2016), degree of formality, complexity and expected duration (Bodas Freitas et al., 2013). In turn, this variability brings additional intricacy to the technology transfer process as elaborated next.

Technology transfer as a socio-technical process

As demonstrated in Table 1, technology transfer[1] has been defined differently in the literature, whereby seeking a 'canonical definition' for this term has been described as 'futile' (Bozeman, 2000). Despite this unanimity, all definitions emphasize the notion of technology being transmitted from a provider to a recipient. Typically, what is transferred may take one of different shapes (Larimo and Vissak, 2009), for instance, it can be something tangible such as a new piece of equipment, embodied in a prototype product, a form of knowledge which is codified by a patent license, or a set of design specifications (Mitton et al., 2007). The transfer process would also include the tacit knowledge and experience (i.e., intangible components) stored within the individuals involved in creating and transferring the technology (Muthusamy and White, 2005), because technology and its knowledge base are typically inseparable (Bozeman et al., 2015). However, and despite the progress in this field, many studies show that technology transfer process in a UIC setting is actually complex and fraught with execution-related difficulties and challenges, which can lead to suboptimal output (Miller et al., 2016, Chau et al., 2016, Perkmann et al., 2013). Seeking to unpack the complexity of this process, research has identified some critical factors that influence the effectiveness of technology transfer (Shane et al., 2014), including technology characteristics (e.g., 'articulability' and 'appropriability'); actors' perceived difficulty, compatibility, and observed benefit; technological uncertainty and inexperience (deficit in tacit knowledge to deal with the new technology); business newness (inability to commercialize innovation);

[1] We follow Bozeman's 2000 conceptualization that technology and knowledge are inseparable elements in the transfer process, therefore in this study we regard technology transfer and knowledge transfer as interchangeable.

and high upfront cost of the technology (Yang et al., 2015, Bruneel et al., 2010, Fernández-Esquinas et al., 2016).

Insert Table 1 about here

However, an examination of the definitions in Table 1 indicates that technology transfer is actually a socio-technical process (Inkpen and Tsang, 2005, Frank et al., 2015, Siegel et al., 2003a). That is, effective transfer demands careful and intense interaction between the technical (i.e., technology) and social (i.e., actors) dimensions within the organizations involved. At least three reasons can justify this argument. The first is that the intention of organizations and individuals to exchange technology is found to be essential for the success of the process (Easterby-Smith et al., 2008).

Here, the intention goes beyond formal contract and agreement that regulate the transfer process.

It involves also the desire of scientists and engineers from both parties to interact and exchange expertise and technical capabilities with each other in the absence of a contract, which constitutes an informal channel for exchanging technology and its related knowledge (Azagra-Caro et al., 2017). The second is that research shows that technology transfer is not typically a linear process (Bradley et al., 2013), rather it is a reciprocal exchange practice between the process actors (Tagliaventi and Mattarelli, 2006). In other words, effective technology transfer demands constant interchange of tacit knowledge (that would underpin technology development) between research users and research producers (Mitton et al., 2007). The third is that one of the key challenges in transferring technology is the discrepancies between the donors (the source) and the recipients' organizations (Buratti and Penco, 2001). The differences in long-term objectives, working approaches, and organizational norms can seriously affect the ability to transform and exploit external knowledge as actors across organizational boundaries would struggle to find a common ground to interpret and internalize the external technology (Miller et al., 2016). In fact, the difficulty of establishing and managing effective technology transfer is even more challenging when the process takes place within organizations which belong to different sectors (e.g., public-business, university-business), due to the cognitive and social barriers which are typically rooted in their institutional and cultural asymmetries (Perkmann et al., 2013, Miller et al., 2016). Altogether, these reasons imply that technology transfer is a complex social process (Mitton et al., 2007) that requests careful consideration of human actors involved (Comacchio et al., 2012, Edler et al., 2011).

Drawing on the previous review, the value of studying the micro-foundations (i.e., at individual interaction level) of the technology transfer process became essential. In particular, the above issues show that a great deal of the transfer complexity is actually embedded within individuals and their dyadic interactions. As such, the effectiveness of a collaboration for R&D (between university and firms) can be dependent on the level of interaction between the various actors representing each organization (Siegel et al., 2003a). However, the relationship between technology transfer effectiveness and interaction is not linear, as research shows that in some situations this can take an inverted U-shaped relationship: having more interaction does not always contribute positively to the overall effectiveness of technology transfer (Jiao et al., 2016). As such, studying the factors that determine the shape and magnitude of interaction (e.g., trust, commitment, reciprocal understanding) between collaboration actors becomes vital. This, therefore, justifies the need for conceptual clarity regarding the micro-level activity in UIC which supports the suitability of the social capital perspective as a theoretical lens to understand technology transfer in UIC. Figure 1 presents the study's conceptual framework which conceptualizes the relationship between social capital and technology transfer in engineered UIC as discussed next.

Insert Figure 1 about here

The role of social capital in the technology transfer process

Social capital can be defined as a long-lived group of actual and potential (albeit uncertain) resources stored in the network of relationships which are established and maintained by individuals or organizations (Adler and Kwon, 2002). It has a unique characteristic (when compared to other typical resources) of being possessed by all members of the relationship (Nikolopoulos and Dana, 2017). Nahapiet and Ghoshal (1998) propose that social capital can facilitate the development of intellectual capital by enhancing knowledge exchange and combination. To explain this process, they identified three dimensions.

The structural dimension can be viewed as a series of connections (or networks) that individuals or organizations have with others (Adler and Kwon, 2002). Thus, it focuses on the patterns and ties strength among the members who have common relationships (Hartmann and Herb, 2015). These connections comprise information channels that lessen the amount of time and investment required to assemble information (Filieri et al., 2014, Hughes and Perrons, 2011). The relational dimension specifies the resources created through actors' interaction in the relationships, and thus captures the quality aspect of these relationships (Hartmann and Herb, 2015). Trust, as one example of these resources, can drive collective work and can reduce transaction costs (Careya et al., 2011). Obligation, another resource, would emerge from a willingness to return a favor with a favor, where willingness is a function of the connection strength between the particular actors (Lin, 2002). However, these resources are not always useful, for instance, although shared norms, a third resource, may facilitate communication, it can cause unrealistic expectations of obligatory behavior that creates conflict due to a perception of 'free-riding' (Inkpen and Tsang, 2005). Finally, the cognitive dimension includes resources, such as common understanding and shared interest (Zheng, 2010), which enhances establishing systems of meaning among individuals in the same network, thus optimizing their interpretation of exchanged information (Thune, 2007). Accordingly, developing a common language (as one aspect of the cognitive capital) can facilitate individuals' ability to gain access to people and their information (Nahapiet and Ghoshal, 1998). Common context could also be extended to shared narratives that provide powerful ways for creating, exchanging and preserving rich sets of meanings such as myths, stories and metaphors (Edler et al., 2011). Thus, shared narratives make possible the creation and transfer of new interpretations of events in a way that facilitates the creation and combination of different forms of knowledge, including tacit ones.

This indicates that social capital has a pivotal role in affecting the behavior and attitude of individuals who are involved in the technology transfer process (Filieri et al., 2014), thus influencing the effectiveness of the process itself (Maurer et al., 2011). However, the relationship between social capital and technology transfer is still unclear. First, we have limited understanding of the reciprocal effect between the three dimensions during an ongoing social interaction. In this respect, the vast majority of research has conceptualized and tested the three dimensions as variables with a static (i.e., unchanged) direct effect on an organization's processes and attributes (see for example, Camps and Marques, 2014, Hu and Randel, 2014, Hughes and Perrons, 2011, Maurer et al., 2011, Zheng, 2010). In principle, this assumption contradicts the social capital theory which perceives the dimensions as interrelated and have the potential for mutual reinforcement (Nahapiet and Ghoshal, 1998). In principle, this can explain the inconsistency found in the literature regarding the individual effects of social capital dimensions on the transfer process. For example, while Akhavan and Mahdi Hosseini (2015) saw a positive relationship between the structural dimension of social capital and technology transfer (conceptualized as knowledge sharing), Maurer et al.'s (2011) study reveals insignificant association. Second, the role of actors who are involved in the transfer process is still unclear in regard to de-contextualizing practices within the source organization (i.e., which produces the technology) when compared to the contextualizing practices in the recipient one (Røvik, 2016). As such, research on technology transfer focuses predominately on how the recipient organization can identify, internalize and utilize knowledge and technology from external sources using the absorption capacity lens (Lucena and Roper, 2016, Miller et al., 2016). However, the source organizations are an essential element of transfer success as the knowledge absorption process by the recipient organization cannot effectively unfold without the willingness of the source organization's actors to share and exchange (i.e., de-contextualize) their tacit, sticky, and difficult to codify knowledge and make it ready for consumption by the recipient (Hau et al., 2013). Third, and from a wider perspective, we have limited understanding of how social capital dimensions unfold and affect the process of technology transfer in collaborations that are designed and coordinated by a third-party. While there are few studies that examine social capital in UIC (e.g., Chakrabarti and Santoro, 2004, Thune, 2007), we do not know how the third-party (i.e., a sponsoring body as the government), who may control the collaboration structure and governance, can affect the dynamic of social capital which exists in the relationship between university and industry actors. The diversity between the organizations involved in this process suggests that there might be conflicts of interest and disagreement about the progress on the social interaction (e.g., how the external ties between actors across organizations can be forged and developed with the help of a third-party). This demands further micro-level studies, that focus on the individual level in contrast to the firm level – see for example Scandura (2016), to expose this effect.

