Knowledge Creation through University-Industry Collaborative Research Projects

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Abstract: It is obvious from the study of literature that university-industry (U-I) relationships and their subsequent knowledge transfers are topics of high political, economical, managerial and academic interest. Indeed, technological knowledge is seen as a major source of long-term economic growth and its transfer to the firm is critical since it acts as a significant innovation factor. In order to access this knowledge, a portfolio of sourcing strategies is available to the firm: knowledge creation through internal RandD departments, knowledge sharing with suppliers or market relationships, and also transfer from knowledge institutions such as public and private research centres. In this paper, we recognISe that University is a central source of knowledge but we question the general belief that knowledge is per se flowing between private and academic sphere through the conduct of University-Industry relationships. As a result, this paper presents our literature analysis concerning this research topic and explores one particular mean of inter-organisational knowledge transfer, namely the University-Industry collaborative research project. We present findings from an exploratory study, which aims at examining knowledge flows and collaborative behaviours at stake in such research projects. This interview survey has been realised with respondents actively involved in Belgian university-industry (U-I) interactions and provides qualitative data analysed through the theoretical framework of organisational knowledge creation developed by Nonaka and Takeuchi. We found evidence supporting the existence of a knowledge spiral as a dynamic for the whole projects and identified some knowledge-based limits to the reconciliation process between university's interests and company's needs.

Keywords: university-industry interactions, knowledge transfer, Nonaka

1. Introduction

Assuming that transfer activities between academic and private sectors will contribute to business competitiveness and economic growth (Hitt et al. 2000), researchers have intensively investigated university-industry (U-I) relationships. This research field has been highly influenced by quantitative approaches favouring patents and publications as the main used spillover indicators but it also provides evidence about the significance of traditional open sciences channels (Cohen et al. 1998) and other knowledge interactions such as informal relationships and joint RandD projects. In this paper we present our literature analysis concerning this research topic as well as the results of an exploratory interview survey conducted toward relevant actors in the field of university-industry relationships such as junior and senior academic researchers, Technology Transfer Office members and research project managers. The first part of this paper will be dedicated to the place of university as a knowledge supplier, in particular through U-I collaborative research project. In the following section, we shall describe the theoretical framework used to examine knowledge flows at stake in such projects, namely the SECI process of Nonaka. Next sections will present findings and draw paths for further research.

2. Knowledge transfer through U-I collaborative projects

The knowledge created in the academic sphere takes various paths before finally reaching a competitive recipient, from patent and licences to research publication or consulting. Actually, knowledge is created throughout the three main functions of universities: the education of workers-to-be, the development and dissemination of research work, and their active participation to social and economic development, which has led to the concept of entrepreneurial universities (Etzkowitz and Leydesdorff 2000; Van Looy et al. 2006). This variety of channels leads to a real challenge for researchers interested in the field. We can distinguish between two broad perspectives to approach University-Industry knowledge flows as a research object. In the first one, which we refer to as "untargeted knowledge transfer", knowledge diffusion occurs from the University to the Industry in a one-way relationship. Traditional instruments of open sciences (i.e. publication, conference proceedings) are associated with this perspective, which examines the transfer of codified knowledge originating from academic institutions to unidentified target. From this point of view, knowledge is also defined as a public good. Indeed, knowledge is non-rival per definition since our consumption of it does not hamper further consumption. It becomes a public good when there is no efficient way to prevent free riders from

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accessing it (Maskus and Reichman 2004), or in other words when its access is not restricted to selected and identified agents. Following this definition, patent is an interesting contributor to public knowledge stock through its mandatory publication. Nevertheless, patent has an ambiguous role in this process. It is an indirect source of public knowledge through the mechanism of disclosure, but it is also a direct and excludable source: from the moment an exclusive license is set up between the university and a private firm, the piece of knowledge encapsulated in the patent loses its non excludable nature. The second perspective proposed in this paper thus concerns "targeted knowledge transfer" between a university and one (or more) specific private partner(s), like in licensing, consulting, or collaborative research, when the knowledge interaction gives the private partner the opportunity to access some level of knowledge appropriation. Note that the partial exclusion of other agents is not only due to contractual agreements; it is also caused by the particular nature of knowledge which is transferred through direct interactions (Marr 2005). Indeed, the tacit dimension of the knowledge that will be exchanged also makes it difficult to replicate for external organisations or individuals.

