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Aller au sommaire du numéro

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Résumé de l'article

Cet article évalue les risques de fuite de connaissances associés à la formation dans le cadre des contrats de transfert de technologie. Aujourd'hui, les États veulent maîtriser les technologies souveraines. En conséquence, les entreprises exportatrices ont adapté leurs offres pour répondre aux demandes des clients et donc dispenser une formation. Après avoir recueilli la perception des formateurs engagés dans ces contrats, une typologie des formateurs et de leurs comportements typiques dans les différentes situations professionnelles est proposée. Le tout conduit à des recommandations pour atténuer les fuites de connaissances.

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ABSTRACT

This paper assesses risks of knowledge leakage associated with training in technology transfers. Today states want to master sovereign technologies. As a consequence, exporting firms have adapted their offers to respond to customers' requests and provide training in technology transfer contracts. We have recorded the perception of trainers regarding risks of knowledge leakage associated with training activities. Due to different interpretations of technology transfers and related risks, trainers' assessment of knowledge leakages is not homogeneous in the training process. A typology of trainers and their typical behaviors in professional situations is proposed and leads to recommendations to mitigate knowledge leakages.

Keywords: Knowledge leakages, Risk, Technology transfers, Training, Sovereign technologies

RÉSUMÉ

Cet article évalue les risques de fuite de connaissances associés à la formation dans le cadre des contrats de transfert de technologie. Aujourd'hui, les États veulent maîtriser les technologies souveraines. En conséquence, les entreprises exportatrices ont adapté leurs offres pour répondre aux demandes des clients et donc dispenser une formation. Après avoir recueilli la perception des formateurs engagés dans ces contrats, une typologie des formateurs et de leurs comportements typiques dans les différentes situations professionnelles est proposée. Le tout conduit à des recommandations pour atténuer les fuites de connaissances.

Mots-Clés : Fuite de connaissances, Risque, Transfert de technologie, Formation, Technologies de souverainetés

RESUMEN

Este artículo evalúa los riesgos de la fuga de conocimientos asociados a la formación en los casos de transferencia de tecnología. Actualmente, los Estados desean controlar las tecnologías de soberanía. Como consecuencia, las empresas exportadoras proponen una formación en sus contratos de transferencia de tecnología. Al tomar en cuenta la percepción de los profesores que son confrontados a estas situaciones, hemos observado un riesgo importante de fuga de conocimiento. Por ello, proponemos una tipología de profesores y de sus comportamientos típicos en situación profesional, seguido de recomendaciones para disminuir dichas fugas y tener un mejor control de los conocimientos vendidos.

Palabras Clave: Fuga de conocimiento, Riesgo, Transferencia de tecnología, Formación, Tecnología de soberanía

For a state, sovereign technologies must be mastered in order to freely carry on sovereign missions with the required level of independence or, at least autonomy vis-à-vis foreign entities. Such technologies can contribute to civilian systems (e.g. nuclear power plants, railways, water supply) or defense systems (e.g. combat aircraft, submarines, frigates). In the literature, technology transfers were traditionally considered to be mainly side products of defense export contracts. They can also be seen as a complete and strategic dimension required by importing states to achieve technological leaps forward and become more independent throughout a system's lifecycle.

Technology transfers have strategic implications for firms as well as states regarding national competitiveness and international security. Sovereign industries constitute a good illustration of Ahmad *et al.* (2014, p. 27)'s assessment: "Where the leakage concerns knowledge related to an organization's valuable, rare, inimitable and non-substitutable (VRIN) resources that sustain competitive advantage, recovery can be significantly more challenging." Therefore, technology transfers are at the core of complex negotiations between countries.

Industry is adapting both its organization to respond to customers' expectations, especially through training-based technology transfers. As a result, knowledge and skills management have become highly strategic issues. This paper proposes to open the black box of technology transfer processes by leveraging the literature on knowledge management, with a focus on training activities associated with international contracts. Training is seen not just as a "favored bridge" for technology

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transfers but also as an activity associated with the risks of knowledge leakage.

This research aims to answer the following research questions: For firms implementing training activities in technology transfers, what is the level of awareness regarding the risks of knowledge leakage caused by the human factor? Moreover, is this level identical for the different actors involved in training?

This work is original in the literature. First, research on means and processes developed by firms to manage their intangible assets remains rare in the literature (Barbaroux and Godé, 2012). More particularly, knowledge leakage appears to be an underdeveloped issue (Durst and Ferenhof, 2014).

Second, studies on knowledge management hardly ever consider how knowledge can be protected while implementing technology transfer commitments (Desouza, 2005). We focus on sovereign technologies, which combine the commercial interests of firms and the strategic imperatives of states. More particularly, we explore the micro-sources of knowledge leakage caused by the people involved in training activities, an important point regarding future research in knowledge management (Foss *et al*., 2010). The literature underlines that most security breaches and competitive intelligence operations exploit non-technical weaknesses of an organization (Colwill, 2009; Desouza, 2006). We have analyzed the discourse of stakeholders to understand their personal representation of technology transfers. As our empirical research looks at intangible assets and sensitive industries, a qualitative and exploratory method would appear to be more appropriate to understand trainers' activities and behaviors better. It combines both semi-directive interviews and a lexicometric analysis.

Third, training remains an understudied research field in knowledge management despite major stakes. We suggest some training management practices in the context of international technology transfers in order to better identify knowledge leakages and protect the strategic assets of firms and states.

The article is divided into four sections. The first section presents a literature review of knowledge leakage and focuses on possible knowledge leakage through technology transfers in sovereign technologies. Training activities and the role of trainers are presented to introduce the empirical research. The second section presents the selected methodology. The third section presents results and the fourth section discusses empirical results and management practices.

Knowledge Leakage and Training in Technology Transfers

The Knowledge Leakage Literature

In the technology base of a firm intangible assets often refer to patents, technical skills, experience, knowledge and knowhow, involvement and attitude of employees, reputation, etc. that go well beyond formal intellectual property.

