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Cognitive & Relational Distance in Alliance Networks: Evidence on the Knowledge Value Chain in the European ICT Sector

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Distance cognitive et relationnelle dans les réseaux d'alliances : Evidences sur la chaîne de valeur de la connaissance dans le secteur européen des TIC

Résumé

L'objectif de l'article est d'étudier les incitations à la formation de partenariats technologiques. Nous montrons que les stratégies d'alliance consistent à accéder à des connaissances externes tout en maintenant un niveau suffisant d'appropriation des connaissances internes. Le secteur des TIC (avec d'autres secteurs reliés) est particulièrement concerné par ce dilemme entre appropriation et accessibilité des connaissances. Les questions de modularité, complémentarité, et standardisation jouent un rôle central dans les alliances stratégiques et technologiques. Considérant que la connaissance dans ce secteur est un bien systémique et complexe, nous construisons une typologie théorique des alliances en croisant les niveaux de proximités relationnelle et cognitive avec les phases d'exploration, d'examination et d'exploitation. Cette typologie est testée sur des données empiriques à l'aide d'un algorithme de classification. Les données sont basées sur un échantillon d'alliances dans le secteur européen des TIC issu de la base SDC Platinum. Nous montrons que les alliances sont regroupées autour des phases de la connaissance, les catégories d'alliances qui émergent étant caractérisées par des niveaux de distances cognitive et relationnelle qui confirment partiellement les prédictions théoriques.

Mots-clés : réseaux basés sur la connaissance ; phases de la connaissance ; proximités ; alliances stratégiques ; secteur des TIC

Cognitive & Relational Distance in Alliance Networks: Evidence on the Knowledge Value Chain in the European ICT Sector

Abstract

This paper deals with the firms' motives for entering into knowledge partnerships. We start by showing that networking strategies are designed to access external knowledge whilst maintaining at the same time a sufficient level of knowledge appropriation and tradability. The ICT sector (and interplaying ones) is particularly concerned by this accessibility/appropriation trade-off. The questions of modularity, complementarity, compatibility and standardisation are critical in the formation of corporate strategic and technological partnerships. Considering that knowledge in this sector is complex and systemic, we construct a theoretical typology of knowledge partnerships by crossing the levels of cognitive and relational proximity with the knowledge phases of exploration, examination and exploitation. This typology is then tested on empirical data through the use of a classification algorithm. The dataset is based on a sample of strategic alliances in the European ICT sector extracted from SDC Platinum. We show that strategic alliances are clustered in relation to the knowledge phases (exploration, examination, exploitation), and that the alliance categories are characterised by levels of relational and cognitive distance which actually are in keeping with the theoretical predictions.

Key words: knowledge networks; knowledge phases; proximities; strategic alliances; ICT sector

JEL : **L22; L24; L63; O31**

1. Introduction[1]

There are several theoretical and empirical ways to study networks of innovators, from sociology to economics to management science (Powell, Grodal, 2005). In this paper, we focus mainly on the economic dimensions of knowledge dynamics in order to capture the reasons why firms engage in network relations. As a basic assumption of this work, we suppose that knowledge is not only a public good – imperfect or impure though it may be –, but rather a complex and systemic good (Antonelli, 2005; Sorenson *et al.*, 2006). Knowledge as an output is complex and systemic since it combines many interacting pieces of knowledge as inputs. Knowledge can be viewed as a "recipe" which involves not just some peculiar combinations of "ingredients", but also peculiar integration methods. Knowledge is therefore both complex and systemic insofar as its generation implies some systemic interdependencies between internal and external pieces of knowledge. Joint knowledge production systems observed in various innovation networks attempt to take advantage of these knowledge combinations.

However, network strategies are not the *panacea* for knowledge-based firms' competitiveness. If firms improve their accessibility to external knowledge by establishing partnerships, they also face risks of appropriation defaults (Antonelli, 2006) in doing so. Network relations thus correspond to very peculiar strategies in which each participant considers that the benefits of accessibility exceed the risks of under-appropriation. So that the relation may be of mutual advantage to them all, the partners establish collectively a specific network governance framework which especially defines the shared property rights structure. In this context, it is interesting to examine the scope of these network relations, as well as their critical parameters.

The ICT sector will help us to theoretically and empirically carry out this study. This sector, like many other technological fields, is particularly concerned by the role which networks play in the industrial organisation. In the ICT sector, the questions of modularity, complementarity, compatibility and standardisation are critical in the innovation diffusion process (David, 1985; Aoki, Takizawa, 2002). These sectoral specificities entail some repercussions at the level of the firms' innovative and market performances. Firms operate on a market in which their innovative capabilities do not guarantee market success. Successful firms are not necessarily the most innovative ones, but rather those which can have access to complementary knowledge resources. In this context, firms need to combine appropriation strategies designed to promote and exploit their knowledge in competitive markets with "relational" strategies aimed at finding new opportunities and enhancing the integration of their knowledge into technical systems or platforms. Furthermore, in a complex and systemic view of knowledge dynamics, the ICT sector's network relations are more accurately analysed if they include as well firms belonging to other sectors. Most of high-tech industries

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are nowadays driven by technological convergence processes, and so by several cross-sector and technological windows. Most ICTs, as general purpose technologies (David, Wright, 1999), are particularly concerned by these convergence processes, and network relations thus occur between ICT firms and media industries (web TV, mobile media, *etc.*), transport and aeronautics (on-board guidance systems), care industries (software for molecular information computation), banks and insurance companies (software for secure electronic transactions), and so on.

All these relations are typical of knowledge processes in which knowledge inputs are more or less fragmented into many technological areas. Moreover, the firms' motives for striking up these relations may differ strongly depending on their respective position in the knowledge value chain (Cooke, 2006a). Firms can *explore* new technological fields by combining complementary bits of knowledge in an upstream R&D phase: the goal here focuses on technological feasibility. Firms can *examine* the technological integration of an innovation into an existing technological system, or *examine* the potentiality of shaping collectively a technological standard: the goal here goes from feasibility to the capture of network externalities to potential tradability. Firms can also *exploit* collectively a new technology on a market in an attempt to achieve collectively scale economies. Obviously, the network's governance structure will depend on the knowledge phase in which the firms are involved. It will also differ according to each partner's knowledge bases, as well as according to the cognitive distance between them (Nooteboom, 2000; Wuyts *et al.*, 2005). Such an assumption is consistent with the knowledge trade-off between accessibility and appropriation. Too strong a cognitive proximity may give rise to uncontrolled knowledge spillovers and thus weaken the respective knowledge appropriation capabilities. So, the strength of the relation – that is to say relational proximity or distance – will depend on the private knowledge firms are led to share with other partners, as well as on the specification of the collective property rights they defined with a view to extracting rents from the knowledge output. Relational distance will be even stronger when firms compete in pure arm's length relations. In the ICT sector's specific case, this situation is typical of the "standards war" game. The coexistence of technologies prevails and firms compete strongly, maintaining a high degree of appropriation so that relational proximity is weak. Conversely, firms may decide to gather a large part of their respective knowledge in order to shape a technological standard or to experiment the convergence between two separate technologies (Hill, 1997). In this case, relational proximity can be strong, in particular when frequent meetings and engineers' mobility are the main channels through which the relation unfolds.

Cognitive and relational distances (or proximity) and knowledge phases are critical parameters which permit to understand the variety of network relations in the ICT sector. In the literature, the degree of uncertainty and the existence of transaction costs proceeding from the market functioning are also good indicators of network relations (Hagerdoorn *et al.*, 2000) and still remain important. Yet, we consider in this paper that the variety of corporate governance structures should be complemented with the complexity of the systemic knowledge generation process and the strategies which firms develop in order to mix accessibility and appropriation of knowledge.

The present paper is divided as follows: Section 2 provides definitions of cognitive and relational distance and shows that firms develop positioning strategies in this two-dimension space with a view to handling the appropriation/accessibility trade-off. In Section 3, we show that the firms' motives for shaping alliances and partnerships differ depending on the phases of the knowledge value chain. In Section 4, we develop a theoretical typology of network relations in the ICT sector. Section 5 presents the dataset, the empirical methodology and the results. Section 6 concludes and develops further theoretical and empirical research issues.

2. Cognitive and Relational Proximity (and Distance) in Knowledge Networks

The way firms control the knowledge trade-off between accessibility to and appropriation of knowledge may be analysed by focusing on the combination of cognitive and relational distance. Indeed, firms position themselves in this two-dimension space in order to capture external knowledge, whilst maintaining at the same time efficient conditions of appropriability and tradability of their internal knowledge.

Following Nooteboom (2000), Boschma (2005), Bouba Olga and Grossetti (2006), we may define the level of cognitive proximity between firms according to their respective knowledge bases and paths. Firms are cognitively close when they share close capabilities, not only concerning technological knowledge, but also in relation to marketing or business knowledge. Firms belonging to the same technological fields[2] tend to be cognitively close, whereas those which do not have any technological similarity tend to be cognitively distant. Nevertheless, it would be too simplistic to reduce cognitive proximity (or distance) to the only technological dimension (Nooteboom, 2000). For instance, firms operating in same technological fields can differ strongly if they do not share and develop the same business models or marketing knowledge (research -oriented or market-oriented)[3]. Business, manufacturing and marketing practices are also forms of knowledge which are sometimes procedural, other times declarative.