Table 1: U-I Knowledge Transfer

	Untargeted KT	Targeted KT
Direction	U ⇨ I	U ⇔ I
Nature of knowledge	Public, explicit K	Private, explicit and tacit K
Instruments	Publication, conference proceedings, patent	Consulting, collaborative project, exclusive licenses

Untargeted and targeted knowledge transfers have different but complementary epistemologies. Indeed, knowledge diffusion through publications and patents occurs under a codified, articulated form while the specific relationship built up through targeted transfer allows the sharing of explicit and tacit knowledge. Those different perspectives also suggest a specific meaning of the knowledge interactions. On the one hand, university is seen as the central source of knowledge, reaching recipients in a one-way relationship. On the other hand, the knowledge interaction through targeted transfer implies critical feedbacks from the recipient, the interaction eventually affecting both partners on their research and transfer activities. Accordingly, the study of untargeted or targeted knowledge flows implies distinctive research tools and methodological approaches. A positivist approach seems appropriate to understand and measure knowledge flows under an explicit form such as patents and other formalised sources. An interpretivist or constructivist approach should be more suitable to fully explore knowledge flows occurring through interactions: whereas objective quantitative methods would fall short to capture the tacit component of targeted knowledge flows, a subjective qualitative approach would give the researcher deeper insights about such created knowledge.

While examining the literature dealing with U-I knowledge flows, we observed that an important part of it presents quantitative measurement of untargeted knowledge transfer. This perspective studies open knowledge diffusion in an aggregated way, looking at various means of knowledge transfer but mostly paying attention to publication and patent citations as spill-over indicators. As important as it is, this piece of literature (Jaffe and Trajtenberg, 1998; Autant-Bernard 2001; Rothaermel and Thursby 2005) fails to explore the specific flows at stake in particular projects and the way to maximise benefits for each partner. As a result, the way by which knowledge is exchanged between partners in bilateral agreements is still relatively unknown (Agrawal 2001). Based on this statement, we decided to explore U-I knowledge flows occurring in the context of one of those interactive channels, the U-I collaborative research project. Landry and Amara (1998) defined the collaborative research as "exchange relationships in formal research projects undertaken by university researchers and other research partners". In the context of University-Industry collaborative research, the project is jointly defined and conducted by the science institution and its private partner (Debackere and Veugelers 2005).

The collaborative research project has several strong theoretical advantages. First, the formalisation of interactions through a shared covenant precisely defines the objectives and responsibilities of each partner to ensure the success of the collaboration (Barnes et al. 2002). Secondly, it is a strong form of partnership (Landry and Amara, 1998) inducing a propitious ground for trust building. Thirdly, frequent personal contacts result in an efficient collaboration and the transfer of tacit knowledge between partners (Schartinger et al. 2002). Based on those assumptions and the general belief that collaborations are "good things and should be encouraged" (Katz and Martin, 1997), the collaborative research project has received a growing attention in recent years, both from public concern (European Commission 2000; OCDE 2003), academic world (Davenport et al. 1999;

Hall et al. 2001; Hall 2004; Johnson and Johnston 2004) and practitioners. Until recently, the U-I collaborative project has been mainly explored as an activity. The practical goal of researchers was therefore to develop management practices leading to successful projects. Generic motives for collaborations and barriers inhibiting partnership activities were investigated while some authors turned to the experience of it through the examination of success factors, using multiple research methodologies, from case studies to quantitative analysis of contextual and organisational factors (e.g. Barnes et al. 2002; Mora-Valentin et al. 2004). However, the effectiveness of knowledge transfer is not equal to the success of its dedicated activities (Bozeman 2000; Davenport et al. 1999). For instance, personal feelings about the achievement or successful resources and deadlines management may support the success of the project even if the knowledge transfer itself has been neglected.

As a result, the knowledge processes underlying collaborative research which relate to "day-to-day operations of knowledge creation and innovation management" (Debackere 2000) remain unknown while they may go through some difficulties based on the intrinsic nature of those inter-organisational projects. In addition, changes in the academic environment have put U-I knowledge diffusion in trouble. As an example, the various national "Bay-Dohl Act like" policies and the Lisbon strategy have initiated an irreversible trend toward systematic valorisation of academic research in Europe. Changing environmental conditions have re-defined the conventions that used to rule relationships between universities and companies, urging for a deeper understanding of knowledge creation and transfer mechanisms between partners.

