Collaboration in international technology transfer: the role of knowledge boundaries and boundary objects

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ABSTRACT

Firms increasingly use choose collaborative arrangements to get access to the most recent and advanced technologies instead of trying to develop them in-home. Several emerging economies use such arrangements particularly in the defence industry as a vehicle for technology transfer to the local industry. The effectiveness of technology transfer, however, is affected by many factors. This paper analyzes international technology transfer as a challenge of inter-firm collaboration and a challenge of cross-boundary knowledge management, and highlights the role of boundary objects to mitigate problems of knowledge boundaries such transfers. Building on a comparative case study of two international technology transfer projects, the paper contributes to the understanding of how collaboration problems can affect the transfer of knowledge across knowledge boundaries and how the use of appropriate boundary objects may improve collaboration management and the knowledge transfer.

Jel Code: L20, L29, O39

Keywords: *technology transfer; international collaboration; knowledge management; knowledge boundaries; boundary objects*

1. INTRODUCTION

Beginning in the 1990s, firms in several emerging economies from China and Turkey to Brazil have started to upgrade their technological capabilities in order to change their focus from low-cost manufacturing to innovation and internationally competitive product development (Huang, Audretsch, and Hewitt 2013; Karabag and Berggren 2016;). In practice, however, many emerging economies quickly learn that it is difficult to develop innovation skills only by their own efforts in knowledge intensive industries. Therefore they seek to use international collaborations to access and absorb new technologies, which will then allow further innovations based on incremental improvements (Hobday 2005). Technology/knowledge transfer can provide several advantages for the involved organizations, but several types of complications can affect the efficiency of the transfer process. From the inter-firm collaboration perspective, these complications are related to

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factors such as asset specificity, uncertainty, conflicts of interest between the collaborators and characteristics of the knowledge (Johansson et al. 2013). From a cross-boundary knowledge management perspective, new knowledge is a crucial source of innovation, but can also generate several trypes of barriers, such as syntactic, semanetic and pragmatic basrriers (Carlile 2002; ; Karabag & Berggren, 2017).

Extant literature has identified a number of factors which might affect knowledge transfer in inter-firm collaboration projects, and also analyzes the role of boundary objects in transcending various boundaries. The study presented here extends to this literature by analyzing the relation between the factors affecting international technology transfer projects and the use of boundary objects at the relevant knowledge boundaries. Using a qualitative case study, the paper contributes to the understanding of how collaboration problems can affect the transfer of knowledge across the knowledge boundaries and how the use of boundary objects may improve collaboration management and the knowledge transfer efficiency.

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2. THEORETICAL FRAMEWORK

2.1. Knowledge and technology transfer

Battistella et al. (2015) argue that to acquire technology, the organization needs to integrate all the physical components of the technology, but also build the necessary skills and knowledge to use them. Thus technology acquisition always includes knowledge acquisition (Li-Hua 2003). Based on the relation between technology and knowledge, the literature about technology and knowledge transfer tends to analyze the two processes in a similar way. Usually, this literature focuses directly on knowledge transfer and the factors that can influence its effectiveness, whereas little or no attention is given to the necessary elements involved in transferring the physical assets, such as the costs and logistics, installation and integration with the receiver´s current equipment. In this article, the terms knowledge and technology transfer are used to refer to the knowledge related to and/or embedded in the physical technology transferred. A successful technology transfer is defined as the capacity of the receiver to re-create the transferred knowledge (Cummings and Teng 2003) and its use a source of adaptation and innovation (Hobday 2005). The receiver in a transfer process will receive the new knowledge as data, information, instructions and explanations, but since knowledge is based on individuals, the receiving individuals will combine these elements with their own experiences, values, and beliefs in order to recreate their own knowledge, (Bender and Fish 2000).

2.2. Factors and barriers that can affect technology/knowledge transfer

Various factors can affect the effectiveness of a technology transfer process. This article analyzes these factors from the inter-firm collaboration perspective and the knowledge management perspective including the role of boundary objects in this context.

The literature suggests several models to describe the process of technology transfer. An early example is the model proposed by Davenport and Prusak (1998), which focuses on four aspects: the source, the recipient, the object to be transferred and the transfer channels. The “broadcast model” suggested by Malik (2002) considers the same four aspects, b ut emphasizes technology transfer as a two-way process. A third model, the Contingent Effectiveness Technology Transfer Model proposed by Bozeman (2000) adds a fifth element, the demand environment and from that perspective analyzes the effectiveness of the technology transfer. A fourth model, proposed by Chen et al. (2014), examines the interrelationship between the transfer mechanism (replication and adaptation), the cooperative competency of the involved parties, and the performance of the knowledge transfer. In this model three factors constitute cooperative competency: trust, communication, and coordination, and mediate the effect of the chosen transfer mechanism. In a recent model, Nguyen and Ayoama (2015) argue that culture is a potential dimension that can affect the effectiveness of international technology/knowledge transfers by its influence on attitude, motivation, and complexity, and give examples of cultural differences that lead to conflicts, misunderstandings and communication barriers that affect the knowledge transfer process.