Relational proximity refers to the notion of interaction structure. Firms are relationally close when they have an interaction structure at their disposal which allows them to make transactions on knowledge. The fact that agents are cognitively close does not necessarily imply that they interact (Vicente, Suire, 2007). Relational proximity does not exist without a communication or an interaction structure. Interactions can be strong and frequent, or weak and scarce; they can be purely cooperative and horizontal, or hierarchical and vertical. As a consequence, it should be possible to measure the degree of relational proximity on the basis of the sociological concepts that have recently been used to analyse the properties of complex networks. We could for instance use such concepts as geodesic distance, cliques, community structure, structural equivalence, Small Worlds, and so on[4]. What matters here is to have measures of the intensity of interactions and to characterise the typology of partnership networks. By using such tools, we could understand the way firms position themselves in networks with a view to controlling the trade-off between knowledge appropriation and accessibility. A prerequisite for such analyses would be the construction of relational databases using for example data on financial relations, joint ventures and strategic alliances (Hagerdoorn *et al.*, 2000), co-patents and co-publications (Audretsch, Feldman, 1996; Breschi, Lissoni, 2001), social capital provided by friendships and scholarship (Boschma, 2005), and so on. Unfortunately, such an objective is beyond the scope of the present paper which is mainly focused on knowledge phases and cognitive distance. That is why we shall only propose here a more qualitative assessment of relational distance in strategic alliances (see Section 5.2).

Furthermore, we should underline that, most of the time, cognitive proximity and relational proximity are not pure strategic substitutes, nor pure strategic complements. There are several

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[2] Mowery, Oxley and Silverman (1996, 1998) have introduced the concept of "technological overlap" which is partly similar to our concept of cognitive proximity as far as the technological dimension of this proximity is concerned.

[3] We discuss below the way SIC and VEIC codes can prove helpful in measuring cognitive distance both in terms of its technological and organisational dimension.

[4] For a thorough survey, see for example Watts D. J., 2004.

possible situations where relational proximity can match cognitive proximity efficiently and other situations where relational proximity can perform better with a certain amount of cognitive distance. The critical parameter which determines the efficiency of cognitive and relational proximity combinations is the balance between knowledge spillovers and network spillovers. On the one hand, firms face risks of unintended knowledge spillovers when they share knowledge with other partners. On the other hand, the necessity of acquiring complementary modules of knowledge requires such knowledge-sharing processes, when compatibility and interoperability between systemic and network technologies are the rule of competitiveness (Economides, 1996; Jaffe, 1996). The risks of unintended knowledge spillovers are even more important when cognitive proximity between partners is strong, each partner's technological absorptive capabilities being very similar as a result of the proximity in their respective knowledge paths (Nooteboom, 2000), and the weak differentiation of the markets on which they compete (Vicente, Suire, 2007). In this case, firms can be affected by appropriation defaults which constitute, *ceteris paribus*, a weak incentive for them to form partnerships, and so to enhance their relational proximity. Nevertheless, in many technological fields in which knowledge is complex and systemic, these risks are largely offset by the benefits firms may derive from network externalities (direct and indirect) at the demand level. The ICT sector is, of course, one of the most concerned by such a phenomenon. The consumers' willingness to pay for a technology depends strongly on the interoperability and compatibility between competing technologies (direct externalities). It also depends on the integration of a specific technology into a larger technological system and so on the vertical integration of technologies coming from different firms (indirect externalities). The firms' necessity of capturing these externalities requires a certain amount of relational proximity to shape a technological standard or to solve compatibility or interoperability problems. The more or less reciprocal accessibility to knowledge is, in this case, coupled with some appropriate property rights (such as licensing or cross-licensing agreements) in order to favour accessibility and reduce appropriation defaults. Relational proximity may, however, remain weak when firms perceive that the expected benefits of shaping compatible technologies with a view to capturing network externalities do not exceed the risks of unintended spillovers and compatibility process costs. In this case, "standards war" prevails over cooperation, and firms compete strongly by maintaining a high degree of appropriation.

The above argumentation leads to the following propositions:

> *Proposition 1: firms deal with the knowledge trade-off between accessibility to and appropriation of knowledge by embedding their knowledge strategies within a cognitive and relational space.*
>
> *Proposition 2: in a complex and systemic view of knowledge, the firms' incentives to form partnerships depend on the balance between the benefits of network externalities encapsulation and the risks of unintended knowledge spillovers. The weight of unintended spillovers is even more important when cognitive proximity between partners is strong.*

Nooteboom (2000) and Wuyts *et al.* (2004) argue that there is an optimal cognitive distance which generates a maximum level of learning through interaction. Too strong a cognitive distance causes an excess of mutual misunderstanding between partners. On the contrary, too strong a cognitive proximity lowers the novelty value of the mutual learning process. Beyond the difficult question of the different ways to measure cognitive distance and to infer an optimal one, we would like to develop further the debate about cognitive distance through two interconnected arguments. Firstly, if we acknowledge that too strong a cognitive proximity does not bring enough novelty to produce new knowledge, we want to emphasise that it can, however, play an important role in the diffusion of new knowledge on markets. This is particularly true in the ICT sector as a consequence of the systemic characteristics of knowledge. The balance in partnerships between cognitive proximity and cognitive distance will be different depending on whether firms cooperate with a view to experimenting cross-sector and cross-technological knowledge, or with a view to capturing direct or indirect network externalities. Secondly, we also admit that too strong a cognitive proximity restrains the firms' incentives to cooperate on account of the risks of unintended knowledge spillovers. Nevertheless, property rights are available to enable firms to control these risks and internalise these spillovers. The strength of the property rights governing partnerships thus proves to be one of the critical parameters of the variety of knowledge networks.

3. The Knowledge Value Chain and Alliances Strategies in the ICT Sector

The balance between knowledge appropriability and accessibility, and consequently between network spillovers and knowledge spillovers, may be highlighted by focusing more specifically on the different phases of the knowledge value chain (Cooke, 2006a). The combinations and the respective level of relational and cognitive proximity will differ according to the knowledge phases. As a result, knowledge phases represent decisive determinants of the variety of knowledge networks.

The literature generally puts forward two main phases in the knowledge value chain (Gilsing, Nooteboom, 2006): *i)* a phase of *exploration*, based on a strategy of radical innovation through research and experimentation; *ii)* a phase of *exploitation*, based on a strategy of incremental innovation through product development and adaptation to market change. Though this simple breakdown of the knowledge value chain still remains relevant at the firm level, it fails to grasp the complexity of knowledge generation and diffusion when knowledge inputs are fragmented and when knowledge outputs depend on network effects. Therefore, following Cooke (2006a), we propose introducing a third and intermediary phase of knowledge *examination*.

In network-based exploration phases, a certain amount of cognitive distance in knowledge exchange is necessary for the generation of knowledge, as knowledge is cumulative and emerges from the complementarity between "distant" bits of knowledge. Cognitive distance between partners is thus one of the key parameters of the probability of innovative success in the exploration phase, even if too strong a cognitive distance may bring about misunderstandings between partners. The intensity of relational proximity therefore has to be stronger in this case than in pure exploitation phases insofar as interactive learning through communication is crucial to reach mutual understanding. Such a postulate is all the more important in the ICT sector since it includes a wide range of general purpose technologies (David, Wright, 1999), that is to say technologies with potentials for innovation in many other more or less adjacent sectors. This explains why ICT firms' partnerships often include firms from other sectors such as aeronautics and aerospace, the defence and military, transport, automotive industries, chemistry, business services, and so on. In the very upstream phase of the knowledge value chain, firms try to explore new technological fields by forming alliances with partners from other sectors for two main reasons. The first reason – extensively evidenced by the evolutionary theory of the firm – consists in the preservation of diversity and technological options for the future. The second reason, which is more specific to the ICT sector or at least to general purpose technologies, relates to firms' strategies in the field of "convergent technologies". These situations are typical of knowledge processes in which knowledge inputs are fragmented into many technological areas. The exploration phase thus consists in knowledge combination strategies through more or less formal R&D agreements within the framework of a very upstream technological feasibility research (prototype definition). In this phase, accessibility to external knowledge is the partners' main objective, which has to be supported by a high degree of relational proximity and a certain amount of openness and cooperative behaviour (Cooke, 2006b; Gilsing, Nooteboom, 2006). The difference between the partners' absorptive capabilities justifies the intensity of relational proximity insofar as it implies both frequent meetings and engineers' mobility. Such a proximity is facilitated by the fact that firms do not originally compete in same markets, which means that the risks of unintended knowledge spillovers are lower in this case than in pure exploitation phases[5]. The typical "mutual hostage" situation of technological partnerships is thus compatible with "loose" and "trust-based" research alliances (Gilsing, Nooteboom, 2006). Nevertheless, if the network-based exploration phase succeeds and leads to new knowledge, co-patenting appears to be an appropriate tool to solve the appropriation/accessibility trade-off (Breschi, Lissoni, 2001).

The intermediate phase between exploration and exploitation is examination (Cooke, 2006a). In this phase, appropriation and accessibility interplay in a complex property rights game. If cognitive proximity can possibly be as weak in this case as in the exploration phase, the focus here is not on feasibility, but rather on potential tradability. That is why the solving of compatibility problems between complementary bits of knowledge constitutes an additional phase of the dynamic knowledge generation process. This phase may be divided into two distinct sub-phases depending on whether firms form alliances with a view to capturing indirect or direct network externalities.