3. Theoretical framework

Knowledge transfer, and broadly speaking knowledge management, is traditionally considered as an internal phenomenon, which implies knowledge assets management through building and reinforcement of competences (Amesse and Cohendet 2001) within the organisation to ensure a positive contribution to the firm. From this perspective, when knowledge comes from an external source, as through collaborative research project, the key challenge is to develop competences to acquire, communicate, apply, accept and finally assimilate its content (Gilbert and Corday-Hayes 1996). In such a conceptual framework, the knowledge creator has a passive role of transmitter, most of the absorptive work being made in the target organisation. Likewise, the target organisation has no influence on the creation process. Nevertheless, the iterative and systemic view of innovation (Goh 2005) that has driven the development of the National Innovation System (Freeman 1988; Lundvall, 1992; Nelson 1993), the Mode 2 of the knowledge production system (Gibbons et al. 1993) and the Triple Helix Model (Etzkowitz and Leydesdorff 2000) argues for connections and feedbacks between partners, through interactive learning and the building of absorptive capacities. Recent publications (Castiaux 2006; Johnson and Johnston 2005) made interesting attempts to apply this theoretical framework to inter-organisational context. Those authors used the knowledge spiral of Nonaka and Takeuchi (1995) to explore collaborative modes and the creating process at stake in university-industry collaborative projects where personal contacts between academic researchers and the industrial partner create the appropriate ground for tacit and explicit knowledge sharing. This is shown in Figure 1.

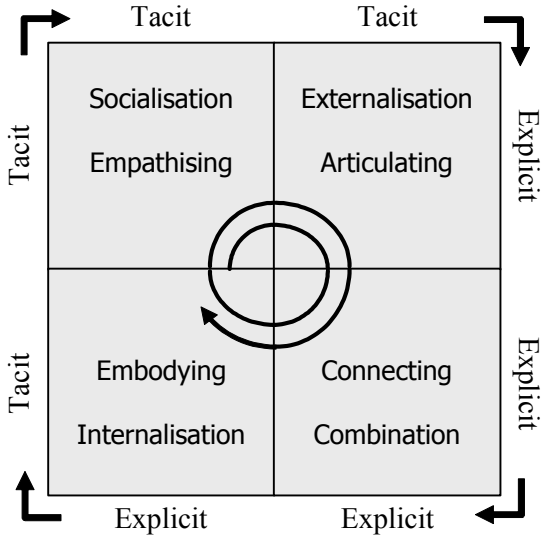

Figure 1 : The Knowledge spiral, adapted from (Nonaka et al. 2000)

First introduced in the work of Polanyi (1967), tacit knowledge is defined by Reed and DeFillippi (1990) as the "implicit and noncodifiable accumulation of skills that result from learning by doing". Bozeman (2000), likewise some other authors (Spender 1996), enlarged that definition by including the fraction of knowledge that is not articulated or explained yet. Quoting Howells (1995), "It would appear that the tacit is not forever tacit; with effort it can be partially formalised and partially communicated". Using the metaphor of the knowledge spiral instead of the circle, the SECI (Socialisation; Externalisation; Combination; Internalisation) process developed by Nonaka and Takeuchi does not only describe the formalisation and communication mechanisms

between partners but it also draws attention to the knowledge creation potential enabled by the transitions between tacit and explicit states. The Socialisation step is described in (Nonaka et al. 2000) as the "process of converting new tacit knowledge through shared experience". The contacts presiding at this phase are rather informal, allowing for the transmission of tacit knowledge (Castiaux 2006). The Externalisation step is defined in (Nonaka et al. 2000) as "the process of articulating tacit knowledge into explicit knowledge". It allows an easier and better diffusion of knowledge in the organisation. Following (Nonaka et al. 2000), "Combination is the process of converting explicit knowledge into more complex and systematic sets of explicit knowledge". In this phase, the organisations are completely devoted to the exploitation of previously acquired knowledge. As defined in (Nonaka et al. 2000), "Internalisation is the process of embodying explicit knowledge into tacit knowledge". It is related to the lessons learned from exploitation.

Following Nonaka and Takeuchi, the SECI process can be viewed as an upward spiral from the individual level to the organisational level and eventually between organisations. However, inter-organisational sharing may occur before that the whole organisation, the university or the company, has gained from the knowledge process. Moreover, inter-organisational knowledge transfer may be a predator for organisational learning due to contractual agreements. This concern is central to the engagement in viable collaborative projects as well as their assessment. As suggested by Cyert and Goodman (1997): "the essential issue is whether these relationships (UI alliances) create learning for a few individuals or whether the learning's are diffused throughout the organisation". In the next sections, we try to uncover the knowledge spiral at stake in U-I collaboration projects by applying the theoretical framework of Nonaka to a qualitative dataset gathered through semi-structured interviews.

4. Interview survey

4.1 Research purpose

The exploratory study developed in the next sections aims at a deeper understanding of U-I collaborative research projects and of their underlying knowledge flows as perceived by the respondents. Another research purpose is to reduce the scope of our research interest. Indeed, our definition of collaborative research still encompasses a large range of projects, characterised by specific intellectual property right agreements and different degrees of financial or scientific involvement of partners.