This study aims to address the above issues using Figure 1 as our conceptual framework. In the following section, we discuss our research context and methods in order to explore the role of social capital in engineered UIC for technology transfer.

METHODOLOGY

Study context

The setting of our study is the Faraday Partnership Initiative (FPI), a government-sponsored program aimed to transform how technology can be exchanged between the UK higher education sector and industry (Loots, 2003). Two bodies took the responsibility of administration: the Engineering and Physical Sciences Research Council (EPSRC), and the Department of Trade and Industry (DTI). The 'Faraday Principles', which are set down by the DTI, are designed to encourage closer contact and exchange. They are expressed as follow (Airto, 2001, p.9):

1. Promote active flows of people, science, industrial technology, and innovative business concepts between the science, engineering and technology base (universities and similar institutions) and industry.
2. Promote partnership ethics in industrially relevant research organizations, business and universities and similar institutions.
3. Promote core research that will underpin business opportunities.
4. Promote business-relevant post-graduate training, leading to life-long learning.

The participation in this initiative was open to all interested universities and companies (no eligibility criteria), but if a group of members agreed on a particular partnership project, a formal contract was required. During the period 1997-2002, four calls for participation were made, asking interested institutions to submit collective proposals. The DTI was responsible for evaluating the proposals and allocating funds. The four calls resulted in 24 partnerships that focused on life science, engineering and technology disciplines (see Table 2 for a summary of these partnerships), and the total value of the FPI research portfolio in the fourth call was £160 million (Airto, 2001).

Insert Table 2 about here

Case selection and data collection

In this research, we adopted a multiple-case study design as this approach can augment external validity (i.e., transferability of research findings) (Tsang, 2014), and help guard against observer bias (Voss et al., 2002). Since the focus of the study was the Faraday Partnership Initiative, the unit of analysis, or what constitutes the case (Yin, 2009), was defined as a Faraday Partnership within the UK Faraday Partnership

Initiative. For the total number of cases, many researchers suggest four to ten cases as adequate to facilitate cross-case analysis for richer theory building (Eisenhardt, 1989, Hedges, 1985). However, there was a need to balance the scope of the case study research with the cases accessibility and project manageability (Eriksson and Kovalainen, 2016), in the view of the geographic spread of the partnerships and partnerships' representatives within the UK (which involved 16 different cities). Accordingly, out of the existing 24 Faraday Partnerships, five cases were involved in the empirical investigation.

A purposive sampling approach was adopted to identify and select the five cases. This approach permits diversity, or theoretical variation, in the sample (Eisenhardt, 1989) to ensure that the study would capture different perspectives on the problem (Creswell, 2007), and also enable the replication logic of the different study issues/themes to take place (which necessary for generalizability) (Yin, 2011). Based on the 24 partnerships, we identified two criteria to ensure diversity in the sample: the lifecycle phase of the partnership growth ('early growth', 'mid growth', or 'mature growth') (see Table 3); and the type of technology addressed by the partnership.

Considering the above criteria, the Managing Director of one of the oldest Partnerships, who was well acquainted with all 24 Partnerships, helped us in identifying and selecting the five diverse partnerships (that varied in their maturity stages and were heterogonous in the sense that each partnership was focusing on a different technology sector), taking also into consideration the potential of being information-rich cases (Miles and Huberman, 2008) and the ease of accessibility for data collection (i.e., getting acceptance to interview representatives from all stakeholder groups involved in each partnership). Due to strict confidentiality agreements, the names of the five partnerships and their technology areas are excluded, as these data would easily enable the identification of partnerships and their involved organizations.

To evaluate the relevance of the data collection approach and to refine our research protocol we conducted two pilot studies, including an interview with the operations director of one partnership, and a technology translator. For primary data collection, we used a semi-structured interview technique with multiple respondents for each partnership to capture different viewpoints, establish comparability and enhance the reliability of the research data. The total number of interviews was 37 (all were transcribed verbatim), with an average duration of 77 minutes. Table 3 provides further details about the interviewees.

Insert Table 3 about here

For each case (i.e., individual partnership), our informants (almost all of whom had been with their partnerships from their founding stage) comprised at least a representative from university, a representative from business and two representatives from the partnership intermediary. We ensured that university and industry representatives were the leading individuals in their institutions in regard to the partnership. The industry actors came from different industries including plastics, health products, oil and engineering. Those from the university side were from science and engineering schools. We also interviewed representatives from the DTI and EPSRC. In addition, the portfolio of interviewees included partnership management representatives and technology translators who were recruited indirectly by the government (through Quo-Tec Limited) to manage and facilitate the partnerships. Quo-Tec Limited was a company commissioned by the DTI to provide independent consultation services and facilitation for all of the partnerships.

Our study utilized three key strategies in the data collection to strengthen research validity and increase the transparency of the findings including: (1) case study protocol, (2) triangulation and (3) case study database. The research protocol provided structure to the data collection process and served both as a prompt for the interview and a checklist to make sure that all topics were covered (Yin, 2009). It included questions on the experiences of the informants with respect to the three dimensions of social capital in the context of their relationship and interaction within any of the five partnerships and their impact on the technology transfer process. On the structural dimension of social capital, the themes of the questions were focused on the structure of the relationships (i.e., how the connections were made) between the university and industry actors, means of communication, partnership formations process and the pre-partnership phase (i.e., the process of finding partners). Questions addressing the relational dimension involved the issue of trust and trust formation (e.g., impact of external factors), facilitators for the technology transfer process, issues associated with the publication from collective research projects, self-interest vs. collective interest, expectations and norms as evolved during the course of the partnership and how they influenced the technology transfer process. Finally, we probed the cognitive capital using questions on issues including the level of common understanding (in regard to the technology utilized) as shared between the actors from both sectors, partnership aims and objectives and perceptions of the effectiveness of the initiative.

Data analysis

Our analysis combines techniques of qualitative analysis for theory development. It involved travelling back and forth between the data and the emerging structure of theoretical argument in an iterative fashion. More specifically, we adopted a mixed approach of Miles and Huberman's (2008) three steps of analysis (data reduction, data display and drawing and verifying conclusions) and (Braun and Clarke, 2006) thematic analysis procedure. We started by reducing the data by summarizing it, as such each of the interview transcripts was condensed from between 30 and 60 pages into between 15 and 30 pages (e.g., by deleting repetition or irrelevant content), which was then entered into the NVIVO software program for coding. However, before commencing the coding procedure, all summarized transcripts were sent to corresponding interviewees for verification. The feedback was, in general, satisfactory and only five interviewees provided complementing information or asked for some minor parts to be removed.

We started coding by reading through the content of each transcript. A series of provisional categories were created (a process akin to the notion of open coding), where we tried to adhere to informants' terms in labelling these categories. As the analysis progressed, we started seeking similarities and differences among these provisional categories. Accordingly, the provisional categories were then gradually collapsed, by combining categories of similar meanings, into a set of final categories (or 'sub-themes'). After several iterations, each group of categories that were found as theoretically relevant, were condensed into a more abstract theme. To do so, we looked for information that would disconfirm or add to the existence of any relationship between the various categories. Indication of a relationship was realized in direct statements as explained by participants. Other information about relationships came from identifying patterns that seemed to co-occur or to cause one another (Saldana, 2012, p. 218). Throughout the analysis, all categories and themes were centered on the three dimensions of social capital and the connection between their underpinning facets and technology transfer process, as illustrated in Table 4.