In the first sub-phase, relational proximity still remains important, even if contacts and face-to-face interactions can be lower than in pure exploration phases as a result of the progress in the knowledge codification process. Firms need to integrate different modules of knowledge and make sure that these are compatible. When the knowledge produced by a firm generates increasing consumer satisfaction only if this knowledge is integrated into existing technologies, the firm in question must pursue a double objective. Firstly, it has to ascertain the compatibility between its module and the technological base into which this module will be introduced. Secondly, in order to capture indirect network externalities at the demand level, it needs to choose its partner according to the breadth of the so-called "installed base". The tradability of complementary modules of knowledge requires these two conditions. Licensing agreements are generally implemented in these situations as, in contrast to exploration phases, knowledge already exists and has to be controlled by the innovative firm. In this examination phase, relational proximity is favoured by the necessity of combining the partners' respective technological expertises (through engineers' mobility for instance). Each partner draws an advantage from this relational proximity: the licensor finds a potential for trade opportunities as far as its technological output is concerned, while the licensee may find some opportunities to enhance its technological installed base and improve its products' functionalities.

The second examination sub-phase rests on a stronger cognitive proximity. If cognitive proximity between firms can favour their respective absorptive capabilities, it reduces the probability of new knowledge generation though. Nevertheless, strong cognitive proximity can be compatible with partnerships when firms focus their efforts on defining a technological standard. Such efforts require reaching a critical mass so that direct network externalities may play their role and reduce the uncertainty firms are confronted with in emergent markets (Hill, 1997). This can be facilitated by the guarantee firms may obtain when they are provided with a public licence or when clearly identified common property rights are defined. However, cognitively close firms may maintain a relational distance if *i)* they want to keep a high

[5] Cantwell and Santangelo (2002) develop a similar argument with is, however, related to geographical instead of relational proximity.

degree of appropriation over their knowledge and if *ii)* they consider that the benefits of shaping compatible technologies do not exceed the risks of uncontrolled knowledge spillovers (and the compatibility process costs as well). In the latter case, "standards war" will prevail over cooperation and collective appropriation. Cognitive proximity can prove very useful in terms of knowledge diffusion when firms seek to combine their knowledge with a view to shaping a new technological standard. In doing so, firms capture the benefits resulting from network externalities at the demand level, even if they thus take the risk of losing private control over their inventions. As regards the ICT sector, we can draw an enlightening parallel between the knowledge appropriation/accessibility trade-off and the network externalities/knowledge externalities trade-off (Jaffe, 1996). Nevertheless, relational proximity in this case tends to be weaker than in the exploration phase since relations focus more specifically on highly-codified knowledge exchanges, rather than on research capabilities and tacit knowledge. Most of the time, the latter had previously been built by each of the firms, or in the context of exploration relations with other firms.

The exploitation phase combines cognitive proximity with a certain amount of relational distance. Following Gilsing and Nooteboom (2006), alliance-based exploitation strategies are particularly well-suited to the purpose of technological *generalisation*. Once the industry standard has been established, firms need to consolidate this standard into a dominant design by enlarging the scale of diffusion not only in the geographical space, but also in the application space. In this context, firms develop manufacturing agreements, marketing agreements and joint ventures in order to extract rents from scale economies and increase their market power. The interaction structure in this phase requires weak ties as the risks of unintended knowledge spillovers are strong due to the high level of cognitive proximity between partners. Firms only share their production or marketing capabilities and maintain a high level of appropriation over their knowledge capabilities through a formal specification of their respective intellectual property rights. The extreme case of contract specification and monitoring is the joint venture strategy in which partners integrate their production or marketing capabilities into a special purpose entity so that they may maintain a strong relational distance between their knowledge capabilities.

The above argumentation leads to the following three propositions:

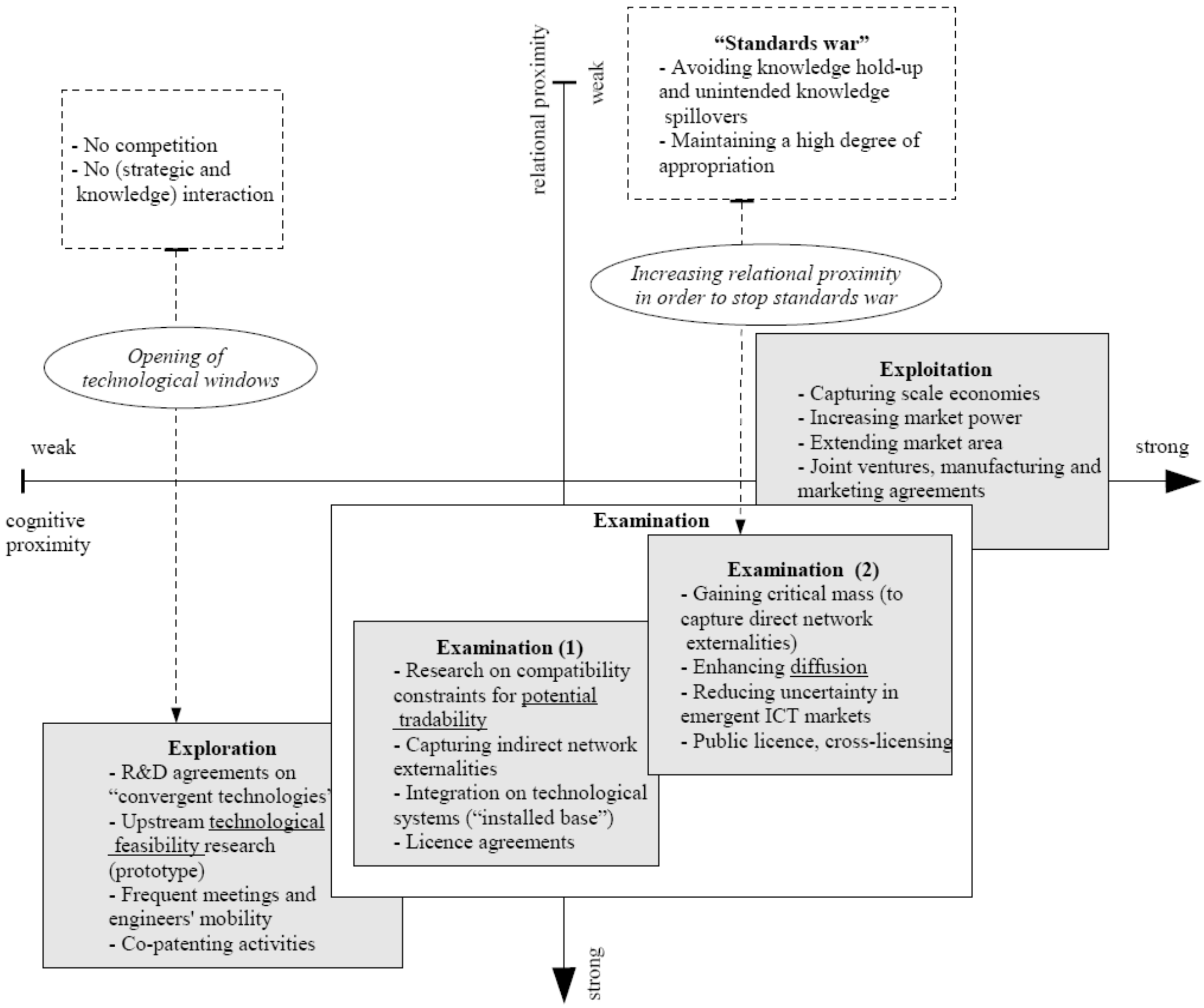
> *Proposition 3: the level of cognitive and relational proximity between firms depends on the phases of the knowledge value chain in the ICT sector.*
>
> *Proposition 4: the intensity of relational proximity is positively correlated with cognitive distance.*
>
> *Proposition 5: the strength of property rights schemes increases with cognitive proximity, reducing the risks of unintended knowledge spillovers along the knowledge value chain.*

4. A Theoretical Typology of Knowledge Partnerships in the ICT Sector

Before we move on to the statistical test of the above-mentioned propositions, we suggest summarising the explanations of the variety of knowledge relations through a typology and a few empirical examples. The typology crosses the cognitive and relational proximity axes with the identified knowledge phases. Empirical examples are extracted from the SDC Platinum database – a powerful database of strategic alliances and joint ventures. It is widely admitted that strategic alliances may be considered as monitoring systems for knowledge sharing and exchange (Mowery *et al.*, 1996, Gulati and Singh, 1998). Alliances can take the form of licensing or cross-licensing agreements, technology transfers, customer/supplier partnerships, joint development agreements, R&D contracts, equity joint ventures, and so on.

Most alliances actually combine several of these characteristics to support complex strategies of knowledge network positioning. Consequently, to understand these strategies, it might be useful to consider the technological specificities of the ICT sector and place strategic alliances within the bi-dimensional space of cognitive and relational distance, as well as within the framework of the three knowledge phases. This will help us to understand alliances as devices for the implementation of complex collective knowledge accumulation and generation processes (Antonelli, 2006). This will also allow us to show that these are flexible tools that may be customised to fit the different phases of the knowledge value chain (Cooke, 2006a).

