TECHNOLOGICAL ADAPTATION: THE TELECOMMUNICATIONS OPERATORS AND THE INTERNET

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ABSTRACT

This paper sets out to identify factors that represent potential for established firms faced with technological discontinuity. A conceptual model is developed and tested using data from the telecommunications industry. The firms in this industry had to contend with the Internet.

KEY WORDS

Company adaptation, inter-company partnership, technology, technological discontinuity, telecommunications.

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INTRODUCTION

Nowadays, most companies accept that it is necessary to permanently adapt themselves to an environment which, in terms of its technological, commercial, regulatory, sociological and cultural components, appears to be very fluid and even increasingly turbulent[1]. Now, if we consider the technological dimension of that environment, two statements can be made. The first is summarized perfectly in the preamble to a study on the technical progress of the OECD (1992), which noted that technological change always imposes new rules and that companies never know where they will originate nor what they will consist of. Moreover, as Drucker (1980) has pointed out, the nature of those changes is in keeping with the era of discontinuity. The second statement relates to the work of Schumpeter (1939) and Tushman and Anderson (1986) who demonstrated the radical effects that those discontinuous changes have on companies by altering time-honored situations, giving rise to company start-ups and triggering selection among the established companies. In addition, Abernathy and Utterback (1978), Dosi (1982) and Foster (1986) have underlined the growing difficulty that companies experience in adapting to such technological discontinuity.

In the light of these two statements, this article will seek to identify the action variables which enable a company to act upon on its capacity to adapt itself to technological discontinuity. It sets out to identify the attributes which favor the development of that permanent technological adaptation capacity which is seen as the expression of an aptitude, of a potential specific to a company, and which rapidly establishes itself as a guarantee of durable competitiveness[2]. We postulate that, for a company, that capacity consists of evaluating, assimilating and applying external technological know-how for commercial ends.

In an initial section, we shall thus define and explain the theoretical bases of our conceptual technological adaptation model. The second section of this article presents the body of hypotheses relating to that conceptual model. The third section, devoted to the methodology used, explains the collection of data, the implementation of our conceptual models' variables and the statistical methods used. Presentation of the results is the subject of the fourth section. We conclude on the factors which have a significant effect on the development of the potential for technological adaptation and we discuss the limits of this research.

1. THE POTENTIAL FOR TECHNOLOGICAL ADAPTATION: THEORETICAL BASES

To characterize the notion of technological discontinuity, it is necessary to bear in mind first of all, in line with Nelson and Winter (1977), that the technological paradigm makes direct reference the existing body of scientific knowledge and to the technological know-how that determines the technological problems that affect firms and the ways in which they attempt to solve them. It thus defines the important problems to be solved and the scientific principles and technological equipment to be used. When a change occurs within the technological paradigm, however, the scientific and/or technological developments change the

[1] By “turbulent environment”, we mean an environment characterized by a high level of both instability and complexity. This concept was fully developed in a book by Martinet and Petit (1982) and in an article by Koenig and Joffre (1981).

[2] The term “durable competitiveness” is borrowed from Lesca (1989). The author defines this notion as follows: “*a company is competitive when it is capable of maintaining itself permanently and voluntarily in a competitive and changing market by achieving sufficient cash flow to ensure its financial independence and the means of its adaptation”* (p. 12).

nature of the problems to be solved and the technological equipment used. Although those changes tend to be a function of a series of gradual improvements having diverse origins, they nonetheless manifest themselves through radical technological innovations. Rosenberg's book (1976) presents some significant case studies of this phenomenon, particularly in regard to aeronautics and machine tools. As Clark (1987) points out, therefore, the consequences of those innovations are that the old technological methods, the links established with the market and the companies' technological capacities are rendered obsolete. Metcalfe and Gibbons (1989) therefore stress that the knowledge base required differs greatly from one technological system to another and that companies have to adapt themselves to the new technological conditions. Lastly, Westney (1988) shows that when a change takes place within the previous technological paradigm, companies must reconfigure their knowledge network.

Therefore, a company wishing to adapt its knowledge base to the new technological system resulting from a discontinuity must integrate the new major problems to be solved, the new scientific principles used and the new technological equipment to be used. Now, Cohen and Levinthal (1989) note that ease of learning within an industrial is directly affected by the level of investment devoted to R&D. Likewise, Nelson and Winter (1987) consider that for companies to be freely able to use the available knowledge, they must invest in R&D. Rosenberg (1976) likens (basic) research activities to the purchase of a ticket giving admission to an information network. Lastly, Tilton (1971) affirms that one of the main reasons for investing in R&D in the semi-conductor field has been to facilitate the takeover of new technologies created elsewhere. While Cohen and Levinthal (1990) emphasize the central role played by internal R&D as a source of takeover capacity, it is also important to stress the important contribution to the phenomenon of technological adaptation that is made by the "technological supply" relationships which exist in the myriad forms of inter-company collaboration.

Myers and Marquis (1969) emphasize the importance of external technological sources in the innovation process. Likewise, the works of Horwitch (1986) and Burgelman and Rosenbloom (1989) draw attention to the essential role played by the development of strategic alliances in the acquisition of expertise in new and emergent technologies when the technological base of an industry changes. Moreover, the high degree of uncertainty which characterizes many emergent technologies, associated with the speed of technical progress, suggests that it is impossible for a single company to be effective in relation to all of the technological advances within its business sector. This position is illustrated perfectly by Hamilton (1986), who, using biotechnology as an example, develops the following argument: "*During the emergence of a new technology, no company has all of the resources required for the initial stages of development. The companies therefore create links (through contracts, joint ventures, licenses, concessions) as a means of having a window open on the new technology, thus creating options for the development and establishment of positions in the new technology." (p. 104).* The partnership also operates as a means of acquiring resources, particularly when they are not available internally or on the market. The source of this argument is to be found in Pfeffer & Salancik's model of organizational interdependence derived from organizational sociology. For those authors, firms maintain relationships of dependency with other firms in order to acquire the resources needed for their survival (reinforced by the scarcity of resources, the existence of intercompany relations or uncertain access to the resources). Therefore, the more difficult the resources are to obtain, the more pressure there is on the firms to consult with one another in order to develop their products. The establishment of collective structures (jointly owned subsidiaries) is conceivable when the firm cannot control its supplier of resources (by acquisition, absorption or merger) or when information has to be exchanged in an uncertain and turbulent environment. The argument for transferring resources between partners has also been put forward by Doz,