Insert Table 4 about here

In addition, we scrutinized the organizational documents following the previous steps. We compared the emerged categories and themes with the categories and themes identified from interview transcript analysis. This comparison allowed us to confirm the interpretation derived from the interviews' data. In addition, evidence extracted from the document review was used in specific places in the findings to corroborate or extend the arguments when the evidence from interviews is perceived as limited or inadequate (Creswell, 2007).

Throughout the analysis, we were mindful of potential sources of bias. Therefore, we took several measures to ensure the validity and reliability of our study, as explained in Table 5.

Insert Table 5 about here

FINDINGS

We structure our key findings across the three dimensions of social capital. In particular, we expose the idiosyncrasy of these dimensions and their interaction in the context of engineered UIC, and how this combination of capitals affects the technology transfer process. Further, we report how technology translation emerges as an essential component of the technology transfer process. We provide discussion which is underpinned by rich quotes on detailed examples.

The structural capital

The university and industry actors in our cases allocated a significant amount of their resources and attention on making structural connections using a number of different activities. These connections acted as channels for various forms of interaction at an individual level, and thus enabled the transfer process to take place. The most prevalent forms were: face-to-face meetings, communication (via mail, email and conference calls), and interaction events (including conferences, workshops, seminars and symposia). These activities and events were essential in boosting the exchange of ideas and experience. However, it was realized that bringing people from diverse institutional backgrounds to communicate regularly was a difficult undertaking due to various cultural and institutional barriers. Thus, specific resources (e.g., a specific fund for regular discussion sessions and workshops) were dedicated in all partnerships to increase the frequency of social interaction from the outset.

The analysis also uncovered a new form of externally-managed activities for building structural connections. This includes the use of the Collaborative Awards in Science and Engineering (CASE); a national studentship program. It was designed and backed by the government, and was partially utilized through the Faraday scheme to encourage the interface between university and industry individuals through students' involvement in industrial projects, and joint supervision of dissertations and theses by academic and industry personnel, which enabled both parties to make sense of each other's setting and thus accelerated the establishment of a common understanding across the sectors.

In addition to the above activities, university and industry actors employed uncommon activities (as compared to interaction within the industry) in developing their structural capital, including lectures by industry members at universities, customized educational programs for industrial personnel, exchange, transfer or secondment of personnel to work at one another's research facilities, employment of graduates, exposition, the use of newsletters and bulletins and joint publication of research outcomes (e.g., academic papers and industry reports). These activities were, in particular, useful in bridging the difference between the two distinct cultures, thus mounting their shared cognitive capital. Interestingly, the role of technology translators was instrumental in these activities given their hybrid experience in both sectors.

> *"With* input from academics, we produce and disseminate information on emerging technologies which are relevant to our technology area, and we also work with the training providers [the university academics] to align the training provision in our technology area to meet the needs of *industry"* (T3)

Also, the partnership management representatives (recruited by the facilitating company) were vital in enriching and stretching the interaction by establishing various communication media to keep all collaborators informed about each other's activities, thus paving the way for more collaborative linkages and identifying new potential areas for transferring university technology within each partnership.

> *"We publish a bulletin every month or two, which provides information on the Partnership's* existing activities to connect people to others and also to let people think about how that could *impact on their businesses"* (M1)

However, because of the discrepancy between the overall aim of each sector when joining the partnership (the industry is driven by commercialization of technology whereas the university is motivated by knowledge creation and dissemination), the effectiveness of these interaction activities was perceived asymmetrically. For example, the views on publications ranged from encouragement by a university to publish, to outright refusal to publish by industry (i.e., can cause knowledge leakage and thus may lead to a loss of competitive edge).

> "We co-author with them [referring to industry], in good journals, and that gives them some publicity. You will find industrial names to some of our publications on our website. But on the other hand, there are some who want to maintain strict confidentiality, and so *we do not publish"* (U4)

Interestingly, we noticed that the nature of the technology that each partnership was considering has caused certain communication activities to prevail. In other words, although the majority of activities were common to all partnerships, we found some activities to be specific to particular partnerships because these activities were more common to the technology areas the partnerships focused upon. For example, only one partnership had university and industry actors involved in 'Training Courses in Universities', and 'Industry involvement in curriculum development'. Also, only one partnership was involved in 'Distance learning Courses' and 'Technology Exchange Consortium'. In addition, three partnerships were involved in 'Representation of University Academics on Industry Boards and Industry Members on University Committees'.

The relational capital

When examining the relational aspect, we found that pre-existing relationships between individuals played a significant role in the formation of the majority of partnerships. These relationships have delivered a convenient environment which helped to reduce, to a large extent, the influence of the differences between the academic and industrial cultures because of the trust that already exists between partners and the mutual perception of trustworthiness.

> *"From my experience, for a successful partnership, I think you do need a degree of successful relationship between parties before you start"* (M6)
>
> *"I will say it is definitely true that my links with University* [...] and also Dr [....] played a key *role in our involvement with this partnership…it is difficult to* trust and partner with someone who *you have just met" (*C7)

However, interactions due to networking promoted by the activities discussed earlier such as conferences, workshops, seminars, symposia and forums, helped to accumulate trust rapidly amongst university and industry actors who did not have the benefit of prior relationships. Interestingly, in a UIC setting, we noticed that the emphasis on pre-existent relationships was mostly between individuals rather than between the organizations themselves. This appears to be a bit out of tune with the literature (e.g., Shane and Somaya, 2007), which underscores the role of pre-existent relationship at individual-level in building institutional relationship (i.e., at organization level). This inconsistency with the literature can be attributed to the difference in working domain (i.e., between university and industry) where employees working in these two sectors are more likely to interact regularly at an individual level (bottom-up) rather than intuitional (top-down), using different interaction mechanisms as addressed in the structural dimension.

> "[Pre-existent relationship] has been in a sense, but it has been a relationship between people rather than organizations. So there was not really a relationship between our two organizations, but there was a relationship between the assistant director of [name of organization] *and me"* (M5)

Mutual trust and trustworthiness, therefore, emerged to be an important factor that facilitated the relationships between the actors. However, the technology translators and management representatives, who acted as impartial intermediaries, were essential in building and enhancing trust between the university and industry actors.

> "Trust is absolutely key to the technology translation process. But fortunately, most of them see us *as honest brokers, and so we usually do not have any problems with trust" (T*1)

In addition to trust, we observed a sense of mutual reciprocity (or obligation) to be embedded in the relationships. Here, university actors expected to access industry's complementary expertise, state-of-the-art equipment and facilities, and also secure employment opportunities for university graduates through, for example, CASE studentships. On the other hand, industry actors expected to have access to university students for internship and academic capabilities. Importantly, the evolved sense of mutual reciprocity was influential in enhancing their personal commitment to the partnership.

> "The academic members value the Partnership in terms of the collaborative projects with industry they get out of it, as it is a straight impact arrangement which is mutually beneficial to both of us, and it stimulates and encourages our *commitment to get on with it"* (C2)

Moreover, the overall objectives set down (externally) by the DTI for the Faraday Partnerships together with the partnerships' own specific targets, were acting as a platform for creating shared values, thus motivated the collaborators to fulfil their obligations and act in a favorable manner towards each other in regard to their technology and knowledge exchange.

> *"I did not know some of our industry partners when we actually started. But once we came* together, we all had the responsibility for delivering the Faraday objectives, which in a way bound us together and kept us focused to meet our obligations*"* (U6)

However, despite the sense of mutual obligation, all partnerships were controlled by official contracts in order to eschew potential disputes and manage nascent ones. Issues relating to 'inflexible university policies' including Intellectual Property Rights (IPRs), publication rights, and patents and contractual mechanisms', are all active areas for conflicts. In particular, industry actors expressed concerns about stringent attitudes adopted by some universities towards IPRs. A University academic validated these concerns: "The biggest stumbling block is always IP [Intellectual Property], and the stumbling block *these days is the universities, not necessarily industry"* (U7)

Therefore, the Faraday Principles (as included in the study context section above) were vital in this regard as they provided guidance for the conduct of the partnerships, as they were directing (with the help of the mediators) all partnership players regularly toward the common aim of the initiative; to facilitate technology transfer between sectors. This shows that the Faraday scheme principles and objectives were substantial in establishing mainstream relationship norms and understanding (i.e., as part of the conative capital), and thus helped to reduce the influence of cultural inconsistency between its members. At the same time, the mitigating influence of the intermediaries in helping overcome the institutional, cultural and social barriers between the university and industry actors in the partnerships was another factor which aided in reducing the influence of any norms and cultural barriers.