Figure 1: A Theoretical Typology of Knowledge Phases and Alliance Strategies in the ICT Sector



The two axes of the typology cross the respective levels of cognitive and relational proximity and display different combinations corresponding to specific knowledge relations – from no relation to competition, including other cooperative and "coopetitive" agreements and strategies. The top left-hand side of Figure 1 symbolises the absence of interactions between firms. The excess of cognitive distance and the absence of technological convergence opportunities imply the non-existence of knowledge or strategic interactions. Cognitive distance may yet generate knowledge interactions when cross-sector opportunities occur and technological windows are opened. The bottom left-hand side of Figure 1 displays the particular situation of collective knowledge exploration. In this phase, the firms' main motive is to access external modules of knowledge in order to develop a "differentiation through exploration" strategy (Gilsing, Nooteboom, 2006). The purpose in this phase is not the direct tradability, but the feasibility of technology combinations. R&D agreements are generally implemented here and co-patents are the natural output of such a collective process. Relational proximity can be strong in this phase due to the level of cognitive distance between partners which requires the construction of a mutual understanding and, consequently, frequent meetings between engineers and other employees. This strong relational proximity is, however, compatible with "loose" contracts, that is to say agreements in which the *ex ante* definition of property rights is not necessary insofar as the risks of unintended knowledge spillovers between so cognitively distant partners are not very high. The strategic alliance signed between Philips Electronics and Levi Strauss & Co. in August 2000 is characteristic of such a situation:

> Levi Strauss & Co., a unit of Levi Strauss Associates, and Philips Electronics NV formed a strategic alliance to provide research and development services in United States and Netherlands. The alliance was to develop electronic clothing. The clothes were fully equipped with fully integrated computer networks *(SDC Platinum database, deal n°1038365045, August 2000)*.

Beyond the surprising but very illustrative character of this alliance, many other such partnerships occur between firms from different sectors, thus confirming the fact that ICTs are general purpose technologies which give rise to technological convergence processes. The technology combinations taking place between ICTs, biotechnologies and nanotechnologies are among the most recurrent ones:

> Molecular Design (MDL) and ICI Pharmaceuticals agreed to jointly build a scientific workstation for managing chemical and scientific information. ICI will provide input during the development of MDL's software, participate in progress reviews, and serve as a beta test site. ICI will have access to the new workstation on Apple Macintosh, IBM PS/2, and Digital Equipment Corp. VAX/VMS platforms. *(SDC Platinum database).*

> Advance Nanotech Inc. and Toumaz Technology Ltd planned to form a joint venture named Bio-Nano Sensium Technologies (BNS) to provide research and development, as well as manufacture bio-nano sensors in United Kingdom. BNS was to utilize an intelligent, ultra-low power sensor interface, incorporating wireless communication, to create bio-nano sensors that can be implanted within the body to diagnose and treat a wide variety of medical conditions *(SDC Platinum database)*.

Beta tests and prototypes are generally the natural outputs of these joint knowledge processes.

Potential tradability concerns the examination phase in the bottom part of Figure 1. Recall that when knowledge is fragmented between many interacting agents, the traditional exploration and exploitation phases are not sufficient to understand the knowledge value chain, from technological discovery to diffusion. Integrating complementary modules of knowledge requires an additional and intermediary phase of research in order to capture indirect network externalities at the demand level. The first examination sub-phase focuses on the technological compatibility between modules. Each firm's respective goal differs: one partner's objective may consist in integrating its technology into another complementary and widely installed one with a view to enhancing the potentiality of its diffusion, when the other partner may benefit from this integration by augmenting the variety of services and functionalities, and so by increasing the installed base and the value of the technological standard (Hill, 1997). The following three alliances furnish illustrative examples:

> Agate Technologies Inc. (AT) and Eutron SpA (ES) signed a letter of intent to form a strategic alliance to explore technology integrations. Under terms of the agreement, AT and ES were to develop and market a new product based on AT's Q technology and ES' information security technology. The alliance was to allow AT and ES to explore development activities that utilize secure data storage and mobility *(SDC Platinum database)*.

> Nokia Oy AB (NO) and Eastman Kodak Co. (EK) planned to form a strategic alliance to provide research and development services of kiosk printing services and other retail printing solutions to empower mobile users to turn pictures into prints *(SDC Platinum database)*.
>
> France Telecom SA and Intel Corp. planned to form a strategic alliance to provide research and development services of wireless household devices. Under terms of the agreement, FT and IC were to set up a joint development team to research image, video, music, photo and games devices and share intellectual property resulting from the transaction *(SDC Platinum database)*.

Compatibility and interoperability are at the centre of the second examination sub-phase. In this case, the alliance prospects are typical of "coopetition" situations where competing firms cooperate in order to impose a technological standard. In these situations, cognitive proximity is strong due to each partner's knowledge paths, but the risk of knowledge drain does not exceed the collective benefit firms can gain from the collective capture of direct network externalities, whether these are technological or social. In particular, knowledge stealing is limited when public licences exist (like in the mobile phone industry) or if a collective shared and mutual property rights strategy has been defined. The risks of unintended knowledge spillovers are also reduced when the alliance is not research-intensive, that is to say when technologies exist and the additional research phase focuses only on technological interoperability and the collective marketing strategy. In this case, relational proximity is less important than in the other phases. The mobile phone industry is typical of these partnerships:

> Ericsson Radio Systems and Motorola agreed to cross-license technologies related to the global system for mobile communications (GSM). The companies also agreed to design and manufacture their own cellular equipment, but will conform to specifications set by a 17-country European consortium. Ericsson and Motorola also agreed to a program which enabled Motorola's GSM base station equipment to operate with Ericsson's switching platform. The agreement was extended to Orbitel Mobile Communications, an Ericsson GSM equipment venture *(SDC Platinum database)*.
>
> LM Ericsson Telefon AB, Motorola Inc. and Nokia Oy AB formed a strategic alliance to provide regulation and standardization services for mobile communications. The alliance was called Location Interoperability Forum *(SDC Platinum database)*.
>
> Nokia Oy AB and Sony Corp. planned to form a strategic alliance to provide telecommunications services. The alliance was to develop and create a set of open standards for interoperability between mobile devices *(SDC Platinum database)*.

On the right-hand side of Figure 1, we find the joint exploitation phase in which firms form alliances or joint ventures in order to consolidate their standard or technology into a dominant design. These partnerships are dedicated to the manufacturing and marketing of new products developed in the first two phases. Since appropriability is the main concern here, partners have to find agreements which both diminish relational proximity and delineate precisely property rights. Consequently, joint ventures are the privileged form of alliance used to implement these manufacturing and marketing agreements. Moreover, these kinds of alliances are characterised by low cognitive distance. The two following well-known examples are typical of this collective exploitation phase.

> Fujitsu Ltd (FL) and Siemens AG (SA) formed a joint venture named Fujitsu Siemens Computers (FSC) to manufacture, retail and wholesale computers and peripherals for the European market. FSC was based in Netherlands. Under terms of the agreement, FSC manufactured personal computers and peripherals for corporate users and sold them under FL's and SA's brand names. FL and SA each held a 50% interest in FSC. FL's Fujitsu Computer (Europe) Ltd and SA's Siemens Computer Systems division were combined into FSC *(SDC Platinum database)*.
>
> LM Ericsson Telefon AB (LE) and Sony Corp. (SC) formed a joint venture named Sony Ericsson Mobile Communications (SEM) to manufacture and market mobile phones in United Kingdom. LE and SC spun off their mobile phone businesses to form SEM. LE and SC each held a 50% interest in SEM. SEM was capitalized at US$500 mil. (5.051 bil. Swedish krona/60.7 bil. Japanese yen). LE and SC also opened a branch of SEM in Thailand that combined the strength of LE in terms of mobile phone technology and that of SC in terms of multimedia technology and content.

Finally, on the top right-hand side of Figure 1, we find the "standards war" situations, where firms compete on incompatible and non-interoperable technologies. Cognitively close firms can maintain a relational distance if they want to keep a high degree of appropriation in the exploitation of their knowledge and if they judge that the benefits of shaping compatible technologies do not exceed the risks of uncontrolled knowledge spillovers (and also the costs of the compatibility and interoperability processes). In this case, "standards war" prevails over alliances. For instance, in the video game industry, the coexistence of technologies prevails and firms compete strongly, maintaining a high degree of appropriation so that relational proximity is weak in this sector, at least in the exploitation phase (Venkatraman, Chi-Hyon Lee, 2004).

We should acknowledge here that our theoretical typology is both inspired by the works of B. Nooteboom *et al.* as regards the concept of cognitive distance, and those of Mowery, Oxley and Silverman as regards the concept of "technological overlap" which they have introduced. Nevertheless, our approach differs substantially from the two above-mentioned ones in that *i)* unlike Nooteboom *et al.*, we argue that the optimal level of cognitive distance depends on the knowledge phase, and *ii)* unlike Mowery, Oxley and Silverman who stated that partners with a strong technological overlap were always preferred, we are of the view that, in the exploration phase, it can be optimal to choose cognitively distant partners.

These predictions imply in fact that alliance characteristics are not randomly distributed: there should be a typology of alliances in keeping with the knowledge phases. We shall now proceed to implement a cluster analysis on the ICT sector's alliances in Europe with a view to testing whether these predictions are valid or not.