Knowledge can be defined as a fluid mix of framed experiences, values, contextual information and expert insight (Davenport and Prusak, 1998). In a knowledge-based view, competitiveness and performance of the firm depend on knowledge (Easterby-Smith *et al*., 2008). Knowledge assets increasingly constitute the basis of competitive advantages and creation of value for firms (Mentzas *et al*., 2003). Although, the literature underlines difficulties in precisely identifying knowledge in firms and measuring it, one can classify knowledge assets into four categories (cf. Table 1).

Polanyi (1967) made the distinction between "explicit" and "tacit" knowledge. Explicit knowledge can be codified and is most often legally protected and transmitted in a formal language. Information technologies enhance this feature of transmission. On the contrary, tacit knowledge is either difficult to codify or non-codifiable (Nonaka and Takeuchi 1995). At the individual level, tacit knowledge is rooted in action or a specific context of a person's experience and its transmission requires intensive and repeated human contacts and interactions – often requiring learning-by-doing and learning-by-learning. Given its main features, tacit knowledge is then assumed to be an important component in a firm's technology base.

In a knowledge-based view of the firm, a leakage or loss of knowledge is associated with a decrease in performance. Research dedicated to knowledge protection remains quite scant (Desouza, 2006) notably from an empirical perspective (Durst and Ferenhof, 2014). Some specific knowledge management issues (such as transfer or acquisition) have been intensively studied contrary to knowledge leakage (Parker, 2012). More particularly, few pieces of research have examined the causes or drivers of harmful knowledge transfers, such as knowledge leakage through partnerships (Jiang *et al*. 2013). Literature calls for more research into the potentially harmful effects of sharing and leakage in knowledge management (Foss *et al*., 2010).

TABLE 1
Four categories of knowledge assets

Experiential Knowledge Assets Tacit knowledge shared through common experiences • Skills and know-how of individuals • Care, love, trust and security • Energy, passion and tension	**Conceptual Knowledge Assets** Explicit knowledge articulated through images, symbols and language • Product concepts • Design • Brand equity
Routine Knowledge Assets Tacit knowledge routinized and embedded in actions and practices • Know-how in daily operations • Organizational routines • Organizational culture	**Systemic Knowledge Assets** Systemized and package explicit knowledge • Documents, specifications, manuals • Database • Patents and licenses

Source: Nonaka *et al*. (2000, p. 20)

Knowledge leakage has become a key concern in organizations as well as an important area of research, with two major main sources (Durst and Ferenhof, 2014).

The first source consists of a shortage of knowledge and capability, that is, employees who retire, leave an organization or move from one organization to another. In such situations, when people leave an organization, they take knowledge with them, especially tacit knowledge linked to their own experience, without any obvious or immediate substitute.

The second source consists of knowledge exposure, which occurs when organizations enter into strategic alliances (e.g. joint venture, outsourcing, consulting) or whenever parts of their core knowledge are transferred to others. This is the case when a firm voluntarily transfers knowledge in accordance with formal agreements (e.g. sales contracts with offset).

The literature on knowledge leakage has mainly focused on the use of boundary-spanning information and communication technologies (Ahmad *et al*., 2015) through social media (Colwill, 2009), publications (Jansen, 2010), emails (Caravalho *et al*., 2009) and portable data devices (Agudelo *et al*., 2016). Sensitive data, information, and knowledge can be disclosed to unauthorized parties by mistake (Norman 2001). Leakage most likely occurs in codified knowledge, because it can be more easily formalized and copied than tacit knowledge (Hurmelinna *et al*., 2007).

This paper enriches this literature by examining trainers' behaviors in offset-related technology transfers, which constitute a specific form of cooperation between firms since they are contractually required. We address the question of both forms of knowledge (codified and tacit) with, however, a greater attention paid to the tacit dimension of knowledge.

An Increasing Role of Technology Transfers in International Trade With Offset Policies

Technology transfers are a category of offsets (Ianakiev, 2014, p. 252). A direct offset can be defined as an offset transaction directly related to the exported product (or service). An indirect offset is an unrelated transaction. Figure 1 shows that technology transfers are a hybrid category.

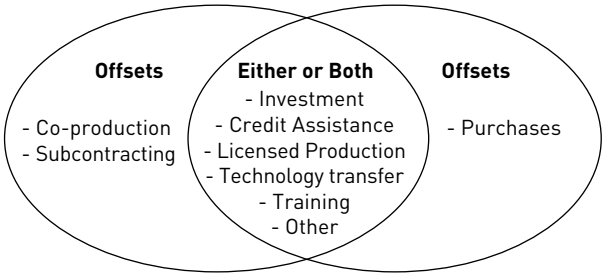
In this article, we define technology transfers as the process through which a technology developed by a firm in country A is transferred to another firm in country B. Thus, technology transfers can be seen as "goods" – or intangible assets – sold along with complex systems such as transportation (trains, aircraft, etc.), energy (power plants, etc.) or defense systems (fighter aircraft, frigates, submarines, etc. (cf. Table 2)).

The study deals with sovereign technology transfers from French firms, with a focus on emerging countries. For the sake of a simple illustration, here are a few examples of such technology transfers:

Technology transfers are now well-established practices in international trade. Historically, such transfers took the form of "turnkey' equipment solutions". Practices in technology transfers have progressively been evolving to deliver a system with the embedded technology.

Today, importing countries increasingly look for autonomy regarding technology and systems engineering. Consequently, technology transfers imply a more qualitative content. Furthermore, in sovereign technologies, such transfers often take place in a politically sensitive context since products usually contribute to national security. In the international defense market, successful sales are increasingly linked to fulfilling offset requirements that have steadily increased since the 1970s (Brauer and Dunne, 2004).