Hamel & Prahalad (1989). For those authors, an essential factor in the success of a partnership is the establishment of contractual terms, and systems and procedures, which make it possible to acquire knowledge from partners in order to consolidate the firm's own know-how and technological base. For all that, firms do not transfer certain types of information which they do not wish to disclose. Similarly, Harrigan (1986) shows that in the case of embryonic industries and/or industries characterized by a volatile competitive environment, companies are more likely to resort to a "spider web" of cooperative agreements between horizontal and vertical players, as this enables the company to cover itself and exploit various possibilities very quickly. While recognizing the multiplicity of organizational forms that collaboration can take, Arora and Gambardella (1990) were interested in knowing whether the different types of collaboration developed by a company were complementary to each other, given that each type of collaboration meets a different need. The biotechnology sector was used as a basis for their research. Because of the numerous agreements that large pharmaceutical companies enter into with other companies, and with new biotechnology companies in particular, they put forward the hypothesis that those agreements are tailored to the product potential and relate to downstream activities to develop and market the discoveries made by the new biotechnology companies. On the other hand, agreements with universities, which generally relate to fundamental research, have been developed in order to obtain basic knowledge in a specific field of research and thus secure a first option on the licenses for the discoveries. Minority equity positions are taken in new biotechnology companies in order to coordinate their internal research activities. Lastly, acquisitions are made in order to complement the companies' internal capabilities, and major ones in the specific domain of biotechnology.

As the previous paragraph has demonstrated the role played by intercompany agreements as regards access to and development of technological capacities, it is now important to discuss the factors that determine a company's ability to integrate an external technological source in order to obtain a new capability. In actual fact, as Metcalfe and Gibbons (1989) highlight: "Given the individual specialization and the correlated nature of the structure of a firm's knowledge, it is easy to appreciate the difficulties associated with technology transfer and the phenomenon of collaboration. The external knowledge actually works like the injection of a foreign body within an existing specialized and interconnected structure. It is therefore not surprising that a firm can produce antibodies quickly." (p. 168). Hamel, Doz, Prahalad (1989) suggest that although some companies are better than others at using strategic alliances, it is certainly not because they draft better contracts, but rather because they are better pupils at all levels within the organization. This position is consistent with that proposed by Harrigan (1986), which underlines the necessity of getting to know one's partner. Analyzing R&D joint ventures, Hladik (1988) supports the thesis that it is important to choose the right partner (i.e. one that one has already collaborated and/or or who has the same type of objectives and/or technical capabilities) and that the framework of collaboration must include predefined limits and objectives. Likewise, Lyles (1988) shows that the ability to put partnerships in place is to a large extent a function of the company's experience in using partnerships. Lastly, according to Galbraith, Merrill and Campbell (1995), technology transfer is dependent on the mechanisms which facilitate inter-organizational communication. It is by recognizing the importance of the staff who form the interface between organizations that Ohmae (1989) stresses that the success of a partnership has more to do with the quality of the people than with the form of the agreement, knowing that the benefit of partnerships is founded on their capacity to be flexible and adaptable to technological and competitive changes. Similarly, Doz (1988), in his research on large groups with minority holdings in small structures, shows that failures stem more often from managerial problems than technical problems.

If one considers, as Reix (1975) does, that a company's adaptation to a component of its environment depends on anticipation (including an element of forecasting) and reaction (with the objective of counterbalancing the effects of external upheavals through the implementation of new command variables), one might suppose that a company's potential for technological adaptation has two dimensions:

1. Acquisition capacity: the company's ability to develop and acquire the technology relating to the new paradigm.
2. Integration capacity: the company's ability to integrate external technology sources within its own facilities.

These two dimensions are the concrete embodiment of the distinction Hamel (1991) makes between access to a partner's competences and the internalization of those competences.

The review of the literature that we carried out enabled us to identify three factors which determine the acquisition capacity:

- The intensity and extent of the internal R&D activities;
- The multiplicity of types of technological partnership;
- The consistency between the choice of management method used to structure a technological partnership and the transfer requirements or learning requirements of such collaboration.

And to identify two factors which determine the integration capacity:

- The technical determinant, which represents the relationship between the company's internal facilities and the technology to be acquired or jointly-developed through technological partnerships;
- The organizational determinant, which has two dimensions:
  - The experience of specific relationships with partners;
1. The availability of communication mechanisms which facilitate transfer from external technological sources.

Figure 1.1 presents a general view of all the factors that favor a company's potential for technological adaptation.