5. Data and Empirical Assessment

5.1. The Data on ICT Alliances in EU-25

We use the well-known SDC Platinum database operated by Thomson Financial. We extracted all effective alliances with at least one participant from the ICT sector and one European (EU-25) participant between 1997 and 2006. We deliberately adopted a broad definition of the ICT industry including not only hardware, software and telecommunication sectors, but also audio/video equipment, navigational instruments, ICT-related commercial services, communication services, media broadcasting, and so on (see full list in Appendix 1). This definition is roughly the same as the official OECD definition of the ICT sector that has recently been extended (see Bourassa, 2006[6]). It is even broader insofar as we also integrate "Content Activities" such as radio and TV broadcasting. These network-based activities are integrated as well since we think they are very similar to the ICT activities in terms of their knowledge production and diffusion processes.

The choice of SDC Platinum as the data source may raise several difficulties. First of all, we must acknowledge that this database is certainly not exhaustive. In this connection, we should more particularly point out that some tacit alliances with true strategic content may not be reported in the data. Moreover, partnerships such as exchange of engineers, joint workforce training, or joint participations in public sector research programmes may not be reported either. There may also be a selection bias whereby only the alliances concerning big and

6 Bourassa F., 2006, "ICT Sector Classification Standards Proposals Based on ISIC Revision 4", OECD, EAS Division, ITU – World Telecommunication/ICT Indicators meeting, Geneva, October 11-13, 2006.

prestigious firms are addressed. However, the sizes of participants reported in the database seem to be correctly diversified.

Furthermore, it would have been misleading to conclude that other well-known alliance databases such as CATI, CORE and NCRA-RJV were more relevant for the kind of study we proposed to undertake[7]. We could not, indeed, use CATI because it is restricted to technological partnerships and excludes manufacturing and marketing agreements. We, in fact, need information about these kinds of non-technological agreements insofar as we set out to identify knowledge value chain phases and we think that there also are some knowledge flows in the exploitation phase. Neither could we use CORE or NCRA-RJV because their data come from the US Department of Justice and are consequently focused on US, rather than on European alliances[8].

So, SDC Platinum appeared to be the most relevant data source for a study of non-technological and technological alliances focusing on the ICT sector in Europe. Its most valuable advantages are arguably the fact that it covers a long period of time and it is implemented by a powerful data mining organisation.

The dataset is split into two sub-periods, namely 1997-2002 and 2003-2006. This will allow us to account for a possible structural instability resulting from the crash of the dot-com bubble and its aftermath. In the sequel, we shall systematically compare the results over the two sub-periods to assess whether this crash has changed partnership behaviours or not.

For the period between 1997 and 2002, there have been 2,390 alliances reported to which 5,231 firms were party. Over the period 2003-2006, 876 alliances occurred with 1,793 firms involved. It thus appears obvious that the Internet crash decreased strongly the activity of strategic partnerships in Europe's ICT sector. By way of illustration, there were, on average, 398 alliances reported per year between 1997 and 2002, and only 219 alliances per year over the period 2003-2006.

Whatever the period, alliance participants mainly come from five sub-sectors: Computer Programming & Data Processing, Telephone Communications, Communications Equipment, Electronic Components & Accessories, and Computer & Office Equipment[9]. The Internet crash did not change this hierarchy, but it affected some sectors more strongly than others: for example, the share of alliance participants from the Telephone Communications sector has dropped while that of Computer Programming & Data Processing has increased. The share of alliance participants from Media Broadcasting and other TV services has experienced a significant drop too, as well as that of Miscellaneous Investing activities. On the contrary, the share of alliance participants from the "Research, Development, & Testing Services" and "Drugs" sectors has gone up significantly. However, it is necessary to be cautious when interpreting these changes insofar as we do not know whether these are due to the crash of the dot-com bubble or to some other – more structural – changes.

We shall now proceed to describe the different kinds of alliances encountered in these two periods. In SDC Platinum, alliances are primarily characterised in terms of institutional arrangement: an alliance is either a 'Joint Venture' or a 'Strategic Alliance'. It is a joint venture if it involves the creation of a special purpose entity – with or without equity participation from the partners – dedicated to the implementation of common activities. Conversely, it is a strategic alliance if no independent entity is created. Either kind of alliance

7 For a description of these databases, see for example Hagedoorn *et al.* (2000).

8 Another well-known data source on ICT alliances is the ARPA database developed at Politecnico di Milano, but which, to our knowledge, only covers the period 1980-1986.

9 Supplementary descriptive statistics can be made available on request.

can then be characterised by its aims as well as by the tools it uses to achieve them. We are thus provided with several binary variables describing the alliances' characteristics. The full list is given in Table 1 below.

A great majority of alliances are simple strategic alliances with a low level of irreversibility. It is worth stressing that this figure is even bigger after the crash of the dot-com bubble (from 73.8% to 90.2%). Financial uncertainty in the post-crash era appears to be a strong barrier to the forming of joint ventures[10]. A great majority of alliances involve participants from different countries (82%), this figure being even bigger in the second sub-period (91%).

Concerning the means and goals of alliances, we can see that services, marketing, manufacturing, licensing, technology transfer and R&D agreements are the most frequent types of arrangements. All these characteristics are directly available as binary variables in the SDC Platinum database[11], except for the category "services agreements". We ourselves created this category to describe alliances which have none of the other characteristics as coded by the SDC Platinum staff. A thorough check of these alliances' deal documents led us to describe them as "services agreements". Most of the time, these concern alliances by which a firm offers some services to other firms – computer, programming, multimedia or Internet services very frequently. The other kinds of services often provided are broadcasting or telecommunication services, and commercial or environmental services.

Many alliances combine several of the characteristics described in Table 1 (for example, manufacturing and marketing agreements or R&D and marketing agreements). Consequently, it is worth assessing whether some combinations of characteristics tend to be recurrent in the sample. In relation to Section 3 where we underlined the probable existence of different phases in the knowledge value chain, we expect the combinations of agreements characteristics to correspond to the different phases of the knowledge value chain. Moreover, we expect the alliance participants to be characterised by different degrees of cognitive proximity from one phase of the knowledge value chain to another.

10 JV in the sequel.
11 A thorough description of each variable can be found on the SDC Platinum server.

Table 1 : Alliance characteristics

	Number of alliances	Frequency (%)	Number of alliances	Frequency (%)
	1997-2002		2003-2006	
Alliance form				
Strategic alliance	1,763	*73.77*	790	*90.18*
Joint venture	627	*26.23*	86	*9.82*
Total	**2,390**	***100.00***	**876**	***100.00***
Alliance characteristics				
Alliance with cross-border participants	1,952	*81.67*	793	*90.53*
Services agreement	1,350	*56.49*	414	*47.26*
Marketing agreement	327	*13.68*	155	*17.69*
Licensing agreement	311	*13.01*	87	*9.93*
Manufacturing agreement	232	*9.71*	71	*8.11*
R&D agreement	189	*7.91*	49	*5.59*
Technology transfer	120	*5.02*	168	*19.18*
Supply agreement	84	*3.51*	3	*0.34*
Cross-technology transfer	51	*2.13*	130	*14.84*
OEM/VAR[12] agreement	24	*1.00*	6	*0.68*
Exclusive licensing agreement	15	*0.63*	6	*0.68*
Spinout	10	*0.42*	4	*0.46*
Royalties	7	*0.29*	0	*0.00*
Equity stake purchase	4	*0.17*	0	*0.00*
Equity transfer	3	*0.13*	0	*0.00*
Cross-licensing agreement	2	*0.08*	2	*0.23*
Cross-equity transfer	1	*0.04*	0	*0.00*
Joint venture stake option	1	*0.04*	0	*0.00*

5.2. Measures of Cognitive and Relational Distances

In Section 2, we defined **cognitive proximity** as the sharing of common knowledge bases, that is to say close technological capabilities, as well as close business and marketing practices. Consequently, cognitive proximity is not restricted to the sole technological aspect of firms' knowledge. What is important to point out here is that common cognition processes between alliance participants generate a higher risk of unintended knowledge spillovers, and therefore require the alliance to protect more efficiently knowledge property rights. There are several ways to measure cognitive proximity but, as underlined by Wuyts *et al.* (2005), it is first necessary to account for organisational and strategic cognition, as well as technological cognition. Technological aspects may be captured through patent field codes or R&D budget allocations across technological fields, but it is more difficult to find information about strategic and organisational practices. Inasmuch as we do not have such information at our disposal, we decided to use SIC and VEIC codes to build our cognitive proximity indicators. Indeed, they are both available in the SDC Platinum database and have the great advantage of being overall indicators capturing both the technological focus and the business characteristics of the firms. SIC codes are well-known US industrial classification codes ("Standard Industrial Classification"). VEIC codes rather describe firms' technological fields.

12 OEM/VAR: Original Equipment Manufacturer/Value-Added Reseller.

They were originally created by the Venture Economics subsidiary of Securities Data to track venture capital-backed companies.

Our measures of cognitive distance are derived from a count of the number of common digits between the primary SIC or VEIC codes of alliance participants. We build two variables. The one based on SIC codes is labelled *distk_SIC*, and the one based on VEIC codes is labelled *distk_VEIC*. They are computed in the following way: if the first digit of the codes considered is common, a score of 1 is assigned; if the first two digits are equal, a score of 2 is assigned; if the first three digits are equal, a score of 3 is assigned; and finally, if the first four digits are equal, a score of 4 is assigned. Consequently, each cognitive distance variable varies between 0 and 4. Yet, this count measure is not satisfactory since it implies a linear increase in cognitive proximity with the number of common codes. For example, the measure's growth is the same when we move from a "first digit in common" alliance to a "first two digits in common" alliance, and when we move from a "first two digits in common" alliance to a "first three digits in common" alliance. In the latter case though, the real increase in the intensity of cognitive proximity is much higher. To account for the probable nonlinearity, we decided to compute the squared scores and the scores' exponential values. These variables are then labelled *distk2_SIC*, *distk_exp_SIC*, *distk2_VEIC* and *distk_exp_VEIC*.