> *"The* industry and academia speak two different languages. When industry describes a problem, it is not necessarily in a way that academia sees it in terms of finding a solution. Also, *academia's* solution is not particularly in a way useful to industry to fixing their problems, and that is where we [i.e., the intermediaries - the technology translators] *come in to work at the interface"* (T6)
> *"I think academics talk one language and industry talks another language. And I think you need* somebody in the middle that can communicate at both levels, somebody that can talk both languages to facilitate the two coming together synergistically*"* (U8)

The cognitive capital

In the context of social capital, the cognitive dimension concerns shared interpretations, expectations and systems of meaning between actors in a given relationship. Overall, the findings showed that the Faraday Principles and the distinguished objectives of each partnership in this initiative constituted a framework for discussion and agreement among the different parties of each case. They were critical to overcome the ambiguity typically associated with any new project. Moreover, pursuing collaborative and communication activities (i.e., as part of the structural capital dynamic) was critical to enhance the level of shared meaning among the university and industry partners.

> *"We have regular communications with the academics and industry people, both face to face and* through email, teleconferencing and letters to make sure that we are aware of what is *happening…enhanced our mutual understanding by discussing the problems being addressed"(*U3)

Also, these collaborative projects provided opportunities for creating effective relationships across the various actors as these individuals were evolving (through frequent interaction) a high level of shared interest and common understanding between them.

> *"*My experience is that such projects require a lot of meetings and discussions, which are very much involving, but actually, they are not a waste of time at all because all of those things develop our capacity for closer engagement*"* (U5)

In the same vein, accounts or narrative by various speakers during the conferences and at training courses, and the exchange of tips and anecdotes including the sharing of experiences by university academics and industry personnel at the different types of meetings (such as the seminars and workshops) enhanced the cognitive dimension within the relationship. This enabled the individuals to better understand the context of best practices in other organizations and other Faraday Partnerships.

> *"The conferences are excellent*, we get the opportunity to listen to cutting-edge technologies, others*'* experiences and also share our own experiences. It is a great forum for conveying technology or knowledge across, which of course leads to other opportunities*" (*C4)

Technology translation and translators

The analysis showed that technology translation emerged as an essential component in the technology transfer process between university and industry. In principle, we found that, for effective transfer of technology, there is a need for translating this technology first. As such, the UIC actors conceived the technologies (and their underpinning knowledge) embedded in the university as immaterial accounts (rather than defined objects) that should be transformed while being transferred (Røvik, 2016). In fact, the power behind the translation of technology stems not from one specific central party (i.e., university or business), but from the richness of interpretations and discussions that the technology triggers in all actors within the partnership when it is adapted.

> *"The work that has been done with the Partnership has definitely influenced the modification of* our processes and the products to the benefit of the business in a way that we would not have done *if we had not participated in the Partnership" (C8)*
>
> *"The [translation process] has stimulated the establishment of a doctoral research*-training center *at University […], which is specifically in our technology area" (M4)*
>
> *"I got case studies that I could use as teaching material. So I was able to give* students more industrial driven projects because I understand more about what industry requires by having gone *through the technology translation process" (U1)*

Within the Faraday partnerships, the translation process takes place in two iterative steps, as explicated in Table 6 and illustrated in Figure 2 (Figure is presented in the discussion section). The two steps (collective sensing and technology adapting) reflect the reality that each sector has its own terminology, systems of working, theorizing, and experimenting which may complicate how opportunities for technology advancement are identified and exploited beyond sector boundaries. Moreover, this highlights an important difference to technology transfer between homogenous organizations (e.g., business to business) and heterogeneous organizations (e.g., university to business), as 'translation' captures the idiosyncrasy of UIC by emphasizing the inherent differences between the two sectors which required a form of transforming to the technology before being ready for exploiting and commercializing.

Insert Table 6 about here

Furthermore, we realized the role of technology translators to be crucial in this process, see the third column in Table 6. Therefore, it can be concluded that the key objective of technology translators was to establish collective sensing and adapting of technology (i.e., technology translation) as an essential phase before internalizing, exploiting and commercializing this technology (i.e., complete the transfer process). In support of this finding, the UK Association for Innovation, Research and Technology Organizations specifies the role of technology translators when defining technology translation as: 'the activity of spanning communities of interest and linking individual participants in a way that goes far beyond older concepts of business support programs or outreach activities of universities. It [i.e., technology translation] requires skills and experience often found only in established intermediaries or in individuals [i.e., technology translators] with years of experience at the academic/industry interface' (Airto, 2001, p. 14).

However, there are two aspects that distinguish technology translator from Technology Transfer Office (TTO). First, TTO is typically an organizational structure created within the university for commercialization and patenting technology (Porcel et al., 2012, Siegel et al., 2003b). Therefore, this office facilitates technological diffusion through licensing inventions or intellectual property which has emerged from university research activity to industry (Bozeman et al., 2015). Technology translators, however, in a Faraday Partnership were essentially responsible for brokering and building the relationship between the university and industry actors (i.e., developing the structural, relational and cognitive capitals) to facilitate the translation of technology. Furthermore, due to their extensive experience in and within (i.e., the interface) the sectors, the technology translators understand the motives of both sets of actors effectively and are thus able at the early stages of the project to reconcile any misalignment or conflict that might emerge between the collaborators. In sum, they were focusing more on the individual level of the partnership rather than the institutional one (in contrast to the TTO). Second, the technology translators were trusted by all partnership actors as they were recruited by a third-party (an independent company, Quo-Tec Limited, which is commissioned and controlled by the DTI), in contrast to TTO that is an organization structure created typically within the university for the purpose of commercializing technology through patenting and licensing (Siegel et al., 2004). This provided more confidence within the partnership and enabled translators to have a better view of the university and industry's in-depth practices, as they were seen as trusted, reliable and impartial advisors (with no potential conflict of interest).

Shedding more light on the role of the translation process, the majority of respondents from universities and industry felt that technology translation within the Faraday Partnerships was reasonably effective in bridging the gap between industry and academic institutions, and was thus perceived as essential for technology transfer to take place. 82% of all the respondents including 66% of university academics, 91% of industry representatives and 85% of management representatives and technology translators claimed that the Faraday Partnership they were involved in had met the aims and objectives of their own organizations through technology translation. In particular, they expressed the view that it had successfully improved research understanding, research communication and research cooperation between the partners. Therefore, the scheme served to build closer alliances between the organizations involved in the partnerships in different ways. In some cases, it had served to initiate 'first-time' collaborative activities while in other cases it had served to extend existing collaborations. They also claimed that technology translation improves the existing technology transfer schemes between university and industry, as it helped to mitigate the effects of the strong language barriers between academia and industry. In addition, and maybe more importantly, it was vital in promoting networking and bringing together all required parties around one table through an intermediary, which was perceived as essential to technology transfer.

> *"Academics can feed into a technology translation process* and industry can gain something from a technology translation process. When this is successful, it is technology transfer. So technology transfer is what comes out of the translation process. So the translation is the process of having

somebody interprets between academic and industry, and technology transfer is what they do *when they got it right" (*U2)

In the next section, we discuss the dynamics connection between the three dimensions of social capital and the process of technology translation, proposing an integrative framework.

DISCUSSION AND CONCLUSION

This paper investigates the impact of social capital on the technology transfer process as unfolded within the collaboration between higher education institutions and industry through an externally triggered initiative. Through the social capital lens, we examined the micro-foundations of the technology transfer process by focusing on the level of individuals' interaction.

The actors in the Faraday Partnerships used different activities to establish their structural connections. The interactions, in particular through face-to-face activities, helped to bridge the cultural gap between the university and industry actors and promoted trust during the relationships. Prior research has suggested that trusting relationships evolve from social interactions (Moran, 2005, Gulati, 1995). As two actors interact, their trusting relationship becomes more genuine, and enables them to perceive each other as trustworthy (Tsai et al., 2014). In addition, the interactions made it easy for the partners to identify with one another and provided opportunities for narratives and sharing experiences that were necessary for technology translation. Typically, tacit knowledge cannot be transferred to others unless there is a rich interaction between individuals that is based on a shared understanding of meaning, assumptions and context (Santoro and Saparito, 2006). This is why Lawson et al. (2008) found that relationships characterized by frequent communication allow for better planning, goal setting and problem-solving.