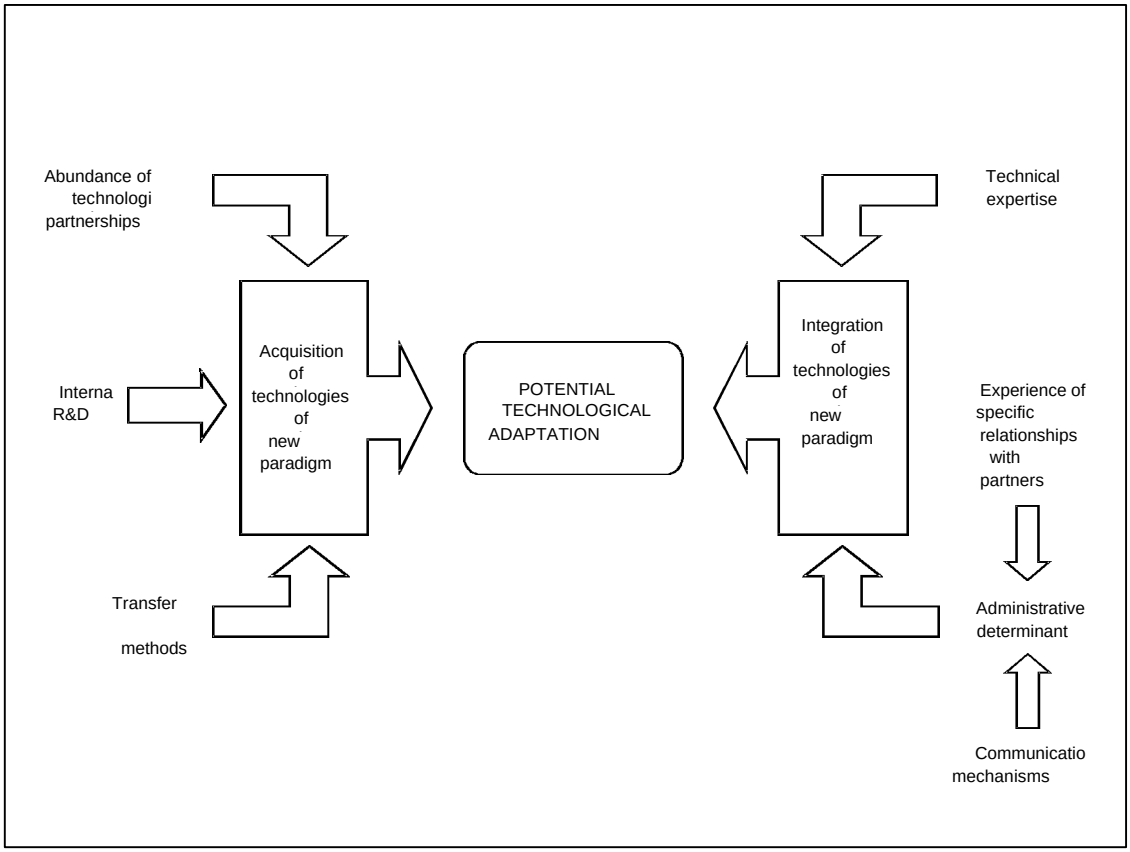

Figure 1.1 – The potential for technological adaptation

2. HYPOTHESES

As Cohen and Mowery (1984) have emphasized, cooperative research is not a substitute for internal research activities. It is necessary for the company to develop a minimum level of internal technological capability. Rosenberg (1976) maintains that "in vitro" research is necessary, given that a substantial research capability is needed to understand, interpret and acquire new knowledge. It is clear that R&D investment is a key factor of a company's ability to evaluate the potential associated with the spin-offs from research. Which enables us to formulate the following hypothesis:

Hypothesis 1 a: Development of a company's potential for technological adaptation is favored by the level of that company's internal R&D investment.

Moreover, when a change of technological paradigm occurs, a variety of technologies are in competition. A degree of uncertainty has to be reduced before one of those technologies can become an industrial standard. When technological discontinuity occurs, the fact of having developed multiple technological activities enables a company to reduce the likelihood of the emergence of a superior technology taking it by surprise. Which enables us to formulate the following hypothesis:

Hypothesis 1 b: Development of a company's potential for technological adaptation is favored by the level of that company's investment in internal R&D.

As we have indicated, Arora and Gambardella (1990) suggest that it is in a company's interest to develop a variety of technological partnerships in order to acquire various kinds of

knowledge and that the different types of technological partnership are complementary to each other and are not interchangeable. We can therefore formulate the following hypothesis:
Hypothesis 2 a: Development of a company's potential for technological adaptation is favored by the multiplicity of types of technological partnership that that company embarks on.

Moreover, one can assume that by developing collaboration with other organizations, the company accentuates and pursues every organizational form of collaboration. Which enables us to formulate the following hypothesis:
Hypothesis 2 b: Development of a company's potential for technological adaptation is favored by the level of that company's involvement in each type of technological partnership.

The literature on transaction costs and strategic management suggests that the *governance modes* used to structure technological collaboration have an effect on a company's technological adaptation. Within the framework of this article, we shall address three forms of technological collaboration: partnerships based on a knowledge gap between the partners, partnerships which involve the partners in collaborative R&D and partnerships which, in addition to involving them in R&D, include marketing activities. In actual fact, in a case in which a company and its partner have the same internal level of technological expertise in regard to the technology to be exchanged, it can be said that the learning prerequisites are weak. Conversely, when the partners are in an asymmetrical position in terms of internal technical expertise in regard to the technology to be exchanged, the learning prerequisites are said to be high. This being the case, when a company is dependent on a technological supplier who has a high level of internal expertise in the technology concerned, the relationship must be structured to ensure that there is a proper transfer of technology. Killing (1980) has thus shown the relationship which exists between the *ownership mode* choice used to structure the technological exchange and the similarity of knowledge bases of the participants in a partnership. Which enables us to formulate the following hypothesis:
Hypothesis 3 a: Development of a company's potential for technological adaptation is favored by recourse to equity-based governance modes to structure partnerships based on a knowledge gap between the partners.

If we examine Pisano's study (1989) based on 195 collaboration agreements in the biotechnology field, we note that *equity arrangements* are preferred when one of the convergence points of the collaboration is R&D, unlike the case in which the object of the collaboration is exclusively downstream (commercial). He concludes that, in order to reduce contractual risks, *equity-based governance modes* are preferred as possible methods for structuring collaborative R&D relationships. Which enables us to formulate the following hypothesis:
Hypothesis 3 b: Development of a company's potential for technological adaptation is favored by recourse to equity-based governance modes to structure partnerships which involve R&D collaboration.

