Convergence in Communications and Beyond
E. Bohlin, K Brodin, A. Lundgren and B. Thorngren (Eds.)

CHAPTER 7

Governance and Technological Change: Transaction Costs in Telco-Equipment Supplier Networks

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1. INTRODUCTION

To what degree is Transaction Cost Theory (TCT) able to highlight organizational choice analysis in a technologically intensive sector like the public switching industry? A previous study by Guertman and Quelin (1993) used TCT in order to analyze the coordination practices in this sector in an international comparative perspective. However, it did not mention the latest developments in technology and organization, like intelligent network architectures (INA), increasing competition in the telecommunications area (Phan, 1996).

This chapter uses Transaction Cost Theory to explain the organizational forms observed in the telecommunications industry's production of public switching equipment in the recent past. Its second goal is to emphasize some limits of this theory in this specific case and to help extend its scope.

The first section gives a brief discussion of the principles of TCT and particular attention is paid first to the *role of technology*. This is not well defined in Williamson's work, where a "semi-weak" form of technological determinism is put forward. The way "technologically separable entities", bounded by "technologically separable interfaces", are defined is, according to Williamson, beyond TCT's domain of analysis, because there is no way to identify a transactional problem in their definition. Therefore technologically closed entities would be the new "black boxes" of transactional analysis. But this first limitation makes "standard" TCT unable to take into account the process of technological evolution itself, when technological change is not an "exogenous" factor.

* The authors acknowledge F. Lotter and S. Saussier (ATOM/Paris I), E. Dognin, J. P. Simon, M. Tréheux (France Telecom) for their helpful comments on an early French draft version of this paper, and E. Bohlin, G. Dang Nguyen (ENT-Bretagne/ICI UBO) and J. Ormrod for their contributions to the English version for the ITS 1998 biennial conference. All remaining errors are our own.

A second theoretical limitation of TCT is the relationship of governance structures and the institutional environment. Williamson (1993a) recognizes both the influence of the institutional environment on governance structures and a feedback effect of governance structures upon the institutional environment. But he claims that these latter effects are "of the second order" and beyond the scope of TCT theory. In this paper we discuss the logical and empirical consequences of this principle, in particular when the actors' strategies are designed to influence the institutional arrangements according to their self-interest.

The consequences of both theoretical limitations are that it is difficult – logically, and empirically in some cases – for the actors to measure *ex ante* the transaction cost for different kinds of governance structure, and TCT cannot by itself explain the transition between different regulatory modes.

The *second section* analyzes the characteristics of transactions between telecommunications operators and equipment manufacturers in the domain of public switching. On the basis of "technologically separable interfaces", TCT analysis enables us to distinguish between three periods. In the first one, the switching system as a whole is a unique technological entity (designed using electromechanical principles), which gives rise to a single transaction between telcos and equipment manufacturers, with a high degree of asset specificity.

In the second period, the switching system is split into two different technological entities: hardware and software, and two different transaction characteristics. *Exogenous* technologically separable interfaces appeared early with space-division electronic switches, as a consequence of the diffusion of computer characteristics into the telecommunications industry. But a separate transaction for software and hardware, respectively, appeared only with the fully digital switch (time-division). Transactions concerning software become the support and the main challenge of asset specificity, first reinforcing it, but then globally reducing it in the long run, for both institutional and technical considerations. With this separation, new transactions occurred through an upgrade of the software for technical reasons or through marketing necessity. The introduction of each new software release provided a competitive advantage for fast movers. Thus, growing competition in the telecommunications services gave strong *endogenous* incentives to the separation of customer services from basic network administration.

According to these incentives, the third period, with the emergence of the Intelligent Network Architecture at *Bellcore*, led to more modular systems with new opportunities for standardization (decrease in asset specificity) and for new technological separation in a third period. The definition of technologically separable entities is consequently mainly endogenous, unlike the previous stage. However, interactions with the computer industry remained important, in the context of the gradual convergence between the computer world and the telecommunications world, through growing networking activity in data communications (ATM, Internet).

The *third section* raises the question of the appropriateness of governance structures to their technological and institutional environment in the long run, taking as an example the United States, from the creation of the Bell Company to the present day. Despite theoretical limitations, TCT enables us to compare *ex post* the relative efficiency of governance structures *in a given institutional and technological context*. TCT also allows us to highlight when governance structures became inadequate, faced with technological and institutional evolution, as is shown in this paper in the case of telco-equipment suppliers.

2. A FRAMEWORK FOR THE "CLASSICAL" APPROACH OF TRANSACTION COST THEORY (TCT)

This section briefly presents useful TCT tools for assessing the power and the limits of TCT as a suitable theoretical framework for analyzing the relationships between public switching equipment manufacturers and Telecom operators.