Considering the relational capital, the analysis exposed how the norm of mutual reciprocity was prevailing in the relationships between partnership actors. This would enable firms to internalize university sticky-tacit knowledge inherent in researchers exploring fundamental ideas who seek to materialize these ideas into innovative technology and products (Yusuf, 2008). Other components of the relational capital which emerged are the social norms of openness and teamwork, which are key features of learning and knowledge acquisition (Nahapiet and Ghoshal, 1998). However, despite the openness and norms of mutual reciprocity between the university and industry actors, formal contracts were used to spell out the set of institutionalized rules and norms that governed appropriate behavior between them. Roessner (2000) asserts that using contracts does not necessarily mean that an inferior form of trust exists between the partners, but rather, it indicates a systematic approach for coordination. Whilst we expected that there would be some difficulties in regard to intellectual property rights (IPRs), we did not expect this to be such a pronounced issue as observed in the cases due to the moderating impact of technology translators. This leads us to conclude that contractual mechanisms in UICs, in particular, those associated with IPRs, is a contentious area, and thus requires more attention in practice (Gans et al., 2017).

For the cognitive-related findings, our study found that shared goals as framed by the Faraday Principles and the Partnerships' own specific objectives provided a fundamental ground for useful platforms for unifying actors' visions in the initiative, and thus helped to focus their attention, provide clarity and guidance through execution. In fact, a shared goal can help the alliance members to generate similar perceptions on how to interact with one another, which promotes mutual understandings and exchanges of ideas and resources, and facilitates the integration of knowledge (De Clercq et al., 2013, Inkpen and Tsang, 2005). However, shared goals should also define the extent to which network members hold collective sense and approach to the achievement of network progress and outcomes (Maurer and Ebers, 2006). Another aspect of the cognitive capital, which received prominence, was the sharing of narratives and experiences as occurred through communication between partnership members during various interacting activities. These activities enabled the development of common context between the actors (Roden and Lawson, 2014), which was crucial to overcome the cultural and conceptual discrepancies between the two sectors by maintaining rich sets of meanings in groups (Hartmann and Herb, 2015).

Social capital and technology transfer: toward an integrative framework

Combining our findings, we propose an integrative framework that explicates the nature of social capital dynamics and its impact on the technology transfer process, as depicted in Figure 2. The framework also shows the role of a triggering entity (i.e., the public institutions).

Insert Figure 2 about here

Typically, the most common way social capital has been operationalized in research is through the structural dimension focusing on social network analysis (e.g., Burt, 2000, Seibert et al., 2001, Filieri et al., 2014). Therefore, several researchers have called for the social capital construct to be defined more broadly to include not only the structure of relationships among actors, but also the nature and content of those relationships (Lee, 2009, Adler and Kwon, 2002). Although there are a number of studies using both the structural and relational dimensions (e.g., Moran, 2005, Tsai, 2000), the application of the cognitive dimension simultaneously with the structural and relational dimensions in the same study appears to be deficient (Maurer and Ebers, 2006, Lee, 2009), especially from within a UIC setting.

Whereas some scholars (e.g., Bstieler et al., 2015, Inkpen and Tsang, 2005) have suggested that the structural dimension is an antecedent to both the relational and cognitive dimensions, and the cognitive dimension is an antecedent to the relational dimension, the findings from our study suggest that the dimensions are not necessarily antecedent of one another, but rather are mutually reinforcing (Nahapiet and Ghoshal, 1998). For example, the interactions through the various activities helped to build trust and trustworthiness and made it easy for the actors to identify with one another (i.e., structural → relational). On the other hand, trust between the actors made them willing to engage in collaborative projects or other activities (i.e., relational → structural). The collaborative projects and the shared narratives at the conferences, workshops, training courses, etc. led to the sharing of experiences which enhanced the level of shared meaning between the actors (i.e., structural → cognitive). The Faraday Principles constituted shared goals which influenced or determined the activities which the university and industry actors engaged in (i.e., cognitive → structural). The trust between the actors encouraged the sharing of their experiences at the conferences and workshops, etc. (i.e., relational → cognitive). Here, the trust resulted from pre-existing relationships, promoted a common understanding between those with prior relationships and made it easier for them to identify with one another on similar interests. In particular, familiarity with a potential partner through prior alliances provides first-hand knowledge including a partner's resources, personnel, culture and decision-making processes which reduces the fear of opportunism by the partner, furthers mutual understanding and develops strong ties for knowledge transfer in alliances (Gopalakrishnan et al., 2008, Gulati, 1995). Similarly, the Faraday Principles and the partnerships own objectives provided a common understanding which facilitated the fulfilment of their obligations in a favorable manner towards one another (i.e., cognitive → relational). Therefore, we propose that in UIC the three types of social capital resources are not contingent on each other, but have reciprocal impact on each other, which in sum would facilitate the process of technology translation through influencing the sensing and adapting of potentially transferable technologies.

The analysis also shows two factors which play a vital role by exerting an influence on the three dimensions: shared objectives set externally and independent technology translators. Clearly laid down objectives through the Faraday Principles (i.e., set by the funding body which has triggered the partnership) influenced the types of structural connections or activities that the university and industry actors engaged in. At the same time, these objectives were important to lay the foundation for common understanding, thus reducing the impact of cultural divergence. Moreover, the objectives, acting as a stimulant, helped the university and industry actors to fulfil their obligations towards one another. Furthermore, the objectives aided the partners in identifying with one another and enhanced the level of shared meaning between them. These observations have some support from the alliance literature. For example, Das and Teng (1998) argued that, in addition to helping set the direction for the alliance, clear objectives also facilitate the institution of specific rules and regulations, which are important for formal control mechanisms. Importantly, these objectives would specify what is expected of partners, and thus make it easier for the partners to identify the activities to engage with in order to exploit their learning potential (Chau et al., 2016).

Similarly, the technology translators, who were assigned by the funding body, helped all partnerships members to overcome their institutional, cultural and social barriers. They were also instrumental in building and enhancing trust between actors from both sectors, and made it easier for them to identify with one another and to link with those with similar interests. Importantly, this was even more evident in our case since these translators were independently hired, and were thus perceived to be trustworthy individuals by all actors. Therefore, these findings underline the role of independent intermediaries in UIC whose bridging role improves the connectedness between the actors and facilitates the diagnosing of needs and the stimulation of the search for solutions (Ankrah et al., 2013). More generally, intermediaries are found to play a particularly important role in facilitating links between universities and the potential users of knowledge, especially commercial firms (Lee, 2011, Jain et al., 2009). As such, intermediaries can perform a ‘midwifery’ (Yusuf, 2008) role by assisting knowledge exchange between universities and industry via the creation of bridging ties and interfaces, by identifying needs and by establishing a dynamic framework for change and working to ensure the change is realized through financing and other means (Porcel et al., 2012). Therefore, we conclude that the value of the bridging or brokering function of intermediaries means that studies considering only non-intermediated industry-academic links are failing to notice an important part of the picture (Tether and Tajar, 2008).

Finally, we conceptualize technology translation as an essential component of UIC for technology transfer. Here, the social capital dimensions (and their dynamics) with the influence of the external factors (i.e., shared objectives and technology translators) facilitate the technology translation. In particular, they facilitate the collective sensing of opportunity and technology adaptation that would be necessary for companies to utilize and commercialize the imported technology. This conceptualization provides important advancement to the literature as it explicitly exposes the role of actors in the transfer process. More specifically, the framework explains the importance of considering these actors in both source and recipient organizations for effective transfer through the translation activity (Røvik, 2016, Sturdy and Wright, 2011). Accordingly, the study offers new insights into the technology transfer literature by shifting the focus from the prevailing perspective of absorption capacity (e.g., Lichtenthaler and Lichtenthaler, 2009, Miller et al., 2016, Tsai, 2001) to embrace a wider perspective that views all organizations involved as active and vital for the success of the collaboration. Furthermore, while there is some research that looked at this wider perspective (e.g., Maurer et al., 2011), the current study advances our understanding of technology transfer in UIC by distinguishing between technology translation and technology internalization, exploitation and commercialization.