FIGURE 1
Categories of offsets



Source: DCBIS (2015, p. 28)

TABLE 2
Selection of Technology Transfer

Sector	Firm	Emitting country	Receiving country	Year	Description of the transfer of technology
Nuclear industry	Framatome	France	South Korean	1981	Nuclear power plant.
Nuclear Industry	Areva	France	China	1991	AFA 2G fuel technology
Nuclear Industry	Areva	France	China	2005	Supply in nuclear fuel the four nuclear plants of Hongyanhe.
Nuclear Industry	Areva	France	Russia	2007	Nuclear fuel technology to the Russian firm TENEX.
Rail Industry	Alstom	France	China	2003	Pendolino trains. Italian technology of 1rst generation (250 km/h).
Defense industry	Thales	France	Malaysia	2011	Combat system (Tacticos) to equip the latest Malaysian corvettes.
Defense industry	Naval Group	France	Saudi Arabia	1994	Combat frigates (Sawari 2).
Defense industry	Naval Group	France	Brazil	2008	Conventional submarines (Scorpène), design of the hull of a nuclear submarine, a naval base / shipyard.

Source: authors

Issues About Knowledge Leakages in Sovereign Technologies

If technology transfers are likely to bring some advantages to firms such as improving innovation capabilities, increasing the pace of innovation, strengthening their competitive advantages, leveraging the local defense technological and industrial base, they also have a "dark side": knowledge leakage (Frishammar *et al*., 2015). Such a leakage may be responsible for an increasing proliferation of technology and a loss of competitive and strategic edge for the exporting country and firms involved.

This questioning is of particular importance in relation to critical technologies which have an impact on strategic industries or the military superiority of the exporting country. Therefore, technology transfers in sovereign technologies are at the core of a complex nexus between industrial and national issues (cf. Table 3).

Technology Transfers and States' Offset Policies

Technology transfers have become a prerequisite to achieve exports of strategic systems. Accepting technology transfers is a way to maintain strategic skills and knowledge domestically. It can also be an opportunity to find new political partners for future cooperation to develop systems further, a process sometimes qualified as "political offsets" (Hébert, 1996).

Nevertheless, a country has to keep in mind that today's customer might become an enemy tomorrow. Even though a conflict can appear unlikely, the importing country can become a competitor if it succeeds in mastering transferred technology (King and Nowack, 2003). Proliferation of sovereign technologies can potentially increase the probability of conflict or nuclear proliferation. This might also entail a political cost regarding both the image and reputation of a country.

Technology Transfers, Knowledge Leakage and Firms

From the firm's perspective, accepting such transfers can open the way to new industrial development, larger economies of scale and improved learning effects, and creates opportunities to find new suppliers and industrial partners. For example, through the sale of F15 fighter aircraft to Switzerland, Northrop and General Electric built industrial partnerships with Swiss firms. If involved in the industrial and technological experiments of the importing country, the selling firm is able to observe new methods, skills and even knowledge developed by the purchasing firm. This practical field experience, gained without having to bear the expense, is all the more interesting in the case of high sunk costs (e.g. submarines, nuclear power plants, etc.).

However, since technology transfers are not the core business of firms, organizing such activities brings additional direct costs (e.g. translation of technical documents, training employees as trainers, building dedicated facilities). Through technology transfers, the selling firm is likely to lose control over critical intangible assets. They open the door to knowledge leakages, i.e. "the extent to which the focal firm's private knowledge is intentionally appropriated by or unintentionally transferred to partners" (Jiang *et al*., 2013, p. 984). As the firm's proprietary technology could be disseminated (Lau *et al*., 2010, p. 966), its non-price competitiveness and innovation capacities can be affected. Even worse, because of their "absorption capabilities" (Cohen and Levinthal, 1990) newcomers can eventually become true competitors for the selling firm. As a result, knowledge transfers must remain under control to avoid involuntary knowledge leakages and limit the loss of intangible assets. Knowledge leakage is difficult to assess – and even harder to control – because it can be unconscious, uncontrolled, and beneficial to only one party (Frishammar *et al*., 2015).

Training as a Requirement for Transferring Tacit Knowledge

In technology transfers, three types of "vehicles" can be identified: technical assistance, documentation, and training. Technical assistance, covering several kinds of services, often includes maintenance, repair and overhaul operations. Technical documentation refers to blueprints, user guides and their translation. Training includes different forms from basic training of end-users and maintenance operators up to scientific and technological training for engineers to give them the ability to design the whole system. The issue is no longer to train workers to assemble a product with detailed handbooks, but to train engineers in R&D to enable them to modify, retrofit, improve or even design the whole system.

TABLE 3
Main issues for countries and firms selling technology

	State	Firm
Advantages	**Export contracts** (trade balance, increase the size of series and make systems more affordable). **Maintaining strategic skills** and knowledge to preserve DTIB. **New political and military partners for future cooperation**. Political side of technology transfers.	**New markets**. New possibilities of increased industrial production. **Economies of scale** **New suppliers and partners**. Increased competitiveness (quality and price). **Free-of-charge learning curve**. Laboratory to observe new methods in "real life".
Disadvantages	**Customer of today is a potential enemy tomorrow**. Customer country might use the technology against the seller. **Spreading**. Political cost of a deterioration of the image and reputation.	**Cost of organizing training.** Additional direct cost associated with the organization of technology transfers. **Potential loss of knowledge.** Technology transfers are likely to cause knowledge leaks with effect on firm competitiveness.

Source: authors

This brings new issues for firms that need to modify and sometimes redefine the knowledge they could sell. New organizational issues arise such as defining the contents of training programs or setting up pedagogic means and training tools. In technology transfers today, a large part of the process consists in organizing training programs that guarantee the effectiveness of technology transfers.

First, these programs involve many different kinds of expertise from specialized workers to engineers highly-qualified in the design of systems and management because customers want to understand and appropriate the whole industrial process. In such complex systems, the global management of design often matters for customers. For example, boats or submarines can be built using two methods: a systemic vision (e.g. hull, engine, weapon system, etc.) or a section-based design where the product is simply "sliced" into sections. Both methods have advantages and disadvantages, and customers often try to obtain access to the information about this choice.