Pisano and Teece (1989) have put forward the hypothesis that collaborations which include both R&D and downstream activities (marketing and promotion for example) are more likely to be governed by *governance structures* than are collaborations based exclusively on R&D. Their reasoning is derived from the fact that investment specific to the transaction becomes more and more important as the relationship moves away from R&D activities towards downstream functions. The most important thing for our research is to note that those two authors suggest that that type of collaboration requires more sophisticated coordination and

communication mechanisms. In the authors' opinion, these more complex processes are best specified in hierarchical channels related to the *equity arrangements*. Which enables us to formulate the following hypothesis:
Hypothesis 3 c: Development of a company's potential for technological adaptation is favored by recourse to equity-based governance modes to structure partnerships which involve R&D collaboration and downstream activities.

Cohen and Levinthal (1990), have stressed the fact that companies need a minimum level of technical expertise to be able to absorb technology from an external source. Lastly, the complementarity level of a company's internal technological expertise has a direct impact on its ability to transfer technology from an external source. Which enables us to formulate the following hypothesis:
Hypothesis 4: Development of a company's potential for technological adaptation is favored by the level of similarity that exists between the technologies sought through partnerships and the company's internal technical expertise.

Lyles (1988) and Hladik (1988) underline the importance of experience of the various types of relationships (joint venture, license, research contract, etc.). They show that this experience effect is regarded as being comparable to the effect resulting from the learning curves and tends to favor relational mechanisms within the framework of inter-company collaboration. Lastly, as Harrigan (1988) and Doz (1988) have pointed out, previous experience with a partner facilitates the solving of problems related to the structuring of the partnership relationship and favors management of the collaboration. Which enables us to formulate the following hypothesis:
Hypothesis 5: Development of a company's potential for technological adaptation is favored by the amount of previous experience with a partner which that company is bringing to a new technological collaboration.

As Tushman & Anderson (1986) have shown, it is important to take account of the communication mechanisms which enable individuals to manage the progress of the partnership on a day-to-day basis and therefore identify any technical or administrative problems which might affect the technology transfer. In this author's opinion, those mechanisms may be formal or informal. The formal communication mechanisms may be taken to be: the identification of progress indicators for the activities; the scheduled reports; meetings to discuss progress; staff exchanges; the identification of an executive to act as the partnership's project manager. For their part, the informal mechanisms are the informal conversations and the unscheduled meetings called to deal with a specific problem. Which enables us to formulate the following hypothesis:
Hypothesis 6a: Development of a company's potential for technological adaptation is favored by the frequency of use of the communication mechanisms.

Hypothesis 6b: Development of a company's potential for technological adaptation is favored by the importance accorded to the communication mechanisms.

We have thus developed a series of hypotheses which relate the elements of this potential for technological adaptation to a set of factors associated with its development. We chose the telecommunications operators sector to test this model empirically. Today, the "traditional" telecommunications operators have to contend with a new technological paradigm relating to the development of the IP (Internet Protocol) technologies which constitute the Internet's underlying technologies.

3. METHODOLOGY

The selection of the sample had to take a number of constraints into account. By its very nature, this research is limited to telecommunications operators having a sufficiently large international business, a proprietary communications network consisting of a set of infrastructures capable of routing voice communications at the standard quality rate applicable in the telecommunications world (99.99%) and research and development activities. The existence of at least one R&D activity implies that the company is of relatively large size, particularly if research beyond the fixed telephony level is being conducted in the IP field. Because of this, the sample was limited to companies whose turnover in 1997 was above 2,000 million dollars.

Data collection

The data required for our study was obtained from several sources. The first source was developed by devising and administering a questionnaire containing a set of explicative, quantitative and qualitative elements that make it possible to define relationships of a quantitative nature (here, the potential for technological adaptation).

Indirect sources were used to obtain qualitative data regarding the telecommunications operators' initiatives in the Internet domain during the period 1989-1998. They were obtained from three distinct sources:

The first source consisted of the newsletters of each telecommunications operator in our sample. In this we followed the methodology used by Garrone and Colombo (1997) who point out that recourse to the companies' information services is imposed by the newness of the sector studied.

The second source of information was the "Datapro Information Services" database, which provides a profile of each telecommunications operator on both a global and an Internet services basis.

The third source used for our research objectives[3] was a limited survey we carried out in the form of interviews. In that limited survey, eleven managers from six telecommunications operators were interviewed. The interviews, of a semi-directive type, lasted for an average of 2½ hours. We began with a very open question to ascertain the respondent's opinion on the relevance of the subject (particularly in relation to the specific problems encountered by that operator). Then, based on the replies given to the open question, we asked more precise questions regarding the nature of the adaptation problems encountered and the solutions used, as well as the objectives and practices in regard to partnerships and R&D. The idea was to let the respondents express themselves as freely as possible regarding their perception of the notion of potential for technological adaptation and on the new technological paradigm relating to the Internet and the role played in the general adaptation process by partnership and R&D factors, as well as the possible repercussions of an adaptation objective on the choice of partners and the associated management methods. The data thus collected gave rise to an exclusively qualitative exploitation. One of the main contributions of that survey was that it enabled us to better understand the different perceptions of the concept of potential for technological adaptation depending on the environmental constraints to which the different operators were subjected and depending on their specific internal characteristics.

[3] That is, to describe the telecommunications operators' behavior in regard to partnership in terms of their contribution to the development of a potential for technological adaptation to address a new technological paradigm.

The model's variables

The dependent variable in our research, the potential for technological adaptation, is a measurement of the extent to which a company has succeeded in acquiring the tools, know-how and knowledge associated with the new technological paradigm. It is for that reason that the potential for technological adaptation is evaluated on the basis of several dimensions: the number of patents the company holds in respect of IP technologies, which will be noted (BRE)[4], the number of products developed using IP technologies which the company has on the market (PRO) and the company's reputation relating to its expertise in the Internet domain (EXP). The research thus uses three different measurements to determine the potential for technological adaptation.

The earlier research generally makes no distinction between internal and external R&D expenditure. The intensity of the R&D is, however, often measured as R&D expenditure applied to sales (Cohen and Levinthal 1990; Kogut 1989). As we are seeking to distinguish between internal and external research, that measurement had to be adapted. The intensity of internal Internet-related R&D is measured on the portion of total R&D expenditure allocated to IP technologies. This data relating to internal R&D intensity relates to two periods 1989-1993 (RDI1) and 1994-1998 (RDI2).