Implications for research and practice

Case studies are often challenged in regard to their generalizability (Gerring, 2007); the extent to which their findings and conclusions can be relevant beyond the current research case(s) settings (Symon and Cassell, 2012, p. 207). However, case study methodologists (e.g., Eisenhardt, 1989, Firestone, 1993, Meredith, 1998, Yin, 2009) emphasize that this issue should not be perceived necessarily as a limitation because the generalizability (or external validity) of case studies findings rely on the analytical rather than statistical generalizability (i.e., the latter refers to the extent to which certain characteristics and patterns in a sample are typical of the population from which this sample was drawn) (for a review, see Tsang, 2014). In fact, using the statistical generalizability approach in generalizing case study research has been described as “a fatal flaw” (Yin, 2009, p. 38) as the cases are actually not sampling units and should not be selected randomly (Eisenhardt, 1989) to draw inferences from data to a population (Meredith, 1998). Instead, analytical (or theoretical) generalizability depends on the consistency between the set of findings emerged from the cases and the existing theory used in the study (Yin, 2009). Therefore, in this research we have taken a number of measures, as illustrated in the methodology section, to ensure the generalizability of our case study findings. First, we adopted a multiple-case study (in contrast to a single case) approach (Eisenhardt, 1989) that included cross-case patterns in data analysis, which enabled the 'replication logic' to take place (i.e., when the empirical results from the case studies are largely consistent and compatible with each other and also with the study conceptual framework and underpinning theory, which in turn support the transferability of the study findings and insights) (Yin, 2009, p. 44). Second, we provided a detailed account of the research settings which should allow adequate comparison with other settings/cases to judge the generalizability of the study (Barratt et al., 2011). Third, we purposively selected our cases in order to be diverse and representative of the key differences across the Faraday Partnerships. Therefore, we see a strong potential to extend our fundamental analysis to other UIC contexts. However, the extent to which these findings and conclusions can apply to other contexts would depend on the degree to which such settings match the situation and conditions presented in this study (Tsang, 2014). In particular, we would expect some differences between our study setting and those from UICs that have different formation modes, industrial features, and institutional conditions which indicates a need for further investigation. For instance, future research could explore the other two formation modes of UIC (i.e., 'emergent' or 'embedded') to assess the extent to which the vital role of technology translators, when regarded as unbiased and trusted facilitators across the collaboration stakeholders (as reported in this study), can impact the effectiveness of the technology transfer process in other UIC situations. This can have important implication as UIC actors might need to rethink the current structure and affiliation of Technology Transfer Office (that is typically owned by the university), because the negative experience (e.g., issues that relate to complex procedures and conflict of interest) associated with this office may drive companies to "engage in opportunistic behavior by contracting directly with faculty members, bypassing the university intellectual property apparatus" (Bercovitz and Feldman, 2006, p. 182). In addition, a research adopts quantitative methods of data collection, and utilizes the study themes to inform hypotheses development, is needed to assess the statistical generalizability of our findings, and thus help to refine and build upon the insights reported in this research. Another area that needs further investigation concerns the operationalization of social capital dimensions. Given the specific setting of our study, and despite the heterogeneity of our multiple cases, we may not have fully captured all the factors that influence the development of social capital in the relationship between university and industry actors. This indicates that other factors might exist due to the idiosyncrasy of collaboration context, which requires further investigation, for example, by conducting a comparative study that involves multiple settings.

In addition to research, there are two main managerial implications from our study. First, the findings indicate that the various aspects of social capital can be useful in enhancing the effectiveness of the technology transfer process during UIC. This understanding is helpful in assisting managers to intervene more appropriately when targeting resources to support these relationships. In particular, government departments (and other agencies) that sponsor such relationships could emphasize explicit mechanisms such as structured objectives for these partnerships, as this facilitates the formation and sustenance of these links. Structured objectives also enable the collaboration's success to be measured by the achievement of these objectives. In addition, we suggest that wherever possible, UIC should build on pre-existing relationships between committed partners. Notwithstanding the value of pre-existing relationships, it is important that a partnership is properly institutionalized to mitigate against partnership breakdown through key players moving on, since personnel turnover during the lifetime of collaborations could be significant. Second, there is a need to pay substantial attention to contractual mechanisms (e.g., in the case if IPRs), as this issue can significantly influence the stability and prospect of any UIC. Therefore, we emphasize the need to maintain a flexible approach in regard to intellectual property rights. For example, the sponsoring body (e.g., the government) can play an important role in designing a plausible approach that can balance between the university eagerness toward disseminating knowledge and the industry view of protecting and sustaining competitive advantage.

In conclusion, the growing interest in UIC has resulted in an abundance of literature from different perspectives. However, we still know little about these organizational arrangements when they are engineered by a third-party. Also, we lack proper understanding into the micro-foundations of technology transfer process using the lens of social capital (SC), which is a necessary inquiry given the prevailing perception of technology transfer as a socio-technical process. We address these issues and our research has yielded a number of conclusions, which should prove useful for theory and practice. Using empirical data from five case studies, we contribute to the UIC literature by developing a conceptual framework that explains how the three dimensions of social capital and their mutual interaction, while being influenced by technology translators and shared objectives imposed by the public funding body, facilitate the technology transfer process. Moreover, we advance our understanding of the nature of technology transfer process by elaborating how knowledge produced by academics can be transformed into useable forms of technology by firms.

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Table 1: A review of technology transfer definitions

Authors	Definition	Key insight/emphasis
COGR (2010)	The handing off of intellectual property rights from the university to the for-profit sector for purposes of commercialization	– Technology transfer (TT) is a linear one-directional process: Discoveries/inventions/creative ideas are transmitted from university and research institutions (funded by government) to industry through formal (e.g., licensing) and informal (e.g., presentations and conferences) channels for the purpose of commercialization.
Easterby-Smith et al. (2008)	An event through which one organization learns from the experience of another	– Four factors to influence knowledge transfer process: donor's and recipient's characteristics, nature of knowledge (e.g., tacitness), and inter-organizational dynamics (e.g., trust and risk). – Recipient's intention to learn and donor's motivation to teach are essential for the effectiveness of knowledge transfer.
Roessner (2000)	The movement of know-how, technical knowledge, or technology from one organizational setting to another	– TT emphasizes commercial value creation (i.e., economic incentive). Therefore, TT can include all processes by which ideas, proofs-of-concept, and prototypes move from research-related to production-related phases of product development. – TT can take place formally and informally
Bozeman (2000) and Bozeman et al. (2015)	A process that involves the transferring of technology, between donor and recipient, as an entity and its underpinning knowledge (i.e., technology and knowledge are inseparable; the knowledge base of technology is inherent, not ancillary).	– Identify five contingent dimensions that determine technology transfer effectiveness: Transfer agent, Transfer medium, Transfer object, Transfer recipient, Demand Factors
Bradley et al. (2013)	Social interaction process that involves intended and unintended exchange of technology between actors belongs to different institutional contexts	– Traditionally, TT was perceived as linear (i.e., from university/government to industry), but now it can take different nonlinear shapes including: reciprocal relationship, 'multiversity' (i.e., many sub-units and programs of the university can interact with companies), and 'open innovation' (i.e., university can acquire and distribute unused intellectual property).
Siegel et al. (2003a)	A process of commercial transfers of scientific knowledge from universities to firms.	– Technology transfer is a socio-technical process. – All stakeholder groups (from university and industry) who are involved directly/indirectly in the TT process can influence negatively/positively the effectiveness of the transfer process.
Mitton et al. (2007)	An interactive process that involves the interchange of knowledge between research users and researcher producers.	– There are many strategies to undertake technology transfer. However, the effectiveness of these strategies is largely context-dependent. – Technology transfer is a complex social process.
Miller et al. (2016)	Knowledge transfer is conceptualized as a boundary-spanning activity that goes beyond the traditional Triple Helix ecosystem (i.e., across academia, Industry and regional Government) to involve the end users as a core stakeholder within open innovation processes (i.e., quadruple helix structures).	– Open innovation context, where multiple diverse stakeholders are interacting, is bringing new challenges to the effectiveness of the knowledge transfer process. – These challenges are induced by the diverse quadruple helix stakeholder groups, as groups embrace distinct organizational-specific traditions, experiences and idiosyncratic practices.