To sum up there are six main elements or dimensions recognized by the literature on technology/knowledge transfer: the source, the receiver, the object, the relationship, the transfer mechanisms and the context. These six dimensions six are chosen as the basis for the analytical model in this study. The source dimension refers to the characteristics of the actor that possesses the technology/knowledge to be transferred (Cummings and Teng 2003). In our model, three source-related factors ar important: the relevance of its knowledge for the recipient, the ackonolwedgment of its domain-specific lmowledge by thje recipient(Malik 2002), and the willingness of the source to share and transfer the knowledge (Malik 2002; Comacchio, Bonesso and Pizzi 2012).

The recipient (Receiver) dimension includes refers to the actor that receives, absorbs and makes effective use of the transferred technology. In our model, the following factors ar important: the receiver´s absorptive capacity (Chen et al. 2014), its revealed priority (Cummings and Teng 2003) and its willingness to participate, as reflected by allocation of resources and transfer of personnel.

The object dimension refers to the knowledge content of the transfer. Three factors taken are taken into account: the articulability (tacit or explicit), the embeddedness and the complexity of the transferred knowloedge.

The mechanisms or media dimension refers to the existence of formal and informal mechanisms, communication quality, existence of common ground and team-based work (Davenport and Prusak 1998), and movement of people.

The relationship dimension concerns the existence of a governance mechanism such as written contracts (Cummings and Teng 2003), explicit coordination mechanisms and the level of trust in the relation (Daellenbach and Davenport 2004).

The context dimension, finally, includes factors such as organizational culture, physical distance and project design, and expected results in terms of product/process deliverables and the role of top management (political factors).

2.3. The cross-boundary knowledge management perspective

The development of a new product requires the integration of specialized and domain-specific knowledge from several functional and technological areas (Rosenkranz et al. 2014). This knowledge, however, tends to be localized, embedded and invested in practice, which makes the integration of knowledge across areas a difficult task (Carlile 2002). The specialization of knowledge, which can provide an innovative solution in one area, may create barriers to other areas, resulting in various knowledge boundaries, which Carlile (2002) has distinguished as either syntactic, semantic or pragmatic. The *syntactic* (lexicon) boundary is related to the existence of a stable and standard syntax to allow the communication between the sender and the receiver. The *semantic* boundary is related to the interpretations of ambiguous knowledge that, even with the existence of a common syntax, can affect the communication and collaboration between the involved parties. The *pragmatic* boundary is related the existence of different disciplinary and organizational interests which need to be negotiated. To enable knowledge sharing across these boundaries, various facilitating mechanism, boundary objects, could be used. Three categories of boundary objects are often used to deal with these three types of boundaries (Carlile 2002): Repositories, standardized forms and methods, and artifacts such as prototypes, models and maps.

At the syntactic boundary, the use of physical repositories, reports, databases or libraries as references or "lexicons" are sufficient to specify requirements and interfaces, and thus allow for the needed knowledge transfer. However, it can become problematic if novelty arises, and the common reference becomes unable to specify differences and dependencies (Carlile 2004). At the semantic boundary, the use of standards for reporting and communication, and templates for cross-functional problem-solving helps to provide a shared meaning and reduce different interpretations across the boundary. However, if novelty results in different interests in each domain there will be a need for negotiations to accommodate these interests (Karabag & Berggren, 2017). This may be seen as the emergence of a pragmatic boundary. Here, effecticiency may be increased by the use of models and more complex representations (sketches, 3-D models, prototypes, mock-ups, computer simulations) showing implications across functional settings and dependencies between different functional areas (Carlile 2002). At such a boundary, the knowledge developed in one domain may negatively affect other domains, generating costs for actors to change their current domain-specific knowledge. For this reason, the boundary object needs to represent different domain interests and facilitate negotiations for the achievement of a common interest (Carlile 2004).

With the existence of different types of boundary objects, the use of the relevant ones becomes of high importance. A minimum requirement for knowledge transfer is the establishment of a shared knowledge base by the use of a common lexicon at the syntactic boundary. More advanced boundary objects, such as prototypes, needed to deal with pragmatic boundaries have the ability to deal with all the knowledge boundaries, but are more complicated and expensive, and their performance can differ from case to case (Carlile 2002) and their use needs to be selective as the necessity arises.