The extent of a company's expertise in the Internet domain was measured by analyzing the services offered by un operator (ACC) in the Internet domain. In fact, as that variable must take account of the scope of an operator's technical expertise, it seemed to us interesting to look at that operator's areas of involvement in Internet services (taking in the search engines on offer, IP telephony, Intranet development, content management, e-commerce offerings, etc.).

The distinction most frequently made in the literature (Jolly, 1992) is between jointly owned subsidiaries, legal entities involving stockholders' equity (equity partnerships) and cooperative agreements without contribution of capital (non-equity partnerships). The spread of partnerships (TALL) is thus measured by the total number of partnerships entered into by an operator. On the other hand, the differences between the different contractual forms a partnership can take led us to introduce the number of licenses (LIC), the number of research contracts (CONTRD), joint ventures (JV), the number of acquisitions (ACQ), the number of minority equity investments (MEI) and the number of R&D partnerships (PARD).

The third hypothesis postulates that recourse to equity-based governance modes (joint ventures, acquisitions and minority investments) will make it possible to increase an operator's potential for technological adaptation.

For this purpose, respondents to the questionnaire were asked to state how often they had had recourse to equity partnerships during the two periods 1989-1993, and 1994-1998, making the following distinctions: partnerships based on a knowledge gap between the partners (FIN1 and FIN2); R&D collaboration partnerships (FCOL1 and FCOL2); R&D collaboration partnerships involving downstream activities (FRDCO1 and FRDCO2).

To determine the level of similarity between a company's internal technical expertise and the technologies it is pursuing through the partnerships it mentions, we used the questionnaire, which, for each category of partnership (license, joint venture, research contract, acquisition, minority investment), asks the respondents to indicate the exact number of collaborations in which the operator had weak or strong technical expertise. The number of partnerships belonging to each category was multiplied by the value of that category. Then,

[4] The names of variables will be expressed in capital letters.

the sum of the total was divided by the total number of partnerships. We thus obtained the variable which reflects a company's internal technical expertise and the type of partnership that it is pursuing (EXPIN).
The notion of experience in the phenomenon of partnerships was made operational by Harrigan (1988) by counting the absolute value of the number of partnerships entered into by the company. However, as we are interested in the specificity of the partnerships in the structuring of the learning deriving therefrom, it seems to us more relevant to take previous experience with a partner into account, as Doz (1988) does. That variable, representing previous collaborative experience with specific partners, is made operational by counting the number of partnerships entered into by an operator that involve a partner with which that operator has already collaborated at least once (EXPALL).
The data relating to the communication mechanisms was obtained via the questionnaire. The respondents were asked to indicate, on a Likert scale, the frequency of use of the different mechanisms identified. They were thus requested to evaluate the frequency of use and the importance accorded to those mechanisms: project follow-up meetings (FREU, IREU), unscheduled meetings (FREPO, IREPO), informal conversations (FCONI, ICONI), written reports (FRAPE, IRAPE), staff changes (FECHP, IECHP) and the appointment of a partnership manager (FRESP, IRESP).

Statistical analysis method

As our sample is small, we had to resort to non-parametrical methods in order to determine the independent variables that have a significant effect on the dependent variables. This analysis will be carried out without prejudging the nature of the relationships linking those variables. To do that, we used two statistical techniques: the Wilcoxon test and a one-factor analysis of variance (ANOVA). First, the operators in our sample will be broken down into two groups (weak potential and high potential) based on their score for each measurement of potential for technological adaptation (the following paragraph will specify the division rule). We shall then compare the distribution of each of the independent variables in the two groups previously defined using the Wilcoxon test. Next, a one-factor analysis of variance (ANOVA) will be used to indicate the effect of the independent variables on the dependent variables. This technique makes it possible to compare the averages of the independent variables for different groups. In our study, the groups were defined through observation of the independent quantitative variables broken down into classes or levels. Apart from the main objective, i.e. the possibility of rejecting or not rejecting our model's underlying hypotheses, the interest of implementing these two statistical methods together lies in identifying the atypical behavior of certain operators.
Initially, therefore, we divided the data so as to create a group of operators with a low potential for technological adaptation and a group of operators with a high potential for technological adaptation. The operators were categorized as having a high potential for technological adaptation if at least two of their dependent PRO, BRE and EXP variables were above the respective median of each of those variables. In the reverse case, the other operators were categorized as having a low potential for technological adaptation. To ensure the reliability of that division, we applied the Wilcoxon test to check the following hypothesis:

h_0: distribution of the variable BRE (PRO and EXP respectively) is the same in group 1 (low potential) and in group 2 (high potential).

h_1: the variable BRE (PRO and EXP respectively) takes significantly lower values in group 1 (low potential) than in group 2 (high potential).

The results of this test are presented in the following tables:

Table 3.1 - Composition of the groups of telecommunications operators

Test[b]

	BR	PR	EX
U of Mann-Whitney	,00	1,50	,00
W of Wilcoxon	21,00	22,50	21,00
Z	-	-	-
Asymptotic (bilateral) meaning	,00	,00	,00
Exact meaning [2*(unilateral meaning)]	,00 [a]	,00 [a]	,00 [a]

a. Not corrected for ex aequos

b. Grouping criterion: GRD1

By using decision rule (II) of the Wilcoxon test, with a weighting of $\alpha = 0.05$, we should find the fractile $t_{0,05}$ for n_1, $n_2 = 6$. Thus $t_{0,05} = 29$ and it must be compared with the W values of each of the variables of table 3.1.
$W_{BRE} = 21 < t_{0,05} = 29$; $W_{PRO} = 22,5 < t_{0,05} = 29$; $W_{EXP} = 21 < t_{0,05} = 29$
One can therefore reject h_0 and accept h_1. We can thus conclude that BRE, PRO and EXP take significantly lower values in group 1 (low potential) than in group 2 (high potential).
We can therefore now identify the dependent variables which take significantly lower values in group 1 (low potential for technological adaptation) than in group 2 (high potential for technological adaptation) and which have a significant effect on the potential for technological adaptation.