TCT was developed early by R. H. Coase in his famous article "The nature of the firm", published in 1937. This paper underlines that the market is not the only means of coordination for economic transactions; the firm can also be considered as an alternative form of coordination. Coase explains the complementarity between the firm and the market through the existence of transaction costs. Transaction costs are the resulting burden of the resources mobilized in order to achieve a transaction through the market. The firm exists because the cost of achieving specific transactions is lower within an organization than on the market.

In the seventies, O.E. Williamson proposed a new framework for analyzing transaction costs. He acknowledged his indebtedness to Coase's seminal work. Williamson attributed to Coase the merit of having presented the problem of economic organization though a comparison between organizational forms.[1] Hence, the goal of TCT is to assess the different forms of governance structures in relationship to the corresponding transaction cost.

Since the end of the eighties, the TCT research program has been enhanced, by taking into account more explicitly the influence of the institutional environment on organizational choices. Moreover, debates on the role of technology and organizational learning have influenced the recent development of TCT.

2. 1 The Main Concepts of Transaction Cost Theory (TCT)

The Sources of Transaction Costs

The transaction is the analytical unit of TCT. A transaction can take place in several organizational frameworks, such as the market or the firm. Every form of coordination is costly. What is the source of these costs? To answer this question, it is convenient to underline two fundamental assumptions concerning the behavior of economic agents and three characteristics. These elements are used to described a transaction.

The first assumption concerns the cognitive nature of the rationality of economic agents. Agents are assumed to search for the less costly form of coordination for organizing their transactions. But their cognitive capabilities are assumed to be "limited" (Williamson, 1985, pp. 45-46).[2] Under this assumption, it is impossible for agents to write "complete" contracts. A "complete" contract is assumed to protect agents against all possible events that might occur in

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[1] Apart from Coase, Williamson recognizes his intellectual debt to K. Arrow, A. Chandler and H. Simon. "The Institution of Capitalism" is dedicated to these four authors. In particular, Herbert Simon supervised Williamson's Ph.D.

[2] This approach is derived from Herbert Simon. Williamson (1985) uses the term "bounded rationality" and not "procedural rationality", also introduced by Simon (1976, 1978). On this question, Williamson refers frequently to Simon (1957): "behaviour is intendedly rational, but only limited so". Like the latter, he justifies bounded rationality by the limitation in the cognitive competence of the agents: "mind is scarce resources" (Simon, 1978, p. 15, quoted by Williamson, 1985, p. 46) but does not have a great deal of interest in the cognitive dimension of rationality itself. Only the economic consequences of bounded rationality matter, such as the incompleteness of contracts. In TCT, agents remain calculating and lead mainly through their self-interest. From this point of view, one can interpret this form of bounded rationality as a weak form of instrumental rationality (Walliser, 1989).

a trade. The incompleteness of contracts might lead to unpleasant effects in relation to opportunism, the second behavioral assumption. Economic agents, driven by their own self-interest, are tempted to manipulate information deliberately, in order to gain advantage for themselves.

Three attributes can characterize the nature of a transaction: the level of frequency, the level of uncertainty and the level of asset specificity.[3] That is, the combination of these three attributes would serve to justify the choice between possible forms of coordination, generally in order to protect against the risk of opportunism. Taking into account the behavioral assumptions and the characteristics of these attributes, the exchange process is therefore intrinsically costly. The corresponding costs are specifically the transaction costs.[4] The aim of TCT is to make an inventory of and assess the institutional arrangements in order to reduce these transaction costs.

The Structures of "Governance"

"Governance structure" denotes the organizational form in which a transaction takes place. The two extreme forms of the set of governance structures are the market and the "hierarchy" (coordination inside a firm). Between these "pure" forms exists a large set of "hybrid forms". Some of them can be qualified as "quasi-market", some as "quasi-integration". One can also consider another structure, like public authorities organizing transactions and other forms of coordination beetween several firms.

Some specific costs are attached to each governance structure. It is possible to assess these costs using two main indicators: the degree of control and the degree of motivation.

The degree of control refers to the capacity of the regulation structure to contain opportunistic behavior, and to enable the compatibility of actions between the agents concerned by the transaction. A weak degree of control by the market may lead to an inefficient allocation of resources (market failure).

The degree of motivation refers to the agents' incentive to search for efficiency in production. There is a hierarchy failure when the hierarchy is unable to produce enough incentives in comparison with the competitive pressure.[5]

The Transactional Choices

The institutional comparison is the fundamental principle which enables the choice between different governance structures to ensure a given transaction. "The Transaction Costs are economized by assigning transactions (which differ in their attributes) to governance structures (the adaptive capacities and associated costs of which differ) in a discriminating way" (Williamson, 1985, p. 18).