Relational proximity is much more difficult to synthesise into a single measure insofar as firms and their stakeholders are embedded in many different interaction structures: financial relationships, interlocking directorates, specialised job markets, social networks, and so on. Consequently, it seems to be nearly impossible to compute a meaningful overall measure of the degree of relational proximity between alliance participants. Nevertheless, what is important here is to have an idea of the relational proximity which the alliance itself creates, which is feasible to a certain extent. We cannot say that a manufacturing agreement implies more or less relational proximity than a marketing agreement. But there are some other alliances' characteristics for which it is much easier to determine whether they create a high level or a low level of relational proximity. Firstly, R&D agreements certainly imply a high level of relational proximity because the exchange of new ideas is not possible without frequent contacts. Licensing agreements or technology transfers also imply a certain degree of relational proximity, at least at the beginning of the agreement, because it is necessary to explain how to use the transferred knowledge. However, this relational proximity will last less time than in the case of an R&D agreement. OEM/VAR agreements and supply agreements also necessitate a certain degree of relational proximity since it is necessary to make sure that the product supplied by one participant to another fits the final product. Some interactions between firms' engineers will consequently be necessary to adjust the products. Finally, we can certainly conclude that OEM/VAR agreements, licensing or technology transfer agreements and R&D agreements all imply a phase of technological adjustment between the participant firms in which their engineers exchange knowledge in order to develop efficient joint products. In these cases, relational proximity is much more necessary than in the case of simple manufacturing, marketing or services agreements.

Relational proximity also varies depending on the alliance's form: a joint venture is certainly a case of lower relational proximity than any strategic alliance since it implies the creation of a separate entity. Thus, in the case of a joint venture, the partners of the original firms do not interact any longer. The interactions are internalised in a distinct entity where only the members of the JV interact, while those that remained members of the original firms do not.

To sum up, we can propose a qualitative measure of the relational proximity created by some characteristics of strategic alliances (Table 2).

Table 2: Qualitative Assessment of Relational Proximity in Alliances

Type of alliance	R&D	Licensing, technology transfer	OEM/VAR, supply	Marketing/manufacturing/services	JV
Relational proximity	+++	++	+	~	~

We are now in a position to combine these quantitative and qualitative measures of cognitive and relational proximity with the above-described alliance characteristics in order to assess the existence of knowledge-related phases in alliances strategies. As already underlined, we expect these phases to be characterised by specific types of alliances creating different levels of cognitive and relational proximity.

We propose testing this hypothesis through the use of a specific classificatory procedure. We shall also have to check whether these specific combinations of agreements are stable across the two sub-periods. This is indeed a matter of concern since the statistics in Table 1 show us that some kinds of agreements clearly dropped after the crash (licensing, services, manufacturing, R&D agreements) while others, on the contrary, went up significantly (technology and cross-technology transfers).

Since there *a priori* are many possible combinations of agreement types, it is necessary to use a specific statistical methodology to identify a limited number of meaningful alliance clusters and characterise them. We expect that some specific kinds of agreements are implemented in the exploration phase of the knowledge value chain, while others are rather used in the examination and exploitation phases. But is this assumption validated by the data? To put it differently, are the combinations of alliance characteristics distributed randomly between alliances or, on the contrary, is it possible to uncover some recurrent types of combinations of alliance characteristics? And, if so, do they make sense in terms of what the theoretical literature has taught us about the aims of partnership in the different phases of the knowledge generation process?

We use a classification procedure with the following steps. First of all, we exclude from the list of variables alliance characteristics with low variance or with low communality. The first criterion amounts to cutting out the characteristics that have too few occurrences (see Table 1 above) such as equity transfer, royalties, spinout, and so on. The second criterion leads us to exclude the variables which have a low correlation with the factors retained in the principal components analysis or which have a significant correlation with several factors so that they cannot be clearly related to any specific factor. This selection of relevant variables leaves 11 alliance characteristics which we combine with our measure of cognitive distance *distk_exp_VEIC*[13] with a view to implementing the principal components analysis (Table 3 below).

13 We preferred to use the measure based on VEIC codes (*distk_exp_VEIC*) rather than the one based on SIC codes as it is more precisely focused on the firm's knowledge base. Nevertheless, the measure based on SIC codes is also introduced below to characterise the alliances' types. We selected the measure computed with the exponential formula since it stresses more strongly the differences in cognitive distance. However, the

Table 3: Descriptive Statistics of the Variables Used in the Classification Procedure

Variable	Definition	Type	Min	Max	Mean	*Std. Dev.*	Mean	*Std. Dev.*
Servicesagree	Whether the alliance is a services agreement or not	Binary (Yes = 1; No = 0)	0	1	0.57	*0.50*	0.47	*0.50*
R_Dagree	Whether the alliance is a R&D agreement or not	Binary	0	1	0.08	*0.27*	0.06	*0.23*
techtransf_all	Whether the alliance implies technological transfer (unilateral or cross-) or not	Binary	0	1	0.07	*0.26*	0.20	*0.40*
licagree_all	Whether the alliance is a licensing agreement (simple, cross-, exclusive) or not	Binary	0	1	0.12	*0.33*	0.10	*0.30*
Allsupplyagree	Whether the alliance is a supply or an OEM/VAR agreement or not	Binary	0	1	0.05	*0.21*	0.01	*0.10*
manufagree	Whether the alliance is a manufacturing agreement or not	Binary	0	1	0.10	*0.30*	0.08	*0.27*
Mkgagree	Whether the alliance is a marketing agreement or not	Binary	0	1	0.14	*0.34*	0.18	*0.38*
Jv	Whether the alliance is a joint venture or not	Binary	0	1	0.26	*0.44*	0.10	*0.30*
strategicall	Whether the alliance is a strategic alliance or not	Binary	0	1	0.74	*0.44*	0.90	*0.30*
numberofpart_r	Whether the alliance involves more than two participants or not	Binary	0	1	0.12	*0.32*	0.04	*0.21*
crosssector	Whether the alliance involves participants from non-ICT sectors or not	Binary	0	1	0.46	*0.50*	0.36	*0.48*
distk_exp_veic	Exponential value of the number of common digits of participants' VEIC codes	Numerical	1	54.60	5.80	*13.13*	8.61	*16.24*

It is worth recalling that even if the frequency of most characteristics is rather stable between the two periods, a few of them experience a significant change between the first and the second period. Most noticeably, the shares of cross-sector alliances and supply agreements respectively drop from 46% to 36% and from 5% to 1%. There is also a significant drop in the percentage of alliances with more than two participants (from 12% to 4%). On the contrary, the share of technological transfers rises from 7% to 20%, and the share of strategic alliances rises from 74% to 90%.

All these changes may generate differences in the alliance typologies between 1997-2002 on the one hand and 2003-2006 on the other.

The principal components analysis conducted on these variables gives the following results (Table 4). We can see that the percentage of explained variance is, whatever the period, very satisfactory, which means that the information contained in the twelve alliance characteristics variables can in fact be synthesised into 5 factors which are able to account for 64% to 70% of the total variance of alliance characteristics.

results remain unchanged whether we use the simple count of the number of common VEIC codes (*distk_VEIC*) or the squared variable *distk2_VEIC*.

Table 4: Principal Components Analysis Results

Component	1997-2002			2003-2006		
	Initial Eigenvalues	% of explained variance	Cumulative %	Initial Eigenvalues	% of explained variance	Cumulative %
1	2.36	19.65	19.65	2.34	21.23	21.23
2	1.86	15.46	35.11	1.74	15.86	37.09
3	1.28	10.68	45.79	1.36	12.37	49.46
4	1.20	10.00	55.79	1.20	10.87	60.32
5	1.02	8.48	64.27	1.01	9.21	69.54

We then perform two non-hierarchical cluster analyses – one for each period – based on the scores of the principal components analysis. To put it differently, we classify the alliances into clusters of statistically meaningful alliance types, combining not the 12 alliance characteristics but the 5 factors extracted from the principal components analysis. In order to determine the final number of alliance clusters, we use three usual criteria: *i)* the statistical accuracy of the classification measured by the ratio of within-cluster and between-cluster variances (Fisher's test); *ii)* the number of firms per cluster; and *iii)* the economic meaning of the clusters identified. According to these criteria, we are able to discern four alliance clusters in the first sub-period and five in the second sub-period. To interpret the categories, we compute the mean of each alliance characteristics indicator in each of these clusters (Tables 5 and 6 below).