2.4. Analytical model

In this study, we will seek to identify key factors and boundary objects affecting international technology transfer both from the perspetive of inter-firm collaboration and from a knowledge management perspective. We will build on the following model (see Fig.1 below).

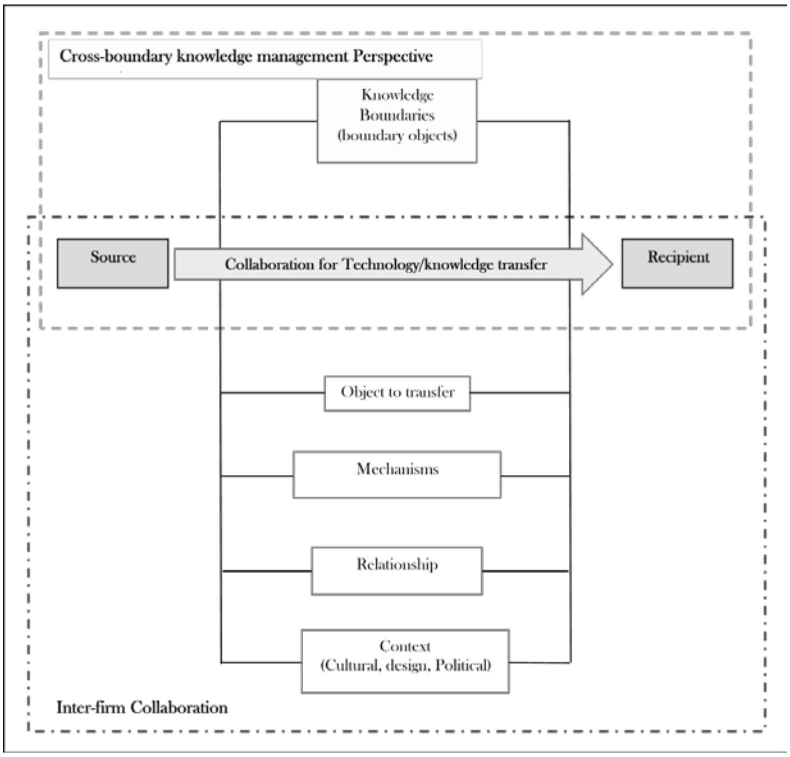

Figure 1 Analytical Framework
(Source: authors' own design based on Battistella et al. (2015) and the literature cited in section 2).

3. RESEARCH METHODOLOGY

3.1. Research design and case selection

This research has the purpose to explore factors that affect international technology transfer projects and to understand how these factors are related to the boundary objects used to facilitate knowledge transfer in these collaborations. A qualitative case study approach, involving two different technology transfer projects, was used to provide rich data and support the generation of new concepts (Gioia et al. 2013). Based on the fact that the first author is a military officer in the Brazilian Army and have been working with development of military equipment for 19 years, two international collaborative projects initiated by the Brazilian Army were chosen. The goal of the first case ("Case A") was to develop a new armored vehicle in high-priority project with a large budget, involving the Brazkilian Army and a large Italian vehicle producer. The project involved transfer of core technologies by measn of the transfer of explicit and tacit knowledge, cross-team work and externsive training, supported by explicit governance mechanisms (contracts) and frequent technical and managerial meetings.

Case B comprised a collaboration project between the Brazilian and Argentinian Armies with a low budget, low priority (at the Brazilian side), transfer only of explicit knowledge, no involvement of core technologies, separately working teams, less frequent technical and managerial meetings and lack of clear governance mechanisms. Thus the sample may be conceived as a maxium difference sample.

3.2. Data collection

The study is primarily based on data from 12 interviews with key participants, 8 interviews in Case A and 4 interviews in Case B, plus internal Brazilian Army project documentation. In addition, we used reports regarding relevant Brazilian legislation, funding agencies and government policies, as well as specialized media reports regarding military equipment and defence industry development. The interviews were mediated by Skype and complemented by written answers from both the Brazilian Army team and the Company team in Case A, and from the Brazilian and Argentinian Army Teams in Case B. Summary information regarding the interviews and the interviewees can be found in Table 1.