4. RESULTS AND DISCUSSION

Tables 4.1 and 4.2 present a summary of those results, indicating the independent variables for each:

- the hypotheses examined using the Wilcoxon test which cannot be rejected (h_0 indicating that the independent variable considered is distributed in the same way in groups 1 and 2; h_1: indicating that the independent variable considered takes significantly lower values in group 1 than in group 2);
- the value of the weighting coefficient derived from the ANOVA associated with each independent variable in relation to each dependent variable (if the weighting coefficient is below the critical threshold of $\alpha = 0.05$, it is marked +, if the reverse applies, it is marked ns).

				MEASUREMENTS OF TECHNOLOGICAL ADAPTATION POTENTIAL		
DETERMINANTS OF TECHNOLOGICAL ADAPTATION POTENTIAL			Wilcoxon Test	*Number of patents*	*Number of products*	*Degree reputation*
				BRE	PROD	EXP
TECHNOLOGY INTEGRATION	**TECHNICAL EXPERTISE**					
	H4: Level of expertise in the partnerships entered into					
		EXPIN	H_1	+	+	+
	COLLABORATION EXPERIENCE					
	H5: Experience of partnerships					
		EXPALL	H_1	+	+	+
	COMMUNICATION MECHANISMS					
	H6a: Frequence of use of the communication mechanisms					
		FREU	H_1	+	+	+
		FREPO	H_0	ns	ns	ns
		FCONI	H_1	+	ns	+
		FRAPE	H_0	ns	ns	ns
		FECHP	H_1	+	+	+
		FRESP	H_1	ns	ns	+
	H6b: Importance of the communication mechanisms					
		IREU	H_0	ns	ns	ns
		IREPO	H_0	ns	ns	ns
		ICONI	H_0	ns	ns	+
		IRAPE	H_1	ns	ns	+
		IECHP	H_0	ns	ns	ns
		IRESP	H_1	ns	ns	ns

Table 4.1 - Summary of the statistical analyses of the integration mechanisms

				MEASUREMENTS OF TECHNOLOGICAL ADAPTATION POTENTIAL		
DETERMINANTS OF TECHNOLOGICAL ADAPTATION POTENTIAL			Wilcoxon Test	*Number of patents*	*Number of products*	*Degree reputation*
				BRE	PROD	EXP
TECHNOLOGY INTEGRATION	**TECHNICAL EXPERTISE**					
	H4: Level of expertise in the partnerships entered into					
		EXPIN	H_1	+	+	+
	COLLABORATION EXPERIENCE					
	H5: Experience of partnerships					
		EXPALL	H_1	+	+	+
	COMMUNICATION MECHANISMS					
	H6a: Frequence of use of the communication mechanisms					
		FREU	H_1	+	+	+
		FREPO	H_0	ns	ns	ns
		FCONI	H_1	+	ns	+
		FRAPE	H_0	ns	ns	ns
		FECHP	H_1	+	+	+
		FRESP	H_1	ns	ns	+
	H6b: Importance of the communication mechanisms					
		IREU	H_0	ns	ns	ns
		IREPO	H_0	ns	ns	ns
		ICONI	H_0	ns	ns	+
		IRAPE	H_1	ns	ns	+
		IECHP	H_0	ns	ns	ns
		IRESP	H_1	ns	ns	ns

Table 4.2 - Summary of the statistical analyses of the integration mechanisms

In these two tables, only the variables shown in bold characters, i.e. RDI2, ACC, TALL, LIC, ACQ, PARD, FIN1, FIN2, FCOL2, FRDCO1, FRDCO2, EXPIN, EXPALL, FREU, FCONI and FECHP have both significantly lower values in group 1 (low potential) than in group 2 (high potential) and a significant effect on the potential for technological adaptation.

Taken overall, the statistical results do not allow us to reject the first three hypotheses. Therefore, as we had suggested, an operator's ability to develop and acquire the technology relating to the new Internet paradigm results in its having a minimum level of R&D in that domain. Moreover, as the knowledge base required differs substantially from one technological system to another, the operators must establish technological partnerships in order to adapt their technological knowledge base. We must nevertheless specify the nature of those results.

In actual fact, although a telecommunications operator's potential for technological adaptation is indeed favored by the level of internal R&D investment (H1a), it is interesting to note that only the internal R&D investment for the period 1994-1998 has a significant effect on the three measurements of potential for technological adaptation. The internal R&D investment for the period 1989-1993 only has a significant effect on one measurement of potential, the operator's expertise. This may be explained by an initial observation which is intrinsic to the nature of the technological division and the sector studied. In fact, in the telecommunications domain, and the Internet sphere more specifically, the concept of TAT[5] (TurnAround Time), which is used to describe the time which elapses between the perception of a need and the availability of a solution, is relatively weak. For example, the Japanese company NTT realized the importance of the Internet at the end of 1994, yet it needed only a year and a half to launch its information transport network OCN (Internet Service Provider) and thus see its number of subscribers rise from 1.5 million at the end of 1995 to 8.5 millions by the end of 1996. This relatively short turnaround time compared with the pharmaceutical sector, in which the lead time can be 10 years, explains why certain operators who had not really invested in internal R&D during the period 1989-1993 nevertheless developed considerable expertise thanks largely to internal R&D investment made during the period 1994-1998 which enabled new products and patentable solutions to be developed. Moreover, it should be noted that those results do not make it possible to endorse a linear model for the innovation process, as this would have required the initial internal R&D investment (1989-1993) to produce innovations protected by patents and the subsequent internal R&D investment (1994-1998), which was geared more to development, to result in a product and/or service. In one sense, the relationships identified between investment in internal R&D during the two periods and the three measurements of potential for technological adaptation would tend to confirm the interactions and consequences of the innovation process[6].