Second, training programs involve specific time and spatial constraints. Technology transfers require long-term organization and often involve geographical constraints related to the distance between the selling firm (or country) and the receiving firm. For example, France sells submarines with a 30-year contract, to Brazil and Australia, that involves many exchanges between countries and firms separated by thousands of kilometers.

Third, training programs imply a wide range of training and educational tools with a mix of theoretical and empirical knowledge and in-situ learning-by-doing. Basically, three main training channels exist (Table 4): lectures, practical work and learning-by-doing. One can also add a very different channel called here "interstitial periods", which refers to the time that trainers spend with customers outside working hours.

Training involves the transmission of both the explicit and implicit knowledge that is necessary to master technology. Explicit knowledge can be transmitted by an *ad hoc* medium such as technical documentation. On the contrary, tacit knowledge requires intensive and repeated contacts between trainers and trainees. Depending on the knowledge transmitted, a "degree of tacitness" can be associated. It also brings new problems because it is hard or even impossible to measure to what extent the technology has been both transferred and absorbed. Since they want to access tacit knowledge, customers tend to increasingly ask for learning-by-doing training, often as a contractual requirement. In addition, firms easily use learning-by-doing training because it is easy and cheaper to organize: it requires no specific infrastructure, no specific course and content, and no specific skills.

The complex systems we study are often based on industrial capabilities in which critical knowledge is tacit due to limited production and advanced technologies. Indeed, it is assumed that the performance of these systems is often related to precise actions and specific technical elements of industrial process (e.g. a specific way to weld two elements), a knowledge accumulated during years and even decades. Tacit knowledge is embodied in the habits and routines of employees. Sometimes people are not aware of the importance of such tacit knowledge and can transmit it without being aware of the related risks or even that they are passing it on. Tacit knowledge is thus difficult to control and manage (Cowan *et al.*, 2000).

In technology transfers, training is also a source of knowledge leakages. Our contribution to the study of the micro-sources of leakage is through focusing on trainers' behavior. Tacit knowledge is at the core of relations between the transferring firm and the receiving firm. One can thus identify a dilemma: the transferring firm aims to protect and control what is transferred whereas the receiving firm's goal is to capture as much knowledge as possible to enhance its competencies. The identification of the underlying risks of leakage associated with this dilemma is likely to have an effect on the behavior of the people in charge of training during technology transfers.

Trainers can be responsible for leakages through their spontaneous behavior and personal interpretation of context and situations. For example, such an interpretation matters when trainers arbitrarily consider whether or not to provide knowhow.

TABLE 4
Main training channels encountered in technology transfers

Main training channels	"Learning by doing"	Practical work situations	Lectures	"Interstitial periods"
Description	– job on the field / on the job training – learning situations with direct contact with employees in real professional situations.	– Practical works – learning situations out of real professional situations.	– Lectures with theoretical contents and analysis of technical documentation. – Top down learning situations with presentation of concepts.	– Time spent by trainers with customers out of contractual working hours – evening, holidays, week-ends
Who trains?	– Technology transfers project managers – Intermediate managers – Technicians / Skilled blue-collars	– Technology transfers project managers – Engineers head of technical domain – Technicians / Skilled blue-collars	– CEO, program managers, unit, division or sector – Engineers head of technical domain	– All the members of the technology transfers' team
Level of codification of knowledge	high	low	high	low
Level of tacit knowledge	medium	high	medium	undetermined

Source: authors

In spite of the firm's guidelines on what to transmit, they could take the initiative to protect that knowledge if they consider it to be a national and strategic heritage that must be protected. As such it is important to investigate how trainers actually deal with this dilemma and to what extent the firm is aware, and thus able to control what is really provided through the training process and thereby pinpoint knowledge leakages.

Method

Panel Population and Data Collection

Empirical material comes from a selected panel of 6 strategic French firms operating in different sovereign industries: shipbuilding, electronics, energy, transport and aeronautics. Due to the sensitiveness of related information, it is not possible to disclose individual data but they share distinctive features. They are all considered as "great national champions", created and managed by the French state before being privatized. Focusing for ages essentially on the state's needs, they are not really accustomed to dealing with foreign customers, which have become more important as they can no longer rely on the domestic market.

Semi-structured interviews were conducted over two years (2013 and 2014). They lasted between 60 and 90 minutes, and they were structured around five major questions: Can you describe and explain your activities within the firm? Can you describe your initial training and professional career? How would you define a technology transfer? What is your experience in technology transfer programs? And, according to you, what are the main difficulties, risks and challenges in technology transfers? Interviews are considered as a means to link the professional practice of interviewees to their representations of the profession, values, interests and any symbolic dimensions.

TABLE 5
Panel population

Qualification and function		Number
Skilled blue-collars		3
Technicians		3
Engineers and managers	Middle managers	8
	Engineers: heads of technical domain	5
	Technology transfer project managers	2
	CEO, program managers, unit, division or sector	3

Source: authors

So, it is interesting to ask interviewees with various profiles (e.g. workers, heads, engineers…) to see whether differences of opinion and interpretation emerge.

We used interviews to assess the referential framework of each actor: main purposes, intentions and knowledge involved in training activities. 24 representative interviews presented in Table 5 were completely transcribed in a verbatim (from a total panel of 60 initial interviews).

We conducted a lexicometric analysis using the Alceste method[1] (Reinert, 1990). Our data were implemented in IramuteQ with the free R software[2] The data were coded with two variables for each interview, one as a proxy of the age of the interviewees (three different "ages" have been coded: beginner, expert, senior) and another for six socio-professional level. The exploratory analysis consisted in cross-checking the content of actors' observations and their positions on topics according to their profiles to define different classes of discourses. Some qualitative information collected during interviews completed the lexicometric approach, especially when it came to defining and naming the different classes.