Table 1. Summary information regarding the interviewed participants

CASE	Interviewees' position	Partner team	Time in the team	Currently in the team	Collection Method	Transcript volume	Collection Date
A	Mechanical engineer	Brazilian Army	12	Yes	Skype interview	10 pages	01 Apr 16 03 Apr 16
	Electronic engineer	Brazilian Army	1 ½ years	No	Written answer	5 pages	29 Mar 16
	Mechanical engineer	Brazilian Army	2 ½ years	No	Written answer	4 pages	29 Mar 16
	Communication engineer	Brazilian Army	4 years	Yes	Written answer	5 pages	29 Mar 16
	Project manager (company side)	Brazilian subsidiary	3 Years	Yes	Written answer	5 pages	29 Mar 16
	Quality E	Brazilian subsidiary	5 years	Yes	Written answer	7 pages	29 Mar 16
	Manufacturing manager	Brazilian subsidiary	8 years	Yes	Written answer	5 pages	29 Mar 16
	Product development engineer	Brazilian subsidiary	5 years	Yes	Written answer	4 pages	29 Mar 16
B	Former project manager	Brazilian Army	6 ½ years	No	Skype interview	10 pages	21 Mar 16
	Former project manager	Brazilian Army	3 Years	No	Written answer	5 pages	29 Mar 16 25 Apr 16
	Current project manager	Brazilian Army	3 Years	Yes	Written answer	7 pages	13 Apr 16 25 Apr 16
	Mechanical engineer	Argentine Army	5 Years	No	Written answer	4 pages	26 Apr 16

4. CASE PRESENTATIONS

4.1. Case A: The Brazilian - Italian development collaboration

This case is based on the collaboration between the Brazilian Army, the Italian company IVECO Defence Vehicles, a part of the FIAT Group, and its Brazilian subsidiary. The collaboration involved the development of a new armoured personnel carrier and was governed by two main contracts. In the first contract the Italian company was engage to develop a new vehicle based on the Brazilian Army´s technical and operational requirements, including a prototype, a trial batch and transfer of the intellectual property of the developed vehicle. The second contract refers to the licensed production of 2000 vehicles during 20 years by the Brazilian subsidiary of the Italian company.

In addition to a jointly developed vehicle, a specific production line was built at the Brazilian subsidiary with a maximum production capacity of 200 units per year. Moreover, an external contract has been signed, and exports started to another country. Additionally, the Brazilian Army signed a new contract for the production of an armoured 4x4 military vehicle from IVECO at its subsidiary company in Brazil and a joint development of another armoured 8x8 military vehicle is under elaboration. This will be using the same transfer model as the project studied here, the intellectual property will be trasnferred to the Brazilian Army and the production will be performed under license by the IVECO Brazilian subsidiary.

4.2. Case B: The Brazilian Army/Argentine Army collaboration

In this case we studied the collaboration between the Brazilian and Argentine Armies to develop an air-transportable, general purpose, lightweight military vehicle. The main objective of the collaboration was to share risks and costs and allow the transfer of knowledge (know-how, expertise) between the partners in order to speed up the development process. The project should maximize the use of "off the shelf" parts commercially available in both countries, while fulfilling the requirements of both armies, related to the performance of the vehicle. The project originated from a political decision in 2004, based on an earlier agreement on scientific and technological exchange in the 1980s. Both partners agreed that the new vehicle should use similar percentages of Brazilian and Argentine content, that thee intellectual property would be shared equally and that each side would provide similar financial resources during the development project, without specifying these requirements in a separate contract. Each side of the collaboration intended to share its knowledge and have access to the knowledge of the other and thus both the Brazilian and the Argentine Army teams could be considered as source and recipient in the collaboration process.

5. FINDINGS

5.1. Factors affecting international technology transfers

We previously identified six main dimensions relevant for technology transfer projects. For each dimension, several factors may be of potential importance. In total, we found that 20 factors may affect a technology transfer process (see Table 2). Below we discuss each of them.

Table 2 – Six dimensions and twenty factors which may affect technology transfer

Source	Recipient	Object	Mechanisms	Relationship	Context
Technological capability	Absorptive capacity	Articulability	Formal/Informal	Governance mechanism	Organizational culture
Acknowledgement of its domain-specific competence	Priority	Embeddedness	Communication (quality/frequency)	Coordination mechanism	Policies
Willingness to participate	Willingness to participate	Complexity	Existence of a common ground	Trust relation	Physical distance
-	-	-	Team-based work	-	-
-	-	-	Movement of people	-	-

5.1.1. Source Dimension

In the studied case, the recipient quickly recognized and acknowledged the technological competence of the sender: the Italian company. Moreover, its willingness to participate in the transfer process was high based on the opportunity to access new markets, the financial return, and the opportunity for its subsidiary to absorb new technologies and knowledge. In Case B, both armies were willing to participate in the collaboration in order to reduce the risks of the development project, shorten the development time, share its costs and provide the opportunity to share and acquire knowledge.