4.2 Methodology

A qualitative approach was appropriate given a twofold reason. First of all, it was theoretically relevant given the epistemological approach chosen to explore knowledge flows as "targeted transfer". The significant tacit component of knowledge flows as well as people-related concerns proper to U-I collaboration (Davenport et al. 1999) bear out this direction. Secondly, this explorative study is our first empirical contact with the field we are studying. Performing semi-structured interviews (and subsequent discussions) was a good method to gather rich data about the ground of U-I relationships and to learn to understand this problematic. The study has been conducted toward actors involved in the innovation process, particularly in Wallonian (French speaking part of Belgium) university-industry relationships. We followed an information-based sampling strategy in order to maximise learning from our respondents: different profiles were selected to capture data about U-I relationship from diverse perspectives. As a result, senior and junior academic researchers, technology intermediaries and RandD managers were asked during recorded semi-structured interviews about their experience of inter-institutional collaborations in general and of collaborative research projects in particular. The recorded interviews were systematically transcribed and coded in order to get reliable primary data that were analysed through pattern matching and explanation building techniques (Lee 1999). Table 2. presents the actual respondents' distribution. In addition to those respondents, three members of university Technology Transfer Offices, one more junior researcher and one academic RandD manager were interviewed but not recorded and therefore not included in the table.

Table 2:. Respondent distribution

Respondent category	Academic	Non academic	Cumulative frequency
Researcher	6	--	6
RandD manager	1	4	11
Individual entrepreneur	1	1	13
Technological intermediary	2	2	17

In the next sections, we present findings focusing on communication means and knowledge creation evidence through the SECI process of Nonaka and Takeuchi. The examination of each knowledge conversion mode is followed by a synthesis presenting the knowledge creation

process as well as project's attributes impacting its different steps. Some extracts of the interviews' transcripts were used to illustrate findings and were accordingly included in the text. As interviews were performed in French, the original interviews' fragments are presented as endnotes.

5. The SECI process

5.1 Socialisation

Evidence highlights the key role of the socialisation process at the early beginning of the project in building credibility between potential partners. Indeed, institutional representatives from each side of the partnership-to-be share tacit knowledge about their own skills and capabilities by socialising through observation and discussion, fostering trust which can be defined in this context as a set of beliefs and expectations about the ability of the partner to perform the collaborative tasks and his disposition to act as agreed (adapted from Castelfranchi 2004). Tacit knowledge about the research problem is also shared; the confrontation of experience eventually leads to the redirection of the research activities. This is an interesting illustration of the bilateral interactions built up in such research projects. As one academic researcher said about their industrial partner:

> *"They brought few funds but they brought the basic research ideas, they brought many things on this side." [1]*

(See Notes at the end of the paper for original French text).

The main problem emerging from the data set has to do with the initiation of interactions between the laboratory and new industrial contacts due to what is perceived as a cultural gap. This problem does not seem to occur when a prior relationship exists between partners such as friendship, family and repeated partnering. A solution consists in using a third-party, a technological mediator, which acts as a broker and contributes to trust and credibility building between partners. As socialisation is mainly performed though informal contacts, it may bring an explanation about the lack of success perceived by respondents about formalised events organised by technological intermediaries to bring research centres and industrial actors together in some kind of research exchanges. It rather supports their action as a discrete broker bringing together the knowledge seller and the knowledge buyer in an informal context. Note that even if some respondents perceived the research exchanges as unsuccessful, we personally attended such an event where we met more than 80 research centres and 150 firms' representatives, arguing for a real interest for inter-sector interactions.

Eventually, partners share their ideas and confront institutional positions. As a result, the socialisation process also allows for the creation of tacit knowledge about tasks and partners' responsibilities that will be formalised through the externalisation process.

5.2 Externalisation

The externalisation process formalised the knowledge interactions through a shared covenant, the formal research agreement. This phase strongly depends on the socialisation process as the created tacit knowledge about respective responsibilities and deliverables is converted into explicit knowledge firstly through dialogue and eventually under the form of research contract and confidential agreement. This explicit knowledge should allow for an unambiguous and visible definition of the collaborative work throughout the project. Besides, this phase is characterised by institutional commitment. Indeed, whereas the academic researchers on their own mainly perform the remaining activities, externalisation through formal agreement involves University as an institution through its Technology Transfer Office, which is in charge of contractual, and appropriation issues. As a matter of fact, the success factor identified by Barnes et al. (2002) about formalisation of interactions may also have some impact on the knowledge process. Indeed, findings indicate that physical evidence of confidential agreements enhance the commitment of individuals working on the project and act as a mediator with regard to subsequent knowledge transfers, are they under a tacit or explicit form. Furthermore, the formalisation makes easier the transfer of knowledge created through socialisation and dialogue to researchers who did not take part of it but worked afterward on the project.