Results

Figure 2 shows five classes of discourse. Thanks to added variables that associate interviewees with their respective discourse in the dataset, the lexicometric analysis enables actors who gave rise to the classes of discourses to be identified and ranked by statistically significant socio-professional categories.[3]

It appears that each class of discourse can be associated with a given socio-professional category. The resulting four main classes represent the different kinds of representations, intentions and logic held by people when they are involved in training associated with technology transfers. Classes 4 and 5 are very close to each other and technically can be considered as a single class of response. They deal with the experiences and problems of two employee categories: workers /technicians, and intermediate engineers.

The lexical analysis shows the different representations of technology transfers among the different professional groups. Dilemmas, i.e. great oppositions in the discourse and representations of actors, can be identified. Dilemmas as the "subjective construct about the actors' experience" (Ria, *et al.*, 2001) help to highlight "contradictory realities for the actor" (Bateson, 1984). The identification of potential dilemmas regarding trainer activity helps to define the "backbone" of their reference frame and to understand the guiding principles involved in the "sense-making of their activity" (Weick, 1995). Dilemmas and differences in terms of representations and intentions may represent a risk of knowledge leakage during technology transfers.

Class 1: "Training as a Business as Usual"

Class 1 includes terms referring to business environment and the strategic management of the firm. For example, it is mostly based on terms such as technology, manufacture, produce, develop or transfer. Practical and local problems that trainers could experience are not considered.

In addition, Class 1 discourse is composed of terms referring to a global and competitive business environment. This vocabulary can be associated with the global strategy developed

1. One can refer to Lebart and Salem (1994) for details on the method.
2. See Ratineau and Marchand (2012) for an example of application.
3. Because of the confidentiality constraint, it is not possible to explicitly display the names of both employees and firms.

by CEOs, program directors and executive committee members, main top-level managers of technology transfers in a contractual perspective. No reference to training as a professional practice is mentioned even if these people are sometimes part of training plans, especially initial presentations to customers.

Class 1 discourses mostly belong to senior executive officers (1) and top managers (2) who give main industrial and strategic orientations. These interviewees are sensitive to the political dimension of sovereign technology exports because they are in strong interaction with political decision-makers. Very few of them question technology transfers that are simply part of the evolution of industrial practices. *"Our industries will die if they do not export. We prefer to transfer knowledge rather than having a million unemployed people in our country."* (a member of an executive committee).

They do not seem to identify any risk of knowledge leakage since technology transfers are codified and bounded in the contract. They tend to consider that, at their respective level, each dimension of the contract has been supervised and validated. They trust the effectiveness of the firm's organization to protect its own interests. *"There are no big risks in technology transfers. Everything is very well legally regulated. I always have in mind the example of Coca Cola with their over-protected recipe although everybody drinks Coca Cola all over the world"* (a project manager). According to them, the main source of risk arises when engineers – or sometimes technicians – passionately teach about their domain of expertise, with too many details and explanations. *"The only danger is that our technical experts leak a little too much information when they give a course. They have very high technical skills and are deeply involved in their technical field"* (a member of an executive committee).

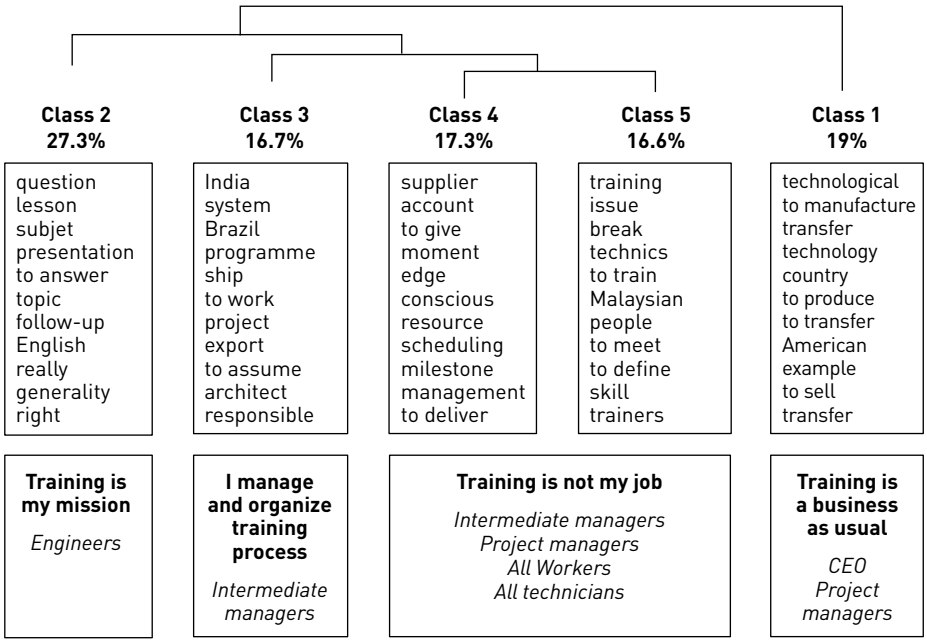
According to them, the only dilemma is related to the level of knowledge to be transferred as defined during the negotiation of contract. Such a level must be the lowest possible, but high enough to help win the contract and satisfy customer's requirements. Their purpose is to implement contractual commitments and to satisfy customers, because fulfillment results in payment. Otherwise, customers may complain to the authorities of the importing country, which may eventually impact firm's executives. In extreme cases, a loss of confidence can result in suspending or even canceling the contract.

Class 2: "Training is my Mission"

Class 2 comprises words belonging to the lexicon of education and training (e.g. question, answer, classroom, module, lecture, presentation, etc.). These terms refer to "classroom environment" and come from engineers focusing on a training situation with students, often top experts in their domain. Our results show a great heterogeneity in terms of age (from 30 to 50) and professional experience (not only in technical fields).

Class 2 people are not involved in managing technology transfer projects. They have in-house trainer profiles or deliver courses outside the firm thanks to regular links with local universities or schools. They usually become involved in technology transfer projects only to provide few hours of training: from two days to several dozen days, depending on topics and the number of available engineers. Some of them do not willfully implement training but are required to do so because of their expertise.