Table 2: The 24 Faraday Partnerships*

Call	No.	Partnership Name	Partnership theme/description
1st Call	1	PACKAGING	Practical innovation for fast-moving consumer goods packaging, manufacturing, and supply. The Partnership covers a range of packaging-related research including advanced materials for functionality and usability, design simulation and modelling tools, and automation and robotics for cost-effective production and supply.
	2	IMAGING	Digital imaging technology. Focuses on security imaging technologies ranging from smart CCTV systems to concealed weapons detection.
	3	PRIME	The East Midlands Faraday Partnership. Developing smart products comprising interdependent mechanical and electrical parts
	4	INTERSECT	Intelligent sensors for control technologies. It focuses on sensors, data fusion and structural modelling for analysis, control and monitoring of processes using non-invasive measurement techniques.
2nd Call	5	ADVANCE	The Faraday Partnership in Automotive and Aerospace Materials. Main objective is to develop new materials and structures required for future low energy consumption, pollution-free transport systems.
	6	FOOD PROCESSING	Developing the underpinning materials, equipment and process knowledge applicable to food processing.
	7	IMPACT	Innovative materials development and product formulation by the application of Colloid Technology.
	8	IMSE	The crux of this partnership is spread the use of industrial mathematics, computing, and system engineering in industrial processes
	9	PLASTICS	The catalyst for innovation in the supply chain – automotive and aerospace
	10	TECHNITEX	Technical textiles. The partnership aims to work in close collaboration with the technical textiles value chain, emphasizing small companies, to create an extensive network of UK manufacturers in the sector and to re-position the industrial network partners to become research-led and internationally leading.
3rd Call	11	COMIT	Aims to develop new materials that will provide high-quality lightweight displays in cars, aircraft and for personal communications that provide information in 'real time'.
	12	CRYSTAL	Aims to develop green technology for cost-effective and more sustainable manufacturing in chemical and allied industry
	13	EPPIC	A Faraday Partnership in Electronics and Photonics Packaging and Interconnection. The objective is to provide a hub for development and exploitation of technology in support of the UK photonics and electronics industry.
	14	FIRST	Innovation remediation science and technology. Seeks to develop scientific methods and technologies for the assessment, remediation and management of contaminated land
	15	HIGH POWER RADIO FREQUENCY	Industrial application for high power radio frequency engineering. Primarily, seeks commercial application of the radio frequency and microwave engineering by developing new technologies in the medical and limitary industries
	16	INREB	The partnership focus is the integration of new and renewable energy in buildings by commercializing knowledge and technologies developed by academic research centers.
	17	PRO-BIO	Focuses on scaling-up bio-catalytic processes for manufacturing
	18	SMART OPTICS	Aims to exploit science in advanced optics, including optical systems, subsystems, devices and technologies that dynamically adjust to provide an enhanced performance or are part of a complex control loop, including novel supporting technologies.
4th Call	19	GENESIS	Farm animal, genetics and genomic
	20	INSIGHT	High throughput technologies for new product and process development
	21	MEDICAL DEVICES	Medical devices development. Aims to provide national infrastructure to facilitate the development and commercialization of medical devices and biomaterials for new and improved patient treatment and increased competitiveness for UK healthcare industries
	22	MINI-WASTE	Develop novel technologies and processes for the minimization of industrial waste
	23	PINPOINT	Global navigation satellite systems (GNSS) applications
	24	POWDERMATRIX	Rapid manufacturing through powered processes which are used in many manufacturing industries including PC, automotive, machine hard metal cutting

*Complied and adapted from different sources including Airto (2001), QTL (2003), Loots (2003), Committee. (2006)

Table 3: Details of interviewees

No.	Title	I.D.[1]	Partnership/key stakeholder	Status of interviewee in Partnership	Status of interviewee in own organization	interview duration (minutes)
1	Dr.	T1	Partnership A (PA) *Relatively Mature Growth*	Technology Translator	Manager	75
2	Mr.	C1		Industry Member	Technical director	73
3	Dr.	U1		Academic Member	Lecturer	68
4	Ms.	C2		Industry Member	Manager	85
5	Mr.	U2		Academic Member	Doctoral Researcher	140
6	Mr.	M1		Ptship Magmt Rep[2]	CEO	55
7	Dr.	C11		Industry Member	Principle Scientist	50
8	Dr.	S1	Partnership B (PB) *Relatively Mature Growth*	Ptship Magmt Rep	Adviser	80
9	Dr.	M2		Ptship Magmt Rep	Managing Director	88
10	Dr.	T2		Technology Translator	Technology Manager	85
11	Prof	M3		Ptship Magmt Rep	CEO	90
12	Prof	U3		Academic Member	Director of Research	73
13	Prof	U4		Academic Member	Associate Dean	73
14	Dr.	C3		Industry Member	Technical Director	71
15	Dr.	C4		Industry Member	General Manager	70
16	Dr.	C5	Partnership C (PC) *Early Growth*	Industry Member	CEO	80
17	Mrs.	M4		Ptship Magmt Rep.	Manager	65
18	Prof	T3		Technology Translator	Consultant/Manager	80
19	Prof	C6		Industry Member	Ex-Director	90
20	Dr.	T4		Technology Translator	Commercial Manager	70
21	Prof	U6		Academic Member	Pro-Vice Chancellor	50
22	Prof	U5		Academic Member	Surgeon	83
23	Dr.	M5	Partnership D (PD) *Mid Growth*	Ptship Magmt Rep.	Managing Director	87
24	Prof	U7		Academic Member	Research Professor	68
25	Dr.	T5		Technology Translator	Managing Director	78
26	Dr.	C7		Industry Member	Principle Scientist	65
27	Prof	C8		Industry Member	Scientist Adviser	84
28	Prof	U8		Academic Member	Deputy Dean	55
29	Dr.	M6	Partnership E (PE) *Early Growth*	Ptship Magmt Rep	Managing Director	80
30	Mr.	T6		Technology Translator	Associate Manager	98
31	Dr.	C9		Industry Member	Principle Consultant	65
32	Prof	U9		Academic Member	Lecture	79
33	Dr.	C10		Industry Member	Principle Consultant	61
34	Mr.	D1[3]	Key Stakeholder	-	Head of Team	110
35	Mr.	D2	Key Stakeholder	-	Manager	62
36	Mr.	R1[4]	Key Stakeholder	-	Coordinator	80
37	Dr.	R2	Key Stakeholder	-	Managing Director	73

[1] I.D = These symbols are used at the end of the interview quotations in the findings section
[2] Ptship Magmt Rep = Partnership Management Representative (usually the Partnership Managing Director)
[3] D1 and D2 = Representatives from the Department of Trade and Industry (a government department)
[4] R1 and R2 = Representatives from the Engineering and Physical Sciences Research Council

Table 4: Summary of study key themes and categories

Categories (sub-themes)	Themes
– Common identification of problem	Cognitive aspects
– Shared meaning of technology	
– Unifying codes	
– Interaction and goal/interest alignment	
– Externally set objectives	
– Reciprocity in accessing castor-related advantages	Relational aspects
– Sector-related norms	
– Pre-existent relation	
– Accumulation of trust through socialization	
– Individual vs intuitional trust	
– Reciprocal trust	
– Norms and cultural barriers	
– Input by intermediaries/facilitators	
– Structural connection	Structural aspects
– New interaction mechanisms	
– Sensitivity of structural connection to industrial type	
– Third-party communication across partners	
– Networking preference	
– Structural – cognitive	Dimensions interactions
– Cognitive – relational	
– Relational – structural	
– Sensing opportunity	Technology translation
– Adapting activity	
– Partnership actors as active participants	
– Contextualization vs. de-contextualization	
– Technology translator input	
– Commercialization	

Table 5: Measures for validity and reliability

Research quality criteria*	**Measures applied**
Construct validity: Focuses on the objectivity of the researcher, and that the drawn conclusions are derived from the data itself and not based on values or theoretical assumption of the researcher.	– Multiple respondents for each of the five partnerships were interviewed to allow for the possibility of different viewpoints to be captured, establish comparability and enhance the reliability of the research data. – The data collection instrument included both open-ended and structured questions. – The majority of the interviewees checked the summarized transcripts of their interviews (feedback from the informants was in general satisfactory and five of them provided minor comments for enhancement). – Data triangulation by using multiple sources of evidence.
External validity: The extent to which the results obtained from the study can be generalized beyond the settings of the current case study.	– Using multiple case studies allowed for achieving theoretical generalizability (the 'replication logic' can take place because the consistent results from each category provide support to the concluded theory). – Providing a detailed account of study setting as the judgment of the degree of transferability is influenced by the information available to the observer about contexts under consideration. – The five cases were selected purposively.
Reliability: Emphasizes the replication of the study findings, or the extent to which a study can be repeated (in same settings) and give similar findings.	– The case study protocol was followed in collecting the data. – A case database was established for the five cases. – All interviews were recorded to reduce observer bias.