Table 5: Mean Value of the Characteristics Variables in Each Cluster of the Alliance Typology

1997-2002													
Cluster (N = Number of alliances)	Servicesagree	R&Dagree	techtransf_all	licagree_all	allsupplyagree	manufagree	mkgagree	Jv	strategicall	numberofpart_r	Crosssector	distk_exp_sic	distk_exp_veic
1 (N = 399)	0.53	0.01	0.05	0.06	0.00	**0.34**	0.09	**0.73**	0.27	0.03	**0.20**	**21.16**	**19.64**
2 (N = 224)	0.42	0.03	**0.12**	0.06	**0.48**	0.04	0.12	0.53	0.47	**0.56**	0.58	9.09	6.83
3 (N= 1322)	**0.80**	0.00	0.08	**0.18**	0.00	0.00	0.00	0.12	**0.88**	0.08	0.50	**6.94**	**2.41**
4 (N = 445)	0.00	**0.40**	0.04	0.05	0.00	0.18	**0.59**	0.14	**0.86**	0.09	0.53	**7.87**	**2.50**
Average across all alliances (N = 2390)	0.57	0.08	0.07	0.12	0.05	0.10	0.14	0.26	0.74	0.12	0.46	9.83	5.80

For the period 1997-2002, the application of the above-described three criteria provides an alliance classification with four clusters. For each alliance characteristics variable, we check whether there is any cluster for which the score is significantly higher (or lower) than the average across all alliances. If such is the case, we use the variable to qualify the cluster. As an example, we can see in Table 5 that Cluster 1 is mainly made up of joint ventures (73%) and is characterised by a higher than average proportion of manufacturing agreements (34%), a lower than average proportion of cross-sector alliances (only 20%) and high levels of cognitive proximity measures (21.16 and 19.64 respectively). So, we may qualify Cluster 1 as the category of *"joint ventures with a high level of cognitive proximity and dedicated to manufacturing and services exchange"*. We may summarise the clusters' characterisation for the period 1997-2002 as follows:

Cluster 1: *"**Joint ventures** dedicated to **manufacturing and services exchange** essentially inside the ICT sector, with a **high level of cognitive proximity**"*;

Cluster 2: *"**Supply** or services agreements with a higher proportion of **technology transfers**, a **high number of participants** and **average cognitive proximity**"*;

Cluster 3: *"Strategic alliances dedicated to services exchange or to **licensing** agreements, with a **low level of cognitive proximity**"*;

Cluster 4: *"Strategic alliances dedicated to **R&D** and marketing, often cross-sector and with **low cognitive proximity**"*.

Table 6: Mean Value of the Characteristics Variables in Each Cluster of the Alliance Typology

2003-2006													
Cluster (N = Number of alliances)	**Servicesagree**	**R_Dagree**	**techtransf_all**	**licagree_all**	**allsupplyagree**	**manufagree**	**mkgagree**	**jv**	**strategicall**	**numberofpart_r**	**crosssector**	**distk_exp_veic**	**distk_exp_sic**
1 (N = 76)	0.49	0.04	0.07	0.01	0.00	**0.38**	0.09	**1.00**	0.00	0.01	**0.61**	8.36	10.94
2 (N = 69)	0.32	**0.54**	0.07	0.06	0.00	0.07	0.09	0.14	**0.86**	**0.55**	**0.67**	**3.88**	**5.65**
3 (N = 166)	0.00	0.04	0.06	0.04	0.01	**0.20**	**0.85**	0.00	**1.00**	0.00	0.34	**10.48**	16.93
4 (N = 363)	**0.98**	0.00	0.00	0.00	0.02	0.00	0.00	0.00	**1.00**	0.00	0.28	7.79	16.15
5 (N = 202)	0.00	0.01	**0.75**	**0.37**	0.00	0.01	0.00	0.00	**1.00**	0.00	0.32	9.37	**19.69**
Average across all alliances (N = 876)	0.47	0.06	0.20	0.10	0.01	0.08	0.18	0.10	0.90	0.04	0.36	8.61	16.30

Concerning the period 2003-2006, we obtain 5 significant clusters with the following characterisation:

Cluster 1: *"**Joint ventures** dedicated to **manufacturing or services exchange**, often involving ICT and non-ICT firms and with average cognitive proximity"*;

Cluster 2 : *"Strategic alliances dedicated to **R&D** or to services exchange, with a **high number of participants**, often cross-sector and with **low cognitive proximity**"*;

Cluster 3: *"Strategic alliances dedicated to **manufacturing** and/or **marketing** with **high cognitive proximity** (VEIC);*

Cluster 4: "*Strategic alliances dedicated to services exchange with average cognitive proximity*";

Cluster 5: "*Strategic alliances dedicated to **technology transfers** and **licensing** agreements with **average cognitive proximity** (VEIC)*".

Several points are worth noticing about these results. First of all, some alliance types are very similar across the two periods:

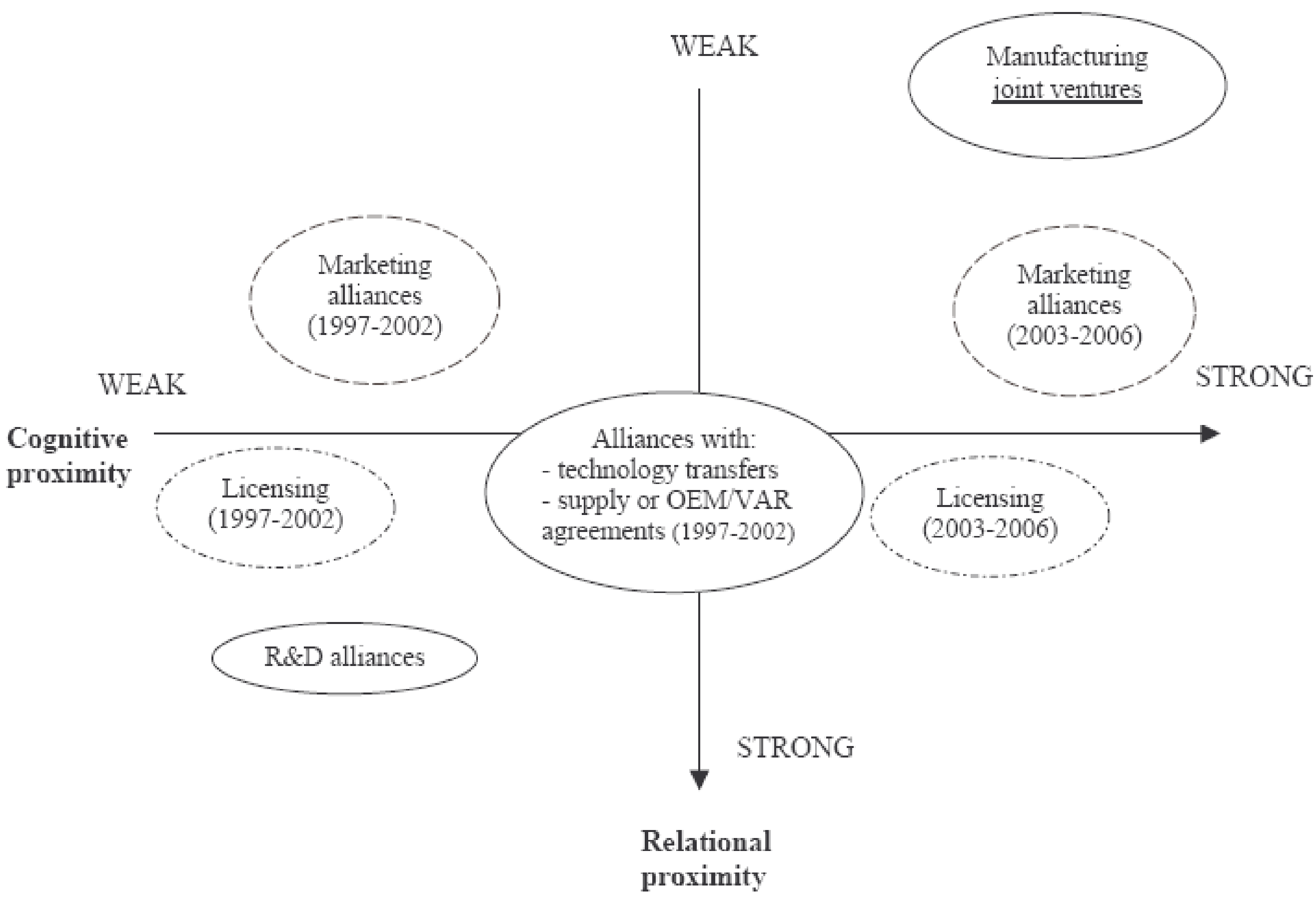
Cluster 4-period 1 and Cluster 2-period 2 are both characterised by alliances that are often cross-sector, R&D-focused and with a high level of cognitive distance;

Cluster 1-period 1 and cluster 1-period 2 are both characterised by manufacturing and services alliances most often in the form of joint ventures. These alliances' cognitive proximity is very high in the first period and only average in the second. Nevertheless, there also is, in period 2, a cluster (Cluster 3) made up of strategic alliances which are dedicated as well to manufacturing (and/or marketing) and characterised by high cognitive proximity. This suggests that the high level of cognitive proximity is a rather robust attribute of manufacturing agreements;

Cluster 2-period 1 and cluster 5-period 2 are both characterised by technology transfers and average cognitive proximity.

These results allow us to position the types of alliances on the axes of relational and cognitive distance with a view to comparing them with the theoretical model as proposed in Figure 1:

Figure 2: An Empirical Typology of Knowledge Phases and Alliance Strategies in the ICT Sector



First of all, the hypothesis of a knowledge exploration phase is empirically validated by the existence, in the two sub-periods, of a R&D alliances cluster clearly positioned in the bottom left-hand side of Figure 2, which means that R&D alliances are characterised by low cognitive proximity[14] and high relational proximity between partners.