FIGURE 2
Lexical analysis of the trainers 'discourse



Source: authors, with IramuteQ software, verbatim focusing on a panel of 24 representative interviews (corpus of 130.959 words)

Engineers express the greater diversity in terms of attitude and representation regarding technology transfers. They have several questions regarding their training activity: about the firm's responsibility and reputation, the high or low price paid by the customer, their personal involvement, the risk that the customer becomes a competitor, and the lack of recognition for their commitment to training activities. *"We have the duty to be honest because the customer spends a lot of money on training and it is then necessary to provide a good quality service [...] It's a state-to-state agreement, we knew we were a little freer in this case."* (an engineer, head of a technical domain).

In fact, many Class 2 interviewees consider that training activity goes too far regarding the transmission of technical contents and assume a risk of knowledge leakages. Contrary to other trainers, they are totally aware of the motives and consequences of their actions. *"If the system fails with human losses, I will feel responsible. I won't be able to live with that in mind. So when it comes to technical stuff, I don't fool around when it deals with security issues. I do everything I need to make it work. If it is necessary, I transmit more information than what was initially requested"* (an engineer).

They feel a strong ambiguity between giving too much knowledge to the customer and not giving enough knowledge with regard to contractual commitments. Consequently, they tend to modify the content of training towards more (or less) transmitted knowledge.

Class 3: "I Manage and Organize the Training Process"

Class 3 comprises terms referring to both the origin of clients (e.g. India, Brazil, China, Korea, etc.) and technologies or systems that are manufactured by firms (e.g. boat, system, aircraft, etc.). It also comprises other terms referring more to the concrete organization of training activities in the industrial field (e.g. program, work, manager, architect).

Class 3 discourse refers to a kind of middle manager position between the trainers in the field and top executives of the firm.

Engineers belonging to Class 3 have to organize training. According to them, training is a kind of product that needs to be managed and delivered following an industrial mode of production to meet customers' requirements, i.e. training schedules and control of trainees' knowledge, in due time. They simply adapt industrial organization to a new product: training.

In a middle manager's tasks, training is intimately associated with the manufacturing agenda, thus requiring some fine-tuning: training must be delivered but it cannot slow down ongoing production. For example, if a middle manager needs an engine to train customers, any delay in the engine delivery will upset the production agenda. As a result, middle managers often have to quickly set up practical exercises because trainees are paying for training and cannot wait. *"It should be noted that if one of the 3 items (training, construction, documentation) does not pass the milestone, it will block the payment key of the complete training package with some additional financial penalties. We are in a state of emergency and permanent reorganization in order to satisfy the customer."* (a middle manager). Middle managers thus face a stressful and permanent tension between the industrial schedule and training contents interfering with such a timetable. Transferring knowledge is their main objective and there is no personal questioning regarding risk of leakage when knowledge is transferred.

Classes 4 And 5: "Training is not My Job"

Class 4 and Class 5 both comprise the discourse of people who consider that training is not one of their professional tasks. In their discourses, there is no clear border as to what is and what is not training. They mainly speak about their job and imposed constraints when customers are in the workshop. They do not seem to be aware of strategic issues associated with knowledge and techniques they master and teach.

Class 4 and 5 discourses are found in workers and technicians with a lexicon belonging to their daily working life with a higher representation of words such as technical, difficulty, milestone, planning, supplier deliveries, etc. In terms of social representation of technology transfers, workers and technicians are a homogeneous category. Some technicians give back-to-basics lectures, which is not the case for workers who mainly implement learning-by-doing training.

Two subcategories can be defined. For some people, training is perceived as an imposed activity, which is clearly not rewarded (with advancement or bonuses, for example). As a result, training is often considered as a waste of time. *"As a worker, I was impressed at first. When they were introduced at the beginning of the session, I saw a dozen specialized engineers [...] I told myself that I was not sure to have something to teach them. But fortunately, they did not want a complete course in my technical field, they only wanted to see how I concretely did my job and to understand my own way of operating."* (a skilled worker).

For others, training is desired. Workers and technicians voluntarily commit and are really interested in teaching. In addition, they like to speak English – commonly used in training related to technology transfers – and, if they have to visit receiving firms, the expatriate status is perceived as rewarding.

However, workers and technicians never questioned the strategic dimension of transferred knowledge. In their discourse, no reference to potential knowledge leakages is found. More particularly, workers do not seem to perceive such a risk or to be aware that their skills can be highly strategic. Their attitude regarding technology transfers can be qualified as "passive attitude" or "unintentional attitude".

Discussion and Consequences on Management Practices

Empirical results highlight the wide diversity of commitments and representations of actors involved in technology transfers. First, the degree of awareness is quite low with overconfidence in informal and contractual frameworks. In addition, the diversity of representations is an important risk factor in mastering knowledge transfers without jeopardizing the firm's intangible assets (and the country's strategic assets). Second, our classification of discourse shows that the level of awareness clearly depends on socio-professional levels. To a certain extent, every person involved seems to individually redefine

TABLE 6
Main training channels, classes encountered and nature of knowledge

Main training channels	Learning by doing	Practical work situations	Lectures	"Interstitial periods"
Level of codification of knowledge	low	high	high	low
Level of tacit knowledge	high	medium	medium	undetermined
Classes				
Class 1	-	-	+	+
Class 2	-	+++	+++	+
Class 3	+++	+++	-	++
Class 4/ Class 5	+++	+++	-	++

Source: authors

contractual terms regarding technology transfers. Our results underline how important it is to prepare not only occasional trainers but also the whole management chain of technology transfers to prevent knowledge leakage.

To discuss our results, we look at the different training channels identified (cf. Table 4) and relate them to our classes to establish whether protection mechanisms could be applied to prevent knowledge leakage.

Table 6 links trainers' profiles to training channels that we have identified in technology transfers. Learning-by-doing mostly involves workers and technicians (Class 4 and 5) and middle managers (Class 3). Transmitted knowledge is mostly tacit. This is the major source of knowledge leakage, since the related population is not aware of the strategic nature of their professional knowledge, especially when it is tacit. To ensure a better protection, it would be necessary to explain to trainers how important both experiential and routine knowledge embodied in their daily activity can be (Nonaka *et al.*, 2000). This also implies a better recognition of their knowledge within the firm. In addition, firms should limit these transmission channels when they implement technology transfers.