As we have stated, the H1b hypothesis cannot be rejected and therefore indicates that, when technological discontinuity occurs, the fact of having developed multiple technological activities enables a company to reduce the likelihood of the emergence of a superior technology taking it by surprise. If we therefore take the case of France Telecom, it will be noted that that operator, having prepared for the emergence of Internet services for several years, has, via its R&D center, the CNET, developed all manner of access facilities, directories, search engines and e-commerce facilities, all of which are available today on all

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[5] For an overview of the new management methods applied to all of the company's functions when an innovation project gets under way, see Potter (1990), "Successfully managing research design and development", *Management of technology II*, Miami 1990.

[6] Kline and Rosenberg (1986) have thus proposed one of the first interactive models for the innovation process, emphasizing the numerous interactions which link the science, the technology and the innovation at each stage of the process.

the telecommunications networks (RTC, Numéris, ADSL, cable, satellite, GSM, etc.). This was done in order to respond simultaneously to the expectations of the public and professional markets and, above all, to be able to offer all possible methods of access. In actual fact, the implementation of the IP technologies differs according to the type of telecommunications infrastructure. At the present time, it is impossible to predict what the dominant network mode will be in the future.

The total number of partnerships entered into by an operator has a significant effect on the three measurements of potential for technological adaptation. That hypothesis nevertheless needs to be qualified in light of the results provided by hypothesis 2b which indicate the relationship between the potential for technological adaptation and the number of partnerships of each type entered into by an operator, thus making it possible to identify the various organizational methods or arrangements which have presided over the development of a new "technical network".

The results of hypothesis 2b show that telecommunications operators with a high potential for technological adaptation have a greater number of partnerships in three of the six categories that we used: licenses (LIC), research partnerships or R&D consortiums (PARD) and acquisitions (ACQ).

It should be noted that the (LIC) variable, as the analysis of variance on that factor shows, has no significant effect on the PRO variable. This result stems from the fact that such licenses relate to software aspects used as a basis for developing services. We thus decided to consider the PRO variable as reflecting the purely technological dimension of development on any type of telecommunications infrastructure.

It should also be noted that the ACQ variable has no significant effect on the PRO variable. This result is logical when one considers that most of the acquisitions made by telecommunications operators involve ISPs (Internet Service Providers). Now, as the trend of Internet demand (particularly on the part of companies) remains complex, and as it is undeniably focused on the provision of tailor-made[7] and local services, which only the ISPs are capable of providing today, most of the operators have chosen not to "dilute" the structure of the ISPs taken over within their organization.

The operators characterized by a high potential for technological adaptation have a greater number of research partnerships or research consortiums (PARD) than the operators with a low potential. It should be noted that such partnerships are usually entered into with computer manufacturers, equipment manufacturers or companies in the electronics industry. This result is in fact logical when one considers that convergence around the transmission of a digital signal necessarily involves a coming together of industries, practices and networks.

On the other hand, one must reject the hypothesis that stipulates that the CONRD (research contract) variable has a significant effect on the measurements of potential for technological adaptation. This situation is explained by the fact that most of the research contracts were entered into in 1997 or 1998. In some cases, they relate to specific developments which will lead to patentable innovations in the months ahead. In other cases, they cover five-year or ten-year basic research partnerships aimed at developing new architectures, protocols and applications for the high-speed networks of the next generation, new interface technologies for networked PCs or software solutions for large-scale networks.

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[7] The immaturity of the market partly explains these expectations (the companies needing to be educated and reassured). Use of the Internet and the Web as a communications vector or a sales channel means that the services go beyond the field of telecommunications and involve the provision of associated services and very broad expertise.

Similarly, we did not find any significant relationship between the potential for technological adaptation and the number of joint ventures (JV). In our opinion, this situation is specific to the telecommunications sector and to the strategic movements it has experienced since the beginning of the 1980s. In fact, when faced with the regulatory changes, the arrival of new players (from associated sectors such as computing, or newly created such as ICX or Williams, or from remoter sectors such as electricity distribution) and the complete opening up of the market, the struggle for position and the quest for strategic research partnerships can only intensify. An astonishing number of agreements have been entered into in the telecommunications sector, particularly in the United States, due to the segmented nature of the market. However, the failure of numerous initiatives has taught the partners to be more rigorous regarding the components and objectives of their partnerships. Telefónica's recent withdrawal from the Uniworld consortium to join Concert, and Deutsche Telekom's abandonment of its old ally France Telecom in favor of Telecom Italia, provide ample illustration of this phenomenon: a partnership always corresponds to a strategy of the players, and if the market data or internal interests diverge, the participants may radically alter their choice. Joint ventures in the telecommunications field have therefore been aimed more at combining strengths in order to capture a specific clientele or a specific geographical area. The sweeping changes and turnarounds that have shaped the joint ventures arena as a result of the players involved changing direction seem to us to be one of the reasons why this type of partnership is used more for downstream activities (distribution and marketing) than for research and development. For example, the Global One joint venture created by France Telecom, Sprint and Deutsche Telekom offers IP facilities (Global IP) on a purely commercial basis. Where R&D is concerned, other types of agreement have been put in place between those three partners. For example, France Telecom's research laboratory, located in Silicon Valley since 1997, entered into a research partnership with Deutsche Telekom Advanced Solutions (DTAS), a subsidiary of Deutsche Telekom's R&D arm, located at Palo Alto. Similarly, a research contract was signed with Sprint's research and development center (Advanced Technology Labs) and the university of Berkeley to develop transactional software solutions.

Lastly, we were unable to conclude that there was a significant relationship between the potential for technological adaptation and the number of collaborations involving start-ups. This unexpected result is explained by the fact that the venture-capital companies created by the telecommunications operators were, from the outset, designed and managed as classic venture-capital companies whose aim is to finance young companies having a growth potential consistent with high financial yields. The few operators which have created venture-capital structures have tended to favor the financial yield to the detriment of the integration of technical spin-offs.