5.1.2. Recipient dimension

The recipient's absorptive capacity (Cohen and Levinthal 1990) was described in both analyzed cases as a facilitator of the technology/knowledge transfer. A certain degree of similarity between the source and recipient, and the alignment of knowledge is necessary to provide an effective transfer. The priority given to the technology transfer collaboration affected the two cases in different ways. In Case A the priority was high, while in Case B there was a difference between the priorities of the two side of the collaboration. These differences affected the commitment at different decision levels, especially at the Brazilian side. The literature (Cummings and Teng 2003) suggests that the priority given to a technology transfer will influence motivation to support the transfer process. A strong end user's demand leads to a higher recipient motivation and is one of the main aspects in determining technology transfer success (Bozeman 2000). In Case A this factor may be seen as crucial for the success of the project.

5.1.3. Object dimension

Both cases involved highly articulable knowledge. In case A, the objects to be transferred comprised the necessary technology to produce the armoured vehicle, and the knowledge related to its development. In Case B, the transferred object was the knowledge of partners regarding their expertise on specific areas for the vehicle's development.

Another factor, the embeddedness of the knowledge, differed between the cases. In Case A, the production process involved highly embedded types of knowledge, while in Case B the embeddedness level of the transferred knowledge was low.

The last factor regarding the object dimension is the complexity of the transferred knowledge, the number of skills or competencies included and the interdependency between them (Zander and Kogut 1995). The more complex the knowledge is, the richer it is considered. It is argued (Davenport and Prusak 1998) that knowledge with higher of complexity or viscosity are more difficult to transfer and will need more apprenticeship or training to be absorbed.

In Case A, the technical knowledge involved in the collaboration was considered high, involving many different technical areas and core technologies, while in Case B the knowledge shared through the collaboration was considered medium, involving different technological areas, but without the use of core technologies. The interdependence with internal functions occurred between the tasks performed by each actor in both collaborations.

From the empirical data, it can be seen that the transfer mechanisms involved in Case A were much more complex than the technical documentation used to transfer knowledge in Case B, with not only by the technical documentation but also through intensive face-to-face interactions and joint training. These facts confirm that higher interdependency hinders technology/knowledge transfer and more personal interactions are needed to ensure the transfer effectiveness. Therefore, this is aligned with the theory, which argues that complex knowledge is more difficult to transfer (Davenport and Prusak 1998; Zander and Kogut 1995).

5.1.4. Mechanisms dimension

Formal mechanisms refer to the use of explicit rules to define the relationship in the collaboration (Sivadas and Dwyer 2000), while informal mechanisms are related to the spontaneous exchange of information (Davenport and Prusak 1998). In both cases, explicit knowledge was transferred by formal ways, including formal technical documentation exchange, access to the company databases and the formal technical and managerial meetings. Tacit knowledge was transferred by face-to-face interactions in Case A, while in Case B the teams worked separately and no perceived tacit knowledge was exchanged between the collaboration partners.

Another factor studied in the cases concerns the role of communication (cf. (Malik 2002). In Case A the communication was frequent, providing ways for the involved teams to improve their understanding, to allow mutual problem-solving and decision-making and to coordinate the tasks between actors. In Case B, the communication was sufficient for knowledge sharing, but insufficient for effectively coordinating the actions that should be performed on each side of the collaboration.

The importance of a common ground between the collaborating partners was another factor that emerged from the analysis of the cases. In Case A, the technical background between the collaboration actors was very similar in most of the technical areas involved in the vehicle's development, but in a small number of areas, there was still a lack and the Brazilian team made an effort to achieve the necessary knowledge level to be able to understand and absorb the transferred knowledge. In Case B, the technical background related to the vehicle's development was similar in most of the necessary technological areas, with complimentary expertise that helped to accelerate the vehicle's development.

This is aligned with previous literature, which claims about the importance of a common ground to improve the effectiveness of the technology/knowledge transfer and enables the fit between the source and recipient knowledge providing the receiver's ability to learn, or in other words its absorptive capacity (Cohen and Levinthal 1990).

Also, some similar knowledge background, with some diversity in specific knowledge and expertise, enabling the existence of complementary capabilities, as occurred in the analyzed cases, confirms which is argued by earlier theories. Cummings and Teng (2003) claim that some knowledge overlapping is necessary to provide the interpretation of the transferred knowledge, essential for R&D collaborations, while Cohen and Levinthal (1990) explains that, even with this overlap, the existence of diversity is necessary to provide the benefits of the linkages and associations between the diverse knowledge.