Firms should set specific training frameworks to limit the risk of knowledge leakage caused by "excessive amounts of" on-the-job training. Obviously, this requires specific training practices and also qualified – and often costly – personnel for the management of training (e.g. "pedagogical engineers"). This is particularly relevant for this "hidden" knowledge, which is hard to codify but necessary to insert in a specific training framework with the objective of having better control over the knowledge transmitted and more specifically transmission parameters.

Practical work situations involve almost all classes except Class 1 (Top-executives and program directors). In such situations, training programs are well planned, organized and codified by firms and eventually often approved by public authorities. To some extent, such a process limits the tacitness of transmitted knowledge. However, these situations are expensive because they require some specifically dedicated trainers (to design learning situations) and specific infrastructure (e.g. training rooms and devices). They also induce some verification and control costs. Moreover, people dedicated to this specific task within the firm are not available for productive tasks, hence an opportunity cost which can be mitigated thanks to online or virtual-reality training.

Lectures mostly involve top executives and program directors (Class 1) but also specialized engineers (Class 2). This population has great confidence in contractual and legal protection tools. They are often at the source of contracts and perfectly know their content, and this is checked by public authorities. Such a codified nature reduces the risk of knowledge leakage. However, materials are formally presented during lessons and oral communication reintroduces tacitness in the loop. Strategic information is thus likely to be disclosed. For instance, students can ask challenging questions to a teacher/trainer who is not just an expert in his technical domain but also a passionate professional. To avoid such a risk, trainers can be trained to cope with in-depth and insistent questions and develop some oral expression techniques to voluntarily control transmitted information. Again, technology can help and remote classes are interesting to ensure a better control.

Finally, empirical research underlines the role of time and spatial characteristics of technology transfers. Strong interactions over long periods favor intimacy that leads to increasing trust, as our interviews note. Trust facilitates exchange of tacit, fine-grained information between firms (Li *et al.*, 2010) through organizational openness greater than scheduled (Andersen, 2012). Our research provides additional insight into the difficulties related to very long training programs that also require taking care of clients during "interstitial periods" (between in-situ training periods). These periods are rarely thought of by organizations and pose great difficulties for their management because revealed contents are not identifiable. Indeed, the intimacy grows between trainers and trainees; progressively it reduces and blurs boundaries between firms that are potential competitors in the long run, thus lowering precautions that trainers take to avoid knowledge leakages. Thus, the longer external people are embedded within a firm, the stronger trainers' training must be to set up safeguard mechanisms against involuntary knowledge leakages.

All classes are concerned by such a situation but people who are expatriated for longer are the most affected. Top-executives and top-managers are relatively less concerned. People of Classes 3, 4 and 5 often spend their evenings, days-off and week-ends

together with customers. They meet several times during these interstitial periods. They usually share the same professional positions or even identify themselves with their counterparts here or abroad. Technicians and workers more particularly have experiential knowledge and they are not aware of the strategic dimensions of their knowledge. Management should strive to minimize their involvement in interstitial periods. One possibility is to increase the turnover of teams here or abroad. However, it is difficult given the specific and rare skills involved in the technology transfers in complex systems and because few of them speak English.

Changing the Model of Training for the Transfer of Technology

The management of training for technology transfers poses different problems for complex systems. Firms tend to favor "learning-by-doing" for several reasons. First, learning-by-doing is easy to set up from an organizational point of view when it is compared to other training situations (e.g. lectures). Second, it is less expensive with no opportunity costs. Third, one cannot master complex systems without learning-by-doing. Firms do not question themselves enough about the strategic importance of knowledge embodied in the people who are chosen to teach. We propose ways to help firms to better understand and mitigate the risks associated with training in technology transfers.

Knowledge is in the Air, or the Importance of "Know Who"

For complex systems, technology transfers are of utmost importance to save time and avoid failure. This is why requirements increasingly focus on in-situ training, since this represents the best solution to grab tacit knowledge that "floats in the air". Being as close as possible to industrial ecosystems constitutes the best means to acquire effectively related skills. As a consequence, receiving firms expect to interact not only with integrators but also their industrial partners throughout the value chain to be able to replicate all industrial skills.

Complex systems involve several interlocutors mastering several subsystems and components with a key role for integrators throughout the value chain. Thus, the effectiveness of the industrial process relies on many pieces of collective knowledge. Complex systems thus lead to complex networks of knowledge, with many layers of tacit knowledge, understandable if and only if there are insertions and interactions within the related ecosystem. In such a context, the knowledge of each employee can be strategic because it helps to better understand how to design and produce a complex system. This embedded collective knowledge, found in routines and embedded knowledge, results from the process of acquiring a shared understanding (Cohendet and Llerena, 1999, p. 219). In addition to the number of participants, the transformation of tacit knowledge into codified knowledge is very difficult and also increases the risk of knowledge leakages.

Such a dimension must be integrated in the design of training programs. Knowledge is also acquired in-situ through a better understanding of observed industrial networks and informal exchanges with trainers throughout training periods. As previously underlined, barriers between trainees and trainers are likely to blur over time, favoring open discussions that can reveal a lot of knowhow and know-who. This represents a true challenge to keep technology transfers under control, even beyond the firm's sites.

Leakage Mitigation as a Strategic Capability of the Firm

All people involved in offset-related training activities must become aware that unprepared actions or inappropriate behaviors can result in the leaking of knowledge. This is especially true in sovereign industries where secrecy has been the traditional means to control knowledge leakages. When opening up to third-party players for contractual requirements, in-house actors have not been prepared to make the right choices. Thus, our empirical research validates Ahmad *et al.*'s (2014, p. 29) statement: "Formal controls include risk assessments, audits, and policies and procedures that provide advice to personnel on the one hand and outline punitive measures for non-compliance on the other."