[14] Please note that this result may explain why Mowery, Oxley and Silverman (1998) could not obtain empirical validation for their hypothesis H5 according to which: "Partners in alliances at early stages of the innovation process (*i.e.* research alliances) will exhibit greater technological overlap than partners in production or marketing alliances". We have provided both theoretical and empirical arguments here which show that the reverse hypothesis might be much more relevant.

Secondly, the existence of a knowledge exploitation phase is also validated in our data since the presence of manufacturing joint ventures clusters with high cognitive proximity and low relational proximity is effective in the two sub-periods.

Finally, there also seems to be at least a partial empirical validation for the hypothesis of an intermediate "knowledge examination phase" where alliances are dedicated to technology transfers between partners of average cognitive and relational proximity. Nevertheless, we must acknowledge that licensing agreements and marketing agreements cannot be clearly assigned to any phase of the knowledge value chain insofar as there position changes between the two periods.

Finally, this cluster analysis does not invalidate our theoretical propositions or the theoretical typology of alliances (Figure 1) we proposed above. Firstly, our general Propositions 1 and 3 are clearly supported by the statistical analysis. In a systemic and complex view of knowledge, the bi-dimensional space of learning strategies (relational and cognitive dimensions) appears to be relevant to classify firms with regards to the way they use alliances to control the knowledge trade-off between accessibility and appropriability (Proposition 1). We also obtain evidence that the different phases of the knowledge value chain are characterised by specific levels of relational and cognitive distances: high cognitive distance and relational proximity in the exploration phase; average cognitive distance and relational proximity in the examination phase; low cognitive distance and relational proximity in the exploitation phase (Proposition 3 and Figure 1).

It is true however that the examination phase is just partially validated insofar as only technology transfer agreements are persistently positioned in the middle of Figure 1 (average cognitive distance and proximity). Yet, in the theoretical part of this paper, we had argued that technology transfers as well as licensing and marketing agreements could be used in the examination phase of the knowledge value chain where firms seek to solve compatibility and interoperability problems with a view to imposing new technology standards or to maximising their installed bases. To explain why licensing and marketing agreements are not positioned where expected, we can argue that the ICT sector was in a phase of technological convergence in the 1990s and that it is now in a phase of maturity where the main concern is to market and diffuse technologies. The purpose of marketing and licensing agreements may thus have changed between the two sub-periods: they may have been used as exploration tools between cognitively distant partners in the first sub-period, and as exploitation tools between cognitively similar partners in the second sub-period.

The empirical analysis also validates in a satisfactory way our more specific Propositions 2 and 4. Indeed, if our relational distance qualitative index is to be accepted, the balance between the benefits of network externalities encapsulation and the risks of unintended knowledge spillovers seems to generate a negative correlation between cognitive and relational distance along the knowledge value chain.

The validation of Proposition 5 is more ambiguous and calls for more theoretical and empirical developments, as well as more data on the property rights schemes of strategic alliances. On the one hand, it is true that the agreements where property rights are the most strictly defined (joint ventures) are characterised by the highest levels of cognitive proximity. On the other hand though, licensing agreements – which are specially designed to ensure the protection of knowledge property rights – are not permanently positioned on the right-hand side of the cognitive proximity axis (Figure 2), as we already acknowledged. Such an ambiguity could actually result from the duality of property rights exchange tools (licensing agreements): besides their traditional appropriation and tradability function, licensing agreements can also be used to explore new possibilities of knowledge combinations between cognitively distant partners (technological convergence and integration). The balance between these two purposes of licensing agreements may therefore have changed between the two periods under consideration in the present paper. Further empirical assessments would be required to validate this conjecture. Nevertheless, these first results encourage us to develop further the analysis on the knowledge examination phase.

6. Concluding Remarks

In this paper, we analysed – theoretically and empirically – the phases of the knowledge value chain in the European ICT sector. In it, we suggested that the trade-off between the appropriation of and accessibility to new knowledge compels innovative firms to develop specific strategies oriented towards the creation of relevant alliance~~s~~ networks. These strategies are conceived in such a way that firms are positioned in three different knowledge phases: the exploration phase, the examination phase and the exploitation phase.

We began with some theoretical considerations about the role of cognitive and relational proximity in knowledge networks. This led us to put forward propositions which we may sum up as follows: the accessibility/appropriation trade-off can be managed thanks to positioning strategies in a two-dimension space, *i.e.* the dimension of cognitive distance and that of relational distance. Firms choose their position in this space in relation to their need in terms of access to new knowledge, as well as in relation to their fear in the face of the risks of unintended knowledge spillovers. Of course, this paper deliberately focuses on the relational and cognitive dimensions of these positioning strategies, but the geographical dimension should not be neglected either. Our view, however, is that this dimension has already been thoroughly explored in the literature. We therefore believe that it would now be relevant to centre the research programme on the assessment of the relative importance of geographical, cognitive and relational proximity in knowledge generation processes.

We then proceeded to describe the nature of knowledge phases. Though our definitions of the exploration and exploitation phases are similar to the usual ones, we also suggest that, especially in the case of the ICT sector, it is relevant to focus on the examination phase as already described by Cooke (2006). Indeed, in this sector where network externalities are so important, innovative firms have to construct the future markets of their new products. To do so, they need to create new standards, solve compatibility problems, and augment the installed base of their innovative goods. Their alliances must therefore permit intense knowledge exchanges oriented towards the generation of technological convergence and compatibility. At the same time, the risk of unintended knowledge spillovers has to be mastered. This explains why this examination phase should be characterised by a lower relational proximity and a lower cognitive distance than the exploration phase.

At the end of this paper's theoretical part, we proposed a typology of alliances based on these knowledge phases and on the relational and cognitive proximity they create. We then used a non-hierarchical classification algorithm to make out an empirical typology of ICT alliances in Europe, which could then be compared with the theoretical one. This investigation, conducted on more than 3,000 alliances, provides convincing evidence concerning the existence of the three knowledge phases. In the exploration phase, Europe's ICT firms use R&D alliances characterised by high cognitive distance and strong relational proximity between participants. In the examination phase, they rather use technology transfers and supply agreements between partners located at a lower cognitive distance and relational proximity. In the exploitation phase, manufacturing joint ventures characterised by high relational distance and strong cognitive proximity are preferred. Though these are quite satisfactory results, we must acknowledge, however, that we failed to position clearly licensing and marketing agreements in the space of relational and cognitive distance due to their changing position between the two periods under examination.

Though still preliminary, these results are very encouraging insofar as they suggest that it might be relevant to focus on alliance networks as a means of positioning the firm at the optimal point of cognitive and relational strategy. This might pave the way for a new research programme in which innovation would not be solely explained by R&D, property rights schemes and geographical proximity, but also by some network positioning strategies. We therefore suggest going further in the exploration of this perspective through three avenues of research: *i)* exploring other types of networks where knowledge can be exchanged (*e.g.* financial networks), and comparing network proximities with geographical proximities as sources of knowledge spillovers; *ii)* conducting a more thorough analysis of the structural properties of networks of innovators in relation to the knowledge trade-off; *iii)* introducing variables capturing the properties of these knowledge networks in the econometrics of innovation production functions.

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APPENDIX 1: Definitions of the ICT Sector

ICT sectors in the study (SIC codes):

357: OFFICE, COMPUTING, ACCOUNTING MACHINES, AND PARTS & ACCESSORIES, NSPF

365: RADIO AND TV RECEIVING SETS, PHONOGRAPHS, RECORDERS, MICROPHONES, LOUDSPEAKERS, AUDIO AMPLIFIERS, AND OTHER AUDIO EQUIPMENT & ACCESSORIES

366: COMMUNICATION EQUIPMENT AND APPARATUS

367: ELECTRONIC COMPONENTS AND ACCESSORIES

381: AIRCRAFT FLIGHT, NAUTICAL & NAVIGATIONAL, LABORATORY & SCIENTIFIC, GEOPHYSICAL, SURVEYING & DRAFTING INSTRUMENTS, AND PARTS, NSPF

382: INSTRUMENTS FOR MEASURING, DETECTING, TESTING, AND/OR CONTROLLING NONELECTRIC QUANTITIES, NSPF, AND PARTS & ACCESSORIES, NSPF

4812: RADIOTELEPHONE COMMUNICATIONS

4813: TELEPHONE COMMUNICATIONS (NO RADIOTELEPHONE)

4822: TELEGRAPH & OTHER MESSAGE COMMUNICATIONS

4832: RADIO BROADCASTING STATIONS

4833: TELEVISION BROADCASTING STATIONS

4841: CABLE & OTHER PAY TELEVISION SERVICES

4899: COMMUNICATIONS SERVICES, NEC

5045: WHOLESALE-COMPUTERS, PERIPHERAL EQUIPMENT & SOFTWARE

5731: RETAIL-RADIO, TV & CONSUMER ELECTRONICS STORES

5734: RETAIL-COMPUTER & COMPUTER SOFTWARE STORES

5735: RETAIL-RECORD & PRERECORDED TAPE STORES

7370: SERVICES-COMPUTER PROGRAMMING, DATA PROCESSING, ETC.

7371: SERVICES-COMPUTER PROGRAMMING SERVICES

7372: SERVICES-PREPACKAGED SOFTWARE

7373: SERVICES-COMPUTER INTEGRATED SYSTEMS DESIGN

7374: SERVICES-COMPUTER PROCESSING & DATA PREPARATION

7377: SERVICES-COMPUTER RENTAL & LEASING

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