Those findings are in line with previous studies focusing on factors affecting collaborative research. However, the knowledge processes may also suffer from some impediment effects. For instance, strict written confidential agreements can be perceived as very restricting by academic researchers while effective secrecy requirements are not so firm, leading to suboptimal knowledge creation. It happened when the socialisation mode failed to create sufficient common perspectives about the collaborative field. As a result, we found that the formalisation phase may have some fostering and hampering impact on knowledge creation and sharing practices and therefore should be carefully conducted by organisational

representatives as well as researchers. This mechanism postulates the significance of this phase to become a shared value between partners. While systematic formalisation of interactions turns out to be the rule rather than the exception in the academic community, industrial contacts lacking scientific competences may address this issue quite differently. Once again, technological intermediaries can help value sharing through prior negotiations and the acknowledgment of the need for formalisation.

5.3 Combination

As the research work defined in the joint research agreement goes on, knowledge is developed and converted into more complex sets. Through interview analysis, we identified two main tangible supports for knowledge transfer in collaborative research projects. First of all, project reports have been identified as central supports for knowledge transfer between partners. Beside its channel function, the role of this articulated piece of knowledge is to create meeting opportunities, eventually leading to face-to-face knowledge exchanges and tacit sharing.

> *"We often attend meetings where people did not have time to read the technical report. The best means of informing about progress are the meetings, with discussion, but the report must be, remains necessary to keep a track of what has been carried out." [2]*

Although discussions seem more important during the project than the reports on which they are based, tangible knowledge forms are unavoidable supports for transfers between partners and as outline for further partnerships. Combination also plays a key role in the reconciliation process between industrial and academic needs. Indeed, findings indicate that targeted knowledge flows through collaborative project do not perfectly prevent the diffusion of public knowledge toward competitive outsiders and the academic community. Similarly, findings from Cassier (2002) suggests that despite confidentiality agreements, academic researchers involved in U-I collaborative projects easily conciliate disclosure and reserve, for instance by differentiating between public and private conclusions. For example, we observed that publications and conferences were stated as mandatory objectives in the project agreement of a junior researcher, allowing for the convergence of academic and industrial goals. However, the convergence may be at the cost of publication richness. As other respondents pointed out:

> *"There are sometimes problems to publish because of the constraints of confidentiality. We are stuck in the middle because we make fundamental developments, which we want to be able to communicate to the scientific community, and then there is a lot of data that we cannot mention, therefore it looses some value. It is not the priority of the firm to see the research results published." [3]*

Evidence identified perceived limited diffusion of research results for appropriation reasons. As previous research (e.g. Van Looy et al. 2006) found a positive relationship between engagement in contract research with industry and scientific performance measured in publication outputs, it would be interesting to have a closer look on how the balance actually occurred between knowledge diffusion and appropriation.

5.4 Internalisation

Internalisation refers to the lessons learned from the collaboration activities, the research work and the exploitation of created knowledge. The search for research excellence as a motive for U-I collaboration (Link and Scott 2005) is confirmed by our data, for the industrial partner who exploits scientific outcomes but also for academic researchers who reach access to the industrial reality and accordingly enhance their understanding of the science field. Nevertheless, respondents agreed that massive scientific knowledge was not an automatic outcome from U-I research projects but that trust, credibility and social network enhancements were of underestimated benefits. For instance, academic respondents admitted that collaborative research created the opportunities to build relationships with other scientific partners of the company, eventually leading to academic (U-U) collaborations on more fundamental issues. Furthermore, relationship established between the company and the academic researchers allows for further knowledge transfer outside the project framework, which is in line with Singh's conclusion (2005) about collaborative networks as a determinant of knowledge flows.

Trust has a central role throughout the conversion processes, as a condition for conducting collaborative behaviour, as a mediator for knowledge sharing and interest reconciliation, and eventually as an intangible outcome from the U-I knowledge transfer. For instance, two senior researchers observed that their collaborative projects tend to lead to repeated partnerships and even privileged relationships. Beliefs about respective capabilities and motivations are reinforced between partners, but it can be extended toward external economic agents. For instance, the reputation of the academic laboratory as a valuable partner increases the

credibility of its associated company toward venture capitalists or public authorities. In fact, by collaborating companies signal their openness to the external environment (Fontana et al. 2006). As an example, we found that companies conducting U-I collaboration were signalling a specific profile to external actors. As a member of the management team of a Science Park said:

> *"(…) Effective collaborations between industry and research (…) are not a criterion of eligibility, it is a validation. (…) It makes possible to say: indeed, this company can be classified as having a technological innovative profile." [4]*

As a result, embodied social and scientific knowledge gained from the collaboration is now a starting point for new collaborative projects, with the same collaborators or through new partnerships enabled by their enhanced social network.