There is no doubt that the mitigation of knowledge leakages must constitute a keystone for the selling firm's own organization. Leakage mitigation needs to be considered as a strategic capability at top management level. Legal protection can be useful (Liebeskind, 1996), but this is neither enough nor appropriate when dealing with tacit knowledge (Jiang *et al.*, 2013). The risks of knowledge leakages increase if the selling firm fails to define *and* implement measures to protect its intangible assets when cooperating with another firm. In terms of strategic management, it seems crucial to better inform CEOs and top managers that formal and administrative procedures are not sufficient to completely prevent knowledge leakages.

Trainers as Enforcers of Contractual Clauses

Contrary to a theoretical perspective, the implementation of contractual clauses is not as clear and under control as one may expect with regard to technology transfers. Indeed, stakeholders dedicate a lot of time and energy to designing the perimeter of such transfers ex ante through contractual clauses. These legal tools aim to contain risks through tough negotiations. This is a required but insufficient condition, since the people who draw up the contract are not those who are going to implement it.

Even in sovereign technologies, states and firms do not make sufficient effort in keeping implementation under control, believing too much in the strength of negotiated contracts. Our empirical research reveals the limits of such an approach as well as the excessive focus of today's literature on contract negotiations through legal dimensions and the insufficient assessment of the ex-post phase, through which risks of knowledge leakages can appear.

This raises the question of how to interpret contractual commitments and the relevance of such commitments with regard to the effectiveness of corresponding technology transfers. It appears empirically that trainers individually redefine the content of contract through training activities in which they are involved. Trainers can provide information that is not included in contractual terms because of their personal interpretation

of requirements. Containing transferred knowledge is very difficult for the firm or state because every trainer tends to adjust his mission according to his own representation of the contract as well as the strategic nature of related knowledge. This important result is shown with the different categories of trainers from Class 1 to Class 5. This redefinition process has two main origins.

First, the unintentional behavior of trainers: they are not aware of transmitting too much knowledge to customers. This is notably the case for workers and technicians or engineers involved in "training on the job" tasks. They fulfill this mission with the same professionalism as they do their daily job (Touraine, 1966). Consequently, they tend to disclose more information than expected because of exacerbated professional ethics coupled with a strong recognition of their skills by customers (facilitating reverse engineering). However, top managers tend to neglect this possibility when designing technology transfers.

Second, the voluntary behavior of trainers: some trainers may voluntarily deviate from the firm's initial intentions and commitments by providing more knowledge than expected or, on the contrary, limiting access to the required knowledge. Some of them think that helping the customer to fully understand technology and underlying industrial process is a priority to ensure customer satisfaction. Others choose to give less knowledge even if they have to lie or to fake answers because they perceive a significant risk for the firm or the country. According to them, too much information has been sold and this can be responsible for losing a technological lead and therefore market leadership. Ultimately, they think this can lead to the firm's bankruptcy.

These results underline that several risks result from trainers themselves, but most of the time they are truly underestimated or neglected because of the dual treatment of technology transfers between contractual negotiations and the implementation of transfers. Such duality can be considered to be a legacy of a time when technology transfers were limited to delivering patent licenses, industrial blueprints or turnkey factories. Then, leakage risks were limited due to minimal interactions between employees of delivering and receiving firms. This is no longer the case, since transfers cover a broader scope of knowledge so that receiving firms and countries are truly able to absorb and exploit related technologies.

Successful technology transfers are only possible by steadily increasing interactions between stakeholders. However, two weaknesses are apparent with the definition of transferred technologies and the ex-ante preparation of training sessions. First, tacit knowledge is much more difficult to delimit than codified knowledge. This requires that the actors involved "on the ground" understand how to define boundaries to prevent retro-engineering, which is rarely the case. Nevertheless, it is quite difficult for negotiators to truly understand what is at stake. Second, implementing riskless transfers requires real preparatory training for future trainers before implementing contractual commitments, so that they become aware of corresponding risks and possible consequences of their decisions. Therefore, trainers' training constitutes a real imperative and not an option in the management of the firm's intangible assets. Trainers must be knowledge gatekeepers. They can also become actors of risk mitigation by helping all in-house stakeholders to fully identify possible ex ante sources of knowledge leakages. Such training goes along with a real investment in the design of training programs and the implementation of incentives to align trainers' behavior with the firm's interests.

Headway can be made through developing "protective capacity." Knowledge-retention strategies can help firms reduce the danger of knowledge leakage or loss (Andersen, 2012). To ensure a better protection of the firm's knowledge, it is necessary to question the use of learning-by-doing situations, since they create "open access" to tacit knowledge. To mitigate risks, it should be fruitful to implement comprehensive training policies and enforce a clear segregation between internal and training activities. This can rely on off-site facilities to avoid in-situ training (online courses, serious games, etc.) or dedicated "training rooms" with a skills referential and simulated situations, an approach already used by some firms in rail or naval industries.

Conclusion

This article explores the specific case of technology transfers contractually defined for international sales in sovereign industries. Knowledge leakages are particularly sensitive in such a domain but there was almost no previous literature dealing with such issues despite many strategic challenges for both states and firms. We proposed to open this "black box" by analyzing related training activities and more precisely trainers' representations and possible knowledge leakages linked to their behaviors. Our original empirical study shows a variety of responses to an apparently contradictory mission: guaranteeing customer satisfaction and protecting the firm's and state's assets.

In technology transfers, contracts are very accurately defined before implementation. However, this study highlights that trainers redefine ex post the nature of contractual commitments in their day-to-day training activities. Thus, firms focus excessively on the design phase of contracts (as does the academic literature). They underestimate the implementation phase, which is sometimes even more crucial to protect the firm's intangible assets and the state's technological superiority.

This raises many questions with regard to the preparation of trainers to keep effective control over transferred knowledge. Our conclusions call for further research to understand how strategies to mitigate risks are or can be implemented.

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