*Adapted from Miles and Huberman (2008), Yin (2009), and Eisenhardt (1989)

Table 6: Boundary crossing through technology translation: A continued activity

Step	Activity focus	Role of technology translator	Supporting evidence
Collective sensing of opportunity (includes de-contextualization)	UIC actors seek collectively to identify new technological advantages in academics (i.e., the source) and how it can fit within the industry sector (i.e., the recipient). This involves the de-contextualization of university technology and related tacit knowledge by transforming them into an abstract representation (e.g., images, texts, explicit procedures, formulas) that can be understood by all actors. The de-contextualization becomes particularly challenging when the technology elements are dispersed (e.g., embedded within research teams that crisscross university and national boarders) rather than concentrated in one location (cf. Røvik, 2016).	Given their extensive experience in both sectors, the technology translator has the ability to help partners from the industry to identify what they might internally lack in order to develop better products/services, and to identify where the capabilities needed (whether they are products, technologies, or competences) may reside with universities.	*"You need to identify research in academia that has not yet been identified as valuable to the industry and translating it into something that is valuable to the industry. It is this link that enables the research to be translated into a useful form for industry" U1*
Adapting of technology (includes contextualization)	This step highlights the difficulty of transferring an identified technology (as result in the previous step) from academia to industry, which demands transforming and decoding of the de-contextualization technology (i.e., the abstract representation) into an accessible format to facilitate the internalizing process by the industry. The contextualization is necessary as the imported technology is introduced in a new setting that contains prevailing systems of practices and established procedures (Kostova, 1999).	The technology translators were essentially assisting in brokering the relationship (i.e., crossing the cultural and technical barriers) between university and industry actors which is essential for the abstract ideas or technology to travel from the source and materialize in the recipient (e.g., the company). Importantly, during this step translators realize new opportunities of technology transfer as they become more informed about the existing technical needs and competences, which help in re-starting the sensing step (i.e., move in a circular pattern).	*"Translation is about changes needed to the output of the research program in order to make them accessible to industry…it is about translating of the language that is used, because the language of research is not the language of industry….this is why it requires a translators to facilitate a translation of the output of the research and making it accessible by packaging it appropriately to the industry" T5*

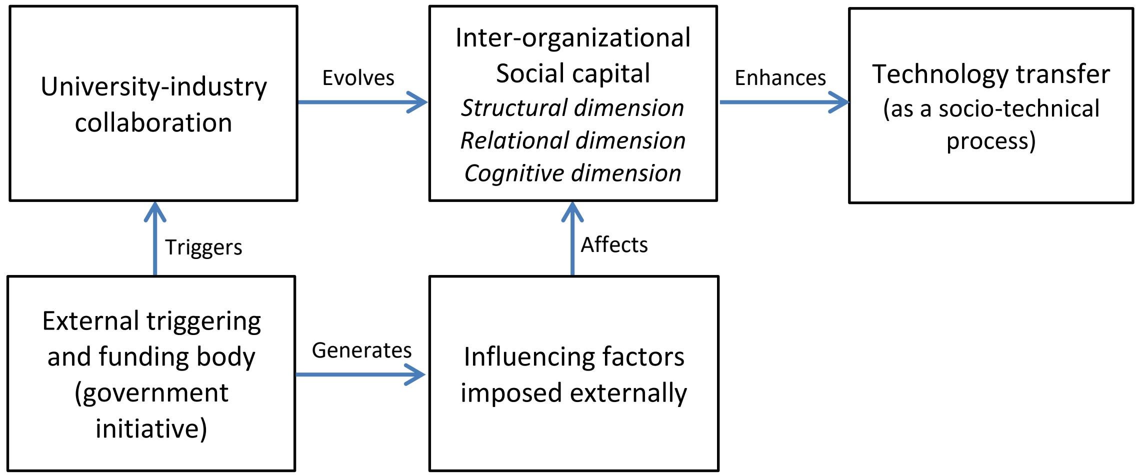

Figure 1: Study conceptual framework

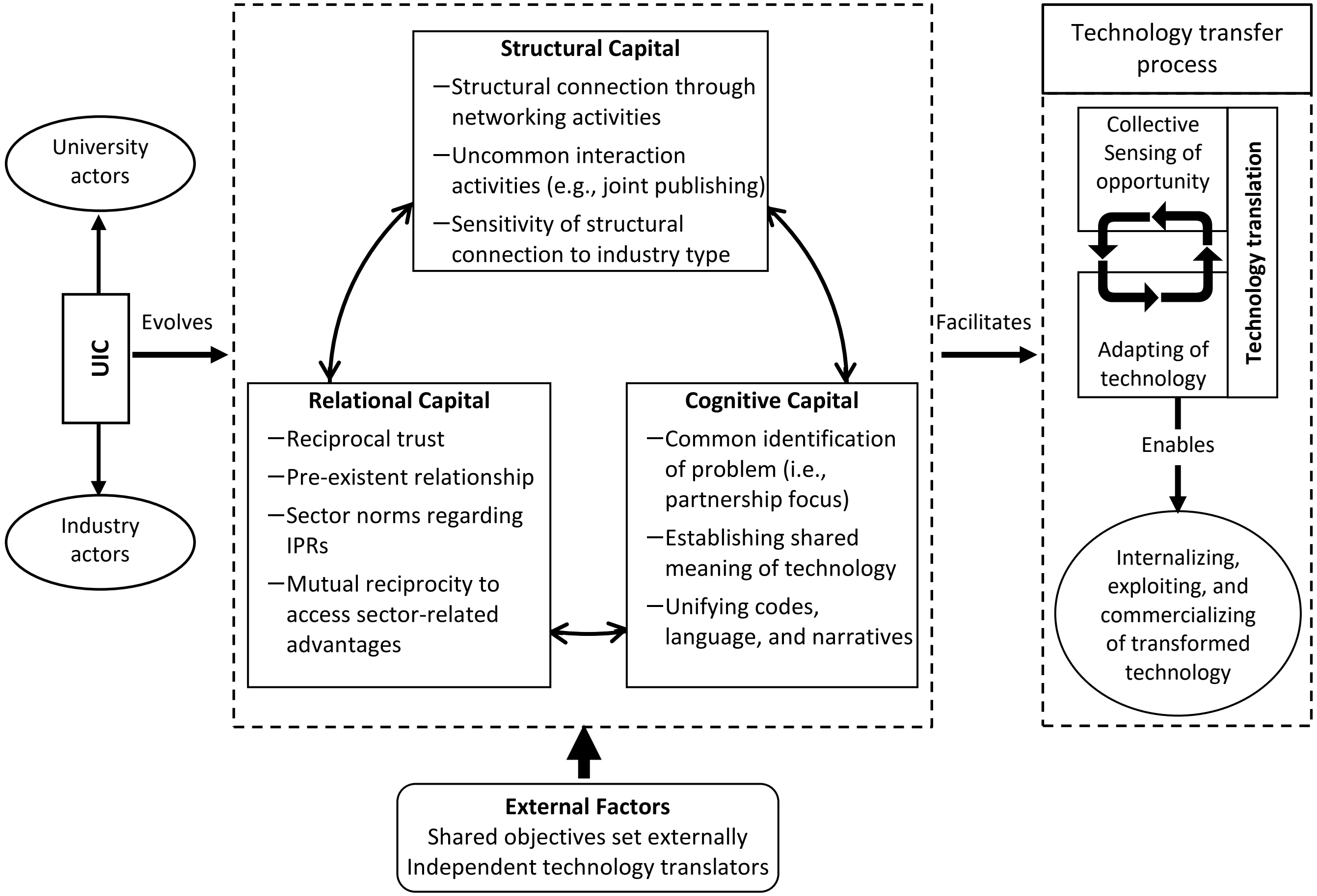

Figure 2: The dynamic of social capital in engineered UIC for technology transfer: A micro-foundations perspective