Another mechanism factor that affected the technology transfer was training. This factor includes both the preparation for the transfer process, and training on the transferred technology. In Case A there was pre-preparation for the technology transfer process at the Brazilian tea, previous experiences with international collaborations at the Italian side and training related to the absorption of knowledge and expertise during the transfer process. In Case B, there was no pre-preparation for the collaboration and no training between the partner teams. The only action considered as training for the collaboration was the work both partners developed on similar vehicle developments before the collaboration, which helped them to achieve a similar knowledge background.

The importance of training is directly linked with the last factor: movement of people between the partners to provide face-to-face interactions and team-based work. In both cases, all actor representatives participated in the technical and managerial meetings to allow the transfer of articulated knowledge and to provide joint decisions. Additionally in Case A, the communication also included the movement of people which led to exchange of high embedded and tacit knowledge. This is in accordance prevous studies, e.g. Cummings and Teng (2003) and Davenport and Prusak (1998), that movement of people can enable face-to-face interactions and learning by observing and doing, and facilitate coordination and knowledge sharing (Nguyen and Ayoama 2015). These interactions also provide socialization and help to create a trust between the partners (Malik 2002).

5.1.5. Relationship dimension

The existence of governance mechanisms, which are related to the mode of organization used in the transfer process, which can be an occasional contract, collaborations, strategic alliances, spin-offs, and others (Battistella et al. 2015), was different in the analyzed cases. In Case A, two main contracts defined the collaboration between the Brazilian Army, the Italian parent company and its Brazilian subsidiary company. These contracts the knowledge transfer, the joint development, the work to be performed, the outputs, the intellectual property, the ways for the technology transfer, the licensed production, the minimum levels of national content, the quantity that should be delivered and the delivery period. In Case B, there was no specific contract to rule the relation between the Brazilian Army and the Argentine Army and the collaboration was based on an earlier general scientific and technological cooperation agreement.

The findings are in accordance with previous literature, which argues that the existence of governance mechanisms, such as contracts, can facilitate the collaboration for technology/knowledge transfer. In fact, the use of governance mechanisms ensures the partner's commitment and the alignment of interests (Gulati et al. 2012) and creates mutual expectations and obligations by established reciprocal exchange (Bstieler and Hemmert 2015). More specifically, development contract and production contract, such as the licensed production in Case A, result in mutual understanding about what should be done in the collaboration and what are the expected results for each partner, which not occurred in a clear way in Case B.

In both cases, the partners stablished coordination mechanisms. In Case A, they stablished the roles, a unique set of technical and operational requirements, standardized tests, and formal channels of communication, cross-team, and regular technical and managerial meetings. However, in Case B, a unique set of technical and operational requirements was established, but with different views concerning evaluation tests and the priority between requirements. Also, the technical and managerial meetings did not occur with the necessary frequency, and common standards were not stablished, leading to several misaligned actions.

These empirical data suggests that the coordination mechanisms used in both cases differed in types and levels. The partners established formal channels for the exchange of explicit knowledge (Benavides-Espinosa and Ribeiro-Soriano 2014), adopted standards to provide parallel work, sequencing to provide the rational organization of the tasks, and group problem-solving and decision-making to provide the necessary mutual adjustments and solutions between them (Van de Ven et al. 1976; Grant 1996). However, their effectiveness varied as a result of some other factors, more specifically in Case B, which confirms the findings from previous literature (Gulati et al. 2012) that coordination failures can result on incompatibility of actions intended to be complimentary, and lead to abandon of the collaboration.

The last factor which emerged as important at the relationship dimension is trust, which is based on the expectation of goodwill and competence of the partner. According to previous studies, trust have a significant impact on a partner´s commitment to the collaboration (Chen et al. 2014) and thus improve the effectiveness of the technology transfer process (Davenport and Prusak 1998; Chen et al. 2014; Cummings and Teng 2003; Malik 2002). Karabag and Berggren (2016) argue that trust and trustworthiness are two of the main factors to affect the effectiveness of collaborations. Trustworthiness relates to the extent that a partner can have confidence in the other partner and is based on competence, integrity and benevolence (Karabag and Berggren 2016). In both analyzed cases, the trust level between the partners was not high at the beginning of the collaborations and improved during the collaboration, though in different levels of improvement due to the collaboration results and misalignment of interests. These findings are in accordance with the previous literature (Benavides-Espinosa and Ribeiro-Soriano 2014), which argues that if partners respond to their partner's expectations, the level of trust will gradually increase. In both cases competence helped to increase the trustworthiness, but especially in case B, trustworthiness was impacted by misalignment in overall goals and strategies.