Hypotheses (H3a, H3b, H3c) could not be rejected. They confirm that, in a situation in which a company and its partner have the same internal level of technological expertise in regard to the technology to be exchanged, it can be said that the learning prerequisites are weak. This being the case, they do not need to establish organizational arrangements closely associated with equity management methods in order to facilitate technology transfer. Conversely, a change in the technological paradigm has placed most of the operators in an asymmetrical position as regards internal technical expertise in the technologies to be exchanged, thus increasing the learning pre-requisites.

The relationships between the factors associated with the integration of technology from external sources and the potential for technological adaptation received substantial confirmation through the statistical analyses. We must nevertheless point out that there are substantial disparities between the three hypotheses (H4, H5, H6) as regards that statistical

confirmation. We shall therefore present the detailed results obtained for those three hypotheses.

Hypothesis 4 cannot be rejected and thus reflects the need for an operator to have a minimum level of technical expertise in order to be able to absorb technology from an external source. In actual fact, such expertise enables an operator to enhance its own developments by using external techniques and thus produce original solutions.

Hypothesis 5 cannot be rejected and therefore confirms the results obtained by Harrigan (1988) and Doz (1988), showing that previous experience with a partner facilitates the resolution of problems relating to the structuring of the partnership relationship and favors management of the collaboration. From our point of view, those results are explained by the main difficulty of implementing technological agreements between two partners, particularly in regard to synchronization of their work.

The frequency and importance of the communication mechanisms have received very different statistical validations. The frequency of use of certain factors of hypothesis (H6a) seem to have a significant effect on the potential for technological adaptation. Scheduled meetings (FREU) therefore appear to be a factor having a significant effect on the three measurements of potential for technological adaptation. This result suggests that it is necessary to establish a structural framework to manage the technological information flows between the members of a partnership. This result is consistent with Kogut (1988), who states that the transfer of an organization's tacit knowledge (such as experience of industrialization, or specific knowledge) takes place through the regular and structured contacts between the partners. The frequency of informal conversations (FCONI) has a significant effect on the potential for technological adaptation. This result confirms the importance of the informal networks established between researchers from different organizations. Crane (1972) had already established, on the basis of empirical research, that knowledge progresses through the diffusion of ideas transmitted partly by personal influence links, particularly through a form of specific interaction: informal conversations. Today, we are witnessing a change in the ways that innovation projects are run, with a "horizontal" organization, the importance of which is corroborated by our results which show that the frequency of staff exchanges between partners (FECHP) has a significant effect on the measurements of potential for technological adaptation. On the other hand, the specific appointment of a partnership manager (FRESP) is a trend which is still new in partnership management. Its effect on the potential for technological adaptation is only very partially reflected in our statistical analysis. In our opinion, this result is explained by the operational objectives of the person in charge of the R&D partnerships. In fact, our limited survey reveals that that person generally handles the administrative management of the partnership. Now, we sought through this factor to take into account the strategic, tactical and operational management of partnerships which makes it possible to structure and develop mechanisms for information-exchange, problem-solving and identification of common needs.

Although we expected to find a certain homogeneity between the frequency of use of the communication mechanisms (H6a) and the importance of those mechanisms (H6b) in the eyes of the managers, the results of our analysis indicate the opposite. This suggests that the respondents accord little importance to those mechanisms. There thus appears to be a gap between the perception of the importance of those mechanisms and their real value. In actual fact, we have shown that three of those mechanisms had a significant effect on the potential for technological adaptation. It seems to us prejudicial for an organization not to establish structures which would systematically favor those mechanisms rather than leaving them to personal and ad hoc initiatives.

CONCLUSION

We have thus been able to show, for the telecommunications operators sector, the factors associated with the acquisition and integration mechanisms of the technologies associated with a new technical system that have a significant and positive effect on a company's potential for technological adaptation. The nature of the processing carried out following the field study does not enable us to put forward a general model of causality linking competence development to internal and external contextual elements. Nevertheless, the results obtained open up interesting perspectives for the creation of such a model.

Our results suggest that it is dangerous to see technological partnerships as a panacea that ensures systematic adaptation to a turbulent technological environment. Indeed, the benefits of a partnership are not systematic. From our perspective, therefore, the pooling, combining and exchanging of resources within a partnership enable the members of that partnership to reap benefits that they could not enjoy individually, provided that they jointly establish certain management arrangements and adhere to a consistent strategy.

In the first place, it is important to emphasize that technological partnerships cannot under any circumstances be substituted for investment in internal research and development. On the contrary, such investment is a *sine qua non* for the development of technological partnerships. Our results therefore strongly suggest that an ability to acquire the relevant technology from external sources appears to be a function of both the number of technological partnerships and the way in which they are implemented. The management must therefore take into account the portfolio of partnerships the company is involved in, since they constitute strategic resources for future action.

Above all, it is essential to stress the prerequisites that are essential for certain types of collaboration to enable them to achieve positive results, and likewise the importance of contractual forms in technology acquisition. Similarly, technical experience of a partnership and administrative experience relevant to technological collaboration are the keys to success in the process of adaptation to technological discontinuity.

Lastly, when one knows that 60% of partnerships fail[8], mainly on account of unsatisfactory relationships between the people involved or the particular role played by the partnership's management, one becomes even more acutely aware of how important it is to provide information on previous experience to all the participants in the new collaboration and to put formal and informal communication mechanisms in place to support technological partnerships.

We must nevertheless note that we remain at a prescriptive level which certainly needs to be supplemented by further work that details the critical components, their possible coordination arrangements and the organizational memorization mechanisms of each factor which appears to favor the potential for technological adaptation. Moreover, the lack of scope for drawing general conclusions from the results of the field study constitutes a further limit to that research. Which is why we consider it necessary to test the soundness of that model in other business sectors.

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[8] This figure is the result of a British survey carried out by R. E. Speakman (1996).

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