6. Knowledge creation process in collaborative research

Nonaka and Takeuchi proposed an integrated model of the organisational knowledge creation process that should in their own words "be interpreted as an ideal example of the process" (Nonaka and Takeuchi 1995, p84). In this section, we adapted the original models from Nonaka and Takeuchi (1995) and Nonaka (1994) to describe the knowledge process developed in collaborative projects and present attributes affecting its components. Briefly, we argue that an ideal knowledge process is composed of several concurrent phases: tacit knowledge sharing leading to the development of common concepts which are crystallised in a first time into written agreement and lately into publications, reports, new process or products. The externalisation and combination modes are tools for concept creation and crystallisation: individuals combine new and existing knowledge through presentation, telephone conversation and electronic mail but we found that reports and subsequent meetings were perceived as the more used means for the transfer between partners who shared explicit knowledge as well as tacit one. Those knowledge-mediating artefacts are then justified by academic peers through acceptance in top journals and by the company through the effective exploitation of created knowledge in its daily activities.

This justification phase originates from the definition of knowledge adopted by Nonaka and Takeuchi. Indeed, knowledge in the organisational knowledge creation theory is defined as a "justified true belief" following the concept originally developed by Plato. New concepts as well as their crystallisation should satisfy the justification phase to be shared at higher levels. For instance, the research work should be confirmed through scientific validation and the developed methods should be successfully applied in a company's department to reach individuals outside the project framework. It is interesting to note that in the context of collaborative research projects, the justification phase implies inter-organisational transfer, toward the private partner as well as toward the academic community. As an example, academic outcomes such as publications are justified through peer review performed by external scientists as a materialisation of the scientific norm of scepticism. As a result, interactions with the external world, the partner as well as other academic researchers, are much more present than in the original model of organisational knowledge creation. In conclusion, this knowledge process should enable individual knowledge to be enlarged and finally transferred to the parent university, the private partner and the academic community by using the four knowledge conversion modes depicted in the above section. This can be seen in Figure 2.

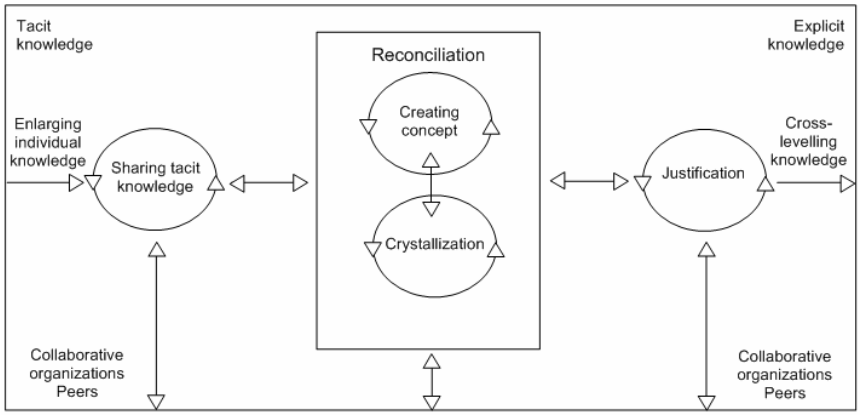

Figure 2 : The knowledge creation process in collaborative research projects, adapted from (Nonaka and Takeuchi 1995; Nonaka 1994)

Please note that although the knowledge creation process is presented sequentially, phases rather occur in a concurrent way. For instance, justifying concepts goes along with cross levelling of knowledge, sometimes by-passing the organisational level if the research laboratory acts in an autonomous way with its partner

We found several project's attributes affecting this process. First of all, we found that the origin of the research idea will have an impact on the way the individuals will develop competences. As the idea comes from the lab, individual researchers will deepen their knowledge, building up on existing competences. As the origin of the research idea comes from the company, individual researchers may be involved in a process, which required the creation of new competences, enlarging their individual knowledge as well as the one of their laboratory. In the first phase, actors share tacit knowledge in order to create the collaborative field. The dominant knowledge conversion mode is obviously socialisation, which allows for the building of trust and shared perspectives about the collaboration and its end, the research work and its deliverables. This vision leads to the creation of common concepts through dialogue and collective reflection. Tacit sharing is thus critical throughout the project concurrently with report presentations and daily progress. We found that tacit sharing within the project framework was fostered by several attributes. Firstly, effective membership of individuals from both sides of the collaboration has a positive impact on tacit sharing, enabling individuals to develop personal contacts and reflective dialogues. Secondly, written confidential agreement also has a positive effect at least when property right rules have been set correctly, allowing for more freely sharing of knowledge about key process and other problems affecting their activities. As one respondent pointed out:

> *"As a matter of fact, we know that there is information transfer flowing from one to another, but it is partly the objective. (…) It is not a problem if the agreements are well done, people are in a well defined framework, and consequently there is no problem, they can talk." [5]*

Another respondent also expressed that without satisfying agreements; companies may be reluctant to give information about daily process. Precisely:

> *"If the relationship is not clear and if the contracts are not clear from the beginning, I refuse to disclose our problems, not even solutions, I refuse to talk about our problems. To ask the interesting questions." [6]*

In fact, knowledge transfer in "unclear" relationships may lead to the valorisation of knowledge mediating artefacts at the cost of one side of the collaboration that maybe brought basic ideas and problems. A third attributes positively affecting this phase is thus the financial involvement of the firm. From that moment, a return is required and the firm can negotiate for appropriate agreements, which should back return on investments and create incentives for knowledge sharing.

The crystallisation of the common vision developed through tacit sharing into written agreement highly depends on socialisation and externalisation modes: informal discussions, observations and adequate formalisation. This phase may be very complex as actors involved in socialisation may not be the same as in the externalisation. Especially in Belgian universities, research agreements are partly prepared by members of the Technology Transfer Office (TTO), which is an administrative department and defends university's interests. From the moment those members are not sufficiently integrated into the socialisation process, it may lead to institutional conflicts between the TTO and the law department of the company who do not share the common vision about the collaboration, its goals and means to achieve them. As a matter of fact, it is very important to integrate all actors in the process in order to share this vision about what is really wanted from the collaboration. To help this convergence, a very positive factor is the existence of a long-term partnership between the company and the science institution because individuals know each other's and have a more clear idea about respective requirement. Besides, this kind of framework involves institutions' commitment from the beginning of the relationship. Shared concepts about deliverables are also crystallised in tangible and intangible research outcomes such as new models, methods and theories, patents and licenses, products and processes, even if this materialisation of created knowledge may occur after the project's deadline. As one respondent pointed out:

> *"There are some research results which allow for having something in one or two years but we are not informed." [7]*
>
> *"In general, after that the University has stopped working, it takes at least one year to say, "I have finished". There is still one year of inside work." [8]*

This can be explained by the proposition of Grant and Baden-Fuller (2004), which states that "knowledge creation requires specialisation, while knowledge application requires diversity of knowledge", the collaborative project being one

particular source. In fact, knowledge transfer in the justification phase may suffer from being conducted outside the project framework as individuals are not informed of what is going on about scientific progress but also about production and scaling problems. Once again, the existence of long-term partnership has a fostering effect on the process as partners are getting in touch despite the end of discrete projects. From the academic point of view, the justification may be impeded by patent opportunities as well as confidential agreements and other IP agreements which impose delays and some level of secrecy. In fact, patent opportunity also has an impact on knowledge sharing with academic peers, in and outside the involved laboratory. Furthermore, we saw evidence indicating that specific IP agreements with the partner hamper the research collaboration with other labs, which are not under the same IP regime. Nevertheless, this manager and other respondents also recognised that even if reconciliation wasn't a straight process, the balance between difficulties and benefits gained from the U-I collaborations was definitely positive, arguing for the preservation of such activities.

7. Discussion

Our first concern has to do the implementation of the Nonaka and Takeuchi's theory in a research context. Indeed, one could suggest that knowledge management tools are not concerned with academic scientific research but day-to-day company business. Nevertheless, the literature has emphasised the role of knowledge management and learning in innovation management. As collaborative research projects are firstly dedicated to knowledge advancement and as scientific progress is per definition a social process, we eventually used the knowledge spiral to approach this area and found a match between empirical evidence and patterns expected from the literature. As a result, we used a theoretical tool usually oriented toward internal organisational learning in a study about inter-organisational projects. We think that the knowledge creation theory of Nonaka and Takeuchi is appropriate to study U-I joint projects, as organisational learning is one of the main issues of this theme. In fact, we think it is a powerful tool as it offers a framework for studying knowledge mechanisms at both the individual and higher levels.

Empirical findings support the existence of a knowledge spiral as a dynamic for the whole U-I collaborative projects and present three main attributes influencing the knowledge process: the financial involvement of the firm, the existence of long term partnership and patent opportunities. But their exploratory nature also raises further interrogations. In fact, individuals are daily involved in some knowledge conversion processes through direct interactions. Tangible knowledge outcomes such as reports and formal presentations are grounds for speculation and informal discussions at an individual level but we still do not know which type of interactions is the most beneficial for daily research progress and knowledge transfer within the organisations. We are aware that this shortcut is mainly due to our research design. Indeed, discrete interviews are useful for gathering data about how the participant perceives the projects and their underlying knowledge flows. But it is a less powerful instrument when it comes to describe the actual knowledge process, as we did not actually observe it. Furthermore, respondents were mainly senior professors and RandD managers. As a result, front-line researchers are not sufficiently represented in our analysis that may suffer from this pitfall.