5.1.6. Context dimension

At the context dimension, three factors were revealed by the empirical data as affecting the technology/knowledge transfer: the organizational culture, the existence of related policies and the physical distance between the partners.

In Case A, the organizational culture was different on each side of the collaboration, however, both organizations were accustomed to high levels of standardization and formalization, which helped to overcome the cultural differences. In Case B, both partners had very similar cultures, based on their military characteristics. Although this similarity facilitated the collaboration at the execution level, at the high decision level (MODs) the cultural differences created challenges for the achievement of joint decisions, which on some occasions almost led to cancel the collaboration.

These facts confirm the findings of previous literature (Nguyen and Ayoama 2015) that cultural differences can affect technology transfer, creating communication obstacles and minimizing information flow and learning, as occurred at the high level decision in Case B. Similar cultures allow a smooth working relationship between the partners in knowledge transfer processes (Cummings and Teng 2003).

Additionally, the findings from Case A also confirms that some management practice elements such as management commitment, quality practice, training, team-based work, and sharing and understanding can alter the impact of cultural differences in cross-cultural technology transfer (Nguyen and Ayoama 2015).

The next factor highlighted is the existence of policies that encourage the technology/knowledge transfer. The factor can result on government subsidies, barriers and protections for the local market, and was analyzed by Battistella et al. (2015) and Bozeman (2000) as one of the external factors that can affect the technology/knowledge transfer.

In Case A, the strategic characteristic of the collaboration provided additional funding focusing on the sustainable development of the country. The values of the contracts included the collaboration in the recent specific Brazilian government policies regarding the requirement of offsets and the preference for local produced equipment with a minimum level of national content.

In Case B, the collaboration was set under a general scientific and technological agreement, the necessary investments for this collaboration was lower than the value prescribed by the Brazilian offset policy and, based on the non-strategic value, low priority and demand by the Brazilian side, the collaboration did not count with additional financing from other Brazilian governmental funding institutions.

In accordance with what the literature suggests (Battistella et al. 2015; Bozeman 2000), the different results in the two analyzed cases show that the existence of related policies can improve the technology/knowledge transfer.

The last factor revealed on the context dimension is the physical distance between the partners in the collaboration, which is referred to the difficulty, time and costs to communicate and to provide face-to-face interactions (Cummings and Teng 2003).

In Case A, the physical distance between the partners was high. However since it was planned and the costs included in the contract values, both partners provided the necessary movement of people, for short and long training periods, to allow the technology/knowledge transfer and the technical and managerial meetings.

In Case B, since both the Brazilian and the Argentine teams were working separately, the impact of the physical distance became more noticeable. The technical channel was sufficient for the transfer of explicit knowledge, but not to provide the means for joint problem-solving and decision-making. Furthermore, the number, and frequency of the technical and managerial meetings were not sufficient since their costs, frequency and planning were not established at the beginning of the collaboration. The findings illustrate that physical distance can negatively impact on the effectiveness of the technology transfer process (Cummings and Teng 2003). However, this impact can be mitigated by the presence of other factors such as a high knowledge articulability and movement of people to provide more face-to-face interactions (see above).

5.2. Factors affecting the effectiveness of boundary objects at the knowledge boundaries

To sum up, 13 of the 20 factors discussed above as affecting the technology transfer process were also identified as positively or negatively related to the use of specific boundary objects (see overview in Table 3**).** The 13 factors include the acknowledgement of the domain-specific knowledge of the source, the recipient´s absorptive capacity, priority and willingness to participate in the collaboration, the articulability and complexity, the existence of a common ground, communication (quality and frequency), trai of the transferred knowledge, movement of people, the existence of governance and coordination mechanisms, and organizational culture. The use of boundary objects may be related to the three different types of knowledge boundaries discussed above, as syntactic, semantic and pragmatic boundaries.

At the syntactic boundary, several boundary objects such as a shared language, the similar background in technical areas and operational requirements facilitated the management of cross-boundary knowledge flows. The use of these boundary objects were facilitated by factors such as the existence of a common ground, the acknowledgment of the domain-specific knowledge, the articulability level of the knowledge, the recipient's willingness to participate, the recipient's absorptive capacity and the existence of governance and coordination mechanisms.

At the semantic boundary, standardized forms and methods provided a shared meaning and format for solving problems. In case A several boundary objects were used here such as standardized technical reports, process descriptions and communication documents, standardized software (simulation, drawing, and modelling), technical and managerial meetings to provide cross-team problem-solving and standardized evaluation methods based on international standards. The effectiveness of these boundary objects were influenced by factors such as priority (different for each partner in Case B), knowledge articulability, complexity, quality and frequency of communication, cross-team training, movement of people and differences in organizational cultures.

In case B, the a lack of more elementary boundary objects, such as standardized evaluation methods and sufficient technical and managerial meetings necessitated the use of more complex and expensive boundary objects early in the collaboration to provide a shared meaning and format for solving problems.

At the pragmatic boundary, specific objects and models are important to clarify dependencies between domain-specific areas and provide a mean for making trade-offs between different interests. The analyzed cases made use of several such boundary objects e.g. computational simulations, 3-D models, mock-ups, prototypes and results from specific evaluation tests (e.g. blast resistance, durability, etc.). The effectiveness of these boundary objects, however, were affected by factors such as different priorities, the quality and frequency of the communication and the existence of explicit governance and coordination mechanisms. The impact of the 13 factors from the inter-firm collaboration perspective on the use of boundary objects at the three knowledge boundaries is summarized in Table 3.

Table 3 The impact of collaboration-related factors on the use of boundary objects at the three knowledge boundaries

Syntactic Boundary		
Factor	**Relation**	
Common ground	Positive	Provides the basis for the establishment of repositories
Acknowledgement	Positive	Facilitates the establishment of repositories by recognizing expertise and defining responsibilities
Coordination mechanism	Positive	
Articulability	Positive	Facilitates the establishment of codification and documentation
Willingness to participate	Positive	Enables the use of repositories providing the necessary effort and capability to establish a common ground
Absorptive capacity	Positive	
Governance mechanisms	Positive	Facilitates the establishment of repositories such as reference guidelines, initial definitions and deliverables

Semantic Boundary		
Factor	**Relation**	**Description**
Priority	Negative	Different priorities between partners can lead to divergent decisions and formats for problem solving
Articulability	Positive	High knowledge articulability facilitates the establishment of shared meaning and understanding
Complexity	Negative	High complexity makes shared understanding of interdependencies difficult
Communication	Positive	Provides shared formats to solve problems and cross-team meetings for decision-making and documentation
Training	Positive	Improves understanding of less articulated knowledge (tacit knowledge)
Movement of people	Positive	
Organizational culture	Negative	May negatively impact the establishment of shared formats for solving problems

Pragmatic boundary		
Factor	**Relation**	**Description**
Priority	Negative	Different priorities related to different interests may lead to the necessity of more complex boundary objects
Complexity	Negative	High complexity reduces the understanding of interdependencies related to different interests and may the necessitate more complex boundary objects
Communication	Positive	Meetings to provide group problem solving by the use of drawings, sketches, simulation and evaluation results and prototypes
Governance mechanisms	Positive	Define resources and responsibilities for providing objects and models such as parts and prototypes and common test procedures
Coordination mechanisms	Positive	Use of objects and models which support group problem-solving and decision-making to accommodate trade-offs between different technical areas and partners

6. CONCLUSION

This study relates two different perspectives on technology transfer: the inter-firm collaboration perspective with a focus on factors that can affect the transfer process, and the cross-boundary knowledge management perspective, with a focus on knowledge boundaries that are created by differences between specialized knowledges fields and the need for appropriate boundary objects to cross these boundaries.

Based on a review of extant literature (Davenport and Prusak 1998; Malik 2002; Bozeman 2000; Chen et al. 2014; Cummings and Teng 2003; Nguyen and Ayoama 2015; Shen et al. 2015; Battistella et al. 2015) the study identified six different dimensions relevant in studies of technology transfer - source, recipient, object, mechanisms, relationship and context, in a next step distinguished several factors within each dimension. The study contributes to this literature by analyzing the relations between the factors affecting technology transfer projects, and the role of various boundary objects at the different type of knowledge boundaries. Extant literature tries to describe the most useful objects for each boundary. This study shows that the factors affecting technology transfer in inter-organizational collaborations need to be taken into consideration, since these factors may create a need for more complex boundary objects which theoretically are not expected at a given boundary, and thus affect the overall project planning. Thus the study suggests that managers need to consider the factors affecting the inter-firm collaboration, when they analyze various knowledge boundaries and select relevant boundary objects to faciliate the transfer process.

7. LIMITATIONS AND FURTHER RESEARCH

This qualitative study has identified a range of factors which may influence international techniology trasnfer projects. The particular impact of each factor needs to be studied in lasrger, quantiatitve studies. Further studies of collaborative projects for development of complex products may uncover other factors, which can influence the use of the boundary objects. For highly complex and expensive products, for example jet fighters or submarines, physical boundary objects e.g. prototypes may not be suitable, and other types of boundary objects may be needed to support the transfer, translation and transformation of knowledge across relevant knowledge boundaries.

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