Some indications nevertheless suggest how individual researchers interact with peers to enable organisational learning as the project is in line with the laboratory competences. Some obstacles to organisational learning were also found such as the loss of human capital as the financial support dries up. Besides, interviews highlight that knowledge diffusion outside the project framework may suffer from appropriation issues. For instance, impediments to organisational learning were perceived in one U-I project involving patent opportunity coupled with a long-term individual relationship between the researcher in charge of the project and the company involved. Once again, one should remind of possible bias from our data collection method; people involved in U-I collaborations with serious patent prospect may identify the industry involvement as the secrecy originator whereas the patent prospect may be itself sufficient for creating restriction on knowledge diffusion. But even in this case, evidence indicates that perfect appropriation is unlikely in the context of scientific research due to concerns toward interests' reconciliation and respect of open science norms such as scepticism and communalism. In fact, it remains true that: "the impact of industrial partnerships on knowledge diffusion and circulation is one of the more controversial issues in economic and sociological literature on university-industry collaborations" (Cassier 2002).

In conclusion, this study is a first attempt to understand the knowledge flows underlying the research work performed through collaborative research projects. It highlights knowledge-based limits to the reconciliation process, leading to limited research diffusion and organisational

learning, but it also confirms the importance of the third role of university, namely participation to economic development. In other words, this survey validates the feasibility of reconciliation when engaging in technology efforts (Van Looy et al. 2006) while it also shows that the knowledge process may suffer from it. As a result, a deeper insight about this process would help companies as well as academic researchers to manage the reconciliation's impact more efficiently and perform more proficient partnerships. In our future research work, we intend to engage in in-depth case studies of collaborative research projects in order to capture all relevant knowledge flows. A deeper analysis of the process should be performed, disclosing the role of metaphors and analogies in the externalisation mode and looking at enabling conditions such as intention, autonomy, fluctuation, redundancy and requisite variety (Nonaka 2000), flexible learning, absence of performance myopia and leadership commitment (Inkpen 1996), etc. This last condition should be particularly interesting as the project leader will be in charge of at least two important communication channels: from one side of the collaboration to another, and from senior RandD managers and professors to front-line researchers. By achieving this research, we aim to contribute to the understanding of knowledge creation and sharing practices through U-I knowledge interactions. Besides, we hope it will bring some insights about the role of university as a knowledge supplier in the overall innovation process and as an active participant to regional and global economic development.

8. Notes

[1] "Ils apportent peu de fonds mais ils ont apporté les idées de base de la recherche, ils ont apporté beaucoup de choses de ce côté."

[2] "On est souvent dans des réunions où les gens n'ont pas eu le temps de lire le rapport technique. Les meilleurs moyens de renseigner l'avancée ce sont les réunions, avec discussions, mais le rapport doit être, reste nécessaire pour garder une trace de ce qui a été effectué."

[3] "Il y a parfois des problèmes pour publier à cause des contraintes de confidentialité, on est parfois un peu mal pris, parce qu'on fait des développement fondamentaux qu'on veut pouvoir communiquer à la communauté scientifique et puis il y a plein de données qu'on ne peut pas mentionner, donc ça n'a plus autant de valeur. C'est pas la priorité des industriels de voir les résultats des recherches publiés. "

[4] "On s'est dit aussi qu'une façon de le mesurer est de voir les collaborations effectives entre industrie et recherche. Ce n'est pas un critère d'éligibilité, c'est une validation. Quand on est au courant, ça nous permet de dire oui, effectivement, cette entreprise là elle est classée profil technologique innovante"

[5] " Fatalement on sait qu'il y a du transfert d'information qui passe de l'un vers l'autre mais c'est un peu le but. Vu qu'on est balisé généralement par des accords de confidentialité ou des accords de propriétés intellectuelles cela ne pose pas de problème. A partir du moment où les accords sont bien faits, les gens sont dans un cadre de propriété intellectuelle bien défini, et par conséquent il n'y a pas de problèmes ils peuvent parler. "

[6] " Et donc moi, si les relations ne sont pas claires et si les contrats ne sont pas clairs au départ, je refuse de donner nos problèmes, même pas la solution, je refuse de donner le problème. De poser les questions qui sont intéressantes. "

[7] "Il y a des résultats de recherche qui permettent en un ou deux ans ensuite d'avoir quelque chose mais on n'est pas tenu au courant.

[8] "Et donc en général ça prend je dirais – entre le moment où l'universitaire finit et qu'on dit voilà j'ai fini il faut au moins compter un an. Donc il y a encore un an de travail à l'intérieur. "

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