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[3] Asset specificity may take different forms. Williamson (1993b) mentions, for instance: site specificity, physical and human asset specificity, dedicated assets. Cf. Williamson (1985, p. 55).

[4] The *ex ante* transaction costs include, for instance, the costs of searching for information, negotiation costs, and the costs related to the safety of the relationship. The *ex post* transaction costs include control costs, adaptation costs, correction costs and conflict costs.

[5] Lack of incentives is, in TCT, the main limitation in the size of firms: "the transfer of a transaction out of the market into the firm is regularly attended by an impairment of incentives" (Williamson, 1985, p.161). The bureaucratic phenomenon (Leibenstein, 1987) is taken into account at a lower level. It is not possible for the management of large companies to limit themselves only to the problem of coordination between departments, given the numerous sources of incentive disabilities, enforced by auditing limits.

From the TCT point of view, the choice of an organizational form results from the intentional search for an appropriate structure to minimize the set of governance costs and the related production costs, for a given set of technological choices. In its positive version, the aim of TCT is to understand how a large variety of characteristics associated with transactions within the capitalist economy lead to a plurality of institutional arrangements: the governance structures. In its normative version, TCT advocates a regulation structure with a strong degree of control when the transaction attributes are selected by the agents, or are characterized by a strong degree of asset specificity. This is a major prediction of the theory.[6]

2. 2 The Place of Technology: A "Semi-weak" Determinism

TCT is involved in the debate on the role of technology for the determination of the firm's boundary. According to Williamson, the degree of influence of a technology over the choice of organizational structures corresponds, in general, to a so-called "semi-weak" form of technological determinism:[7] "technology is neither fully determinative of nor irrelevant to economic organization" (Willliamson, 1988, p. 357). Known technological options would delimit the set of feasible governance structures. The notions of technologically separable entities and technologically separable interfaces are fundamental for understanding the nature of organizational choice allowed through TCT. It makes it possible to go beyond the notion of "standard" theory, in which the firm looks like a "black box", a pure "production function" (Willliamson, 1988, pp. 356, 358).

Technologically Separable Entities and Technologically Separable Interfaces

The use of these notions implies two consequences.

First, under the "semi-weak" form of technological determinism assumption, all processes of production can be stylized by one or several inseparable entities, given the technological knowledge. Between these entities, "technologically separable interfaces" appear. At these points, transactions are possible: "A transaction may thus be said to occur when goods or a service are transferred across a technologically separable interface. One stage of processing or assembly activity terminates and another begins" (Williamson, 1981, p. 1544). The number of technologically separable interfaces can be considered as fixed when it is no longer possible to "break down" a particular production process to identify new interfaces. The choice for governance structure occurs as many times as there are technologically separable interfaces.

Second, there can exist a set of already known technological options in order to organize the production behind every interface. These different options are to be found in the form of different attributes at the transaction level (notably in the scope of asset specificity). Within this set of possible situations, agents have to choose an organizational form. They select the transaction attributes, the governance structures, and the technological configuration of production in the best way according to their interest. In that way, they can group some subsets of entities

[6] This result is illustrated by numerous theoretical studies. Cf. Klein and Shelansky (1995).

[7] Willliamson (1989) proposes to distinguish four degrees in technological determinism. There is a "strong" technological determinism when the technology is assumed to be the unique determinant of economic organization. There is a "semi-strong" form when the technology is not the main determinant, but matters. There is a "semi-weak" form when the technology defines a set of feasible organizations within TCT which alone allows the choice. Finally, there is a "weak" form when the technology plays an insignificant role, having as a consequence "technology does not matter", and organizational forms are completely determined by transactional factors.

within firms or within other "hybrid" forms of governance (alliances, joint ventures, and other forms of inter-company agreements).

The transactional arbitration of TCT is therefore equivalent to stating the problem of the organization of productive activities in these terms: how can the segment of activity be spread out among economic organizations in order to economize transaction costs, for a given technological background?

Are Technologically Closed Entities the "Quarks" of TCT ?

One problem remains unsolved. The area within an entity considered as "inseparable" is outside TCT's domain of analysis, because it is no longer possible to identify a transactional problem. Therefore technologically closed entities would be the new "black boxes" of transactional analysis. Williamson (1987) recognizes the limits of TCT for taking account of the creation and the evolution of firms.[8] In fact, TCT does not manage to explain how the set of technological options appears and what factors contribute to their emergence. However, taking into account the possible evolution within the set of technologically closed entities plays a non-negligible role in the definition of the entities' boundaries. Some authors argue that the question of endogenous technical change may be solved by the introduction of another dimension, like competence, or capabilities.[9] But for TCT "fundamentalists", it is by nature a radically different approach, because transactions are no longer the only unit concerned in the analysis (Lotter, 1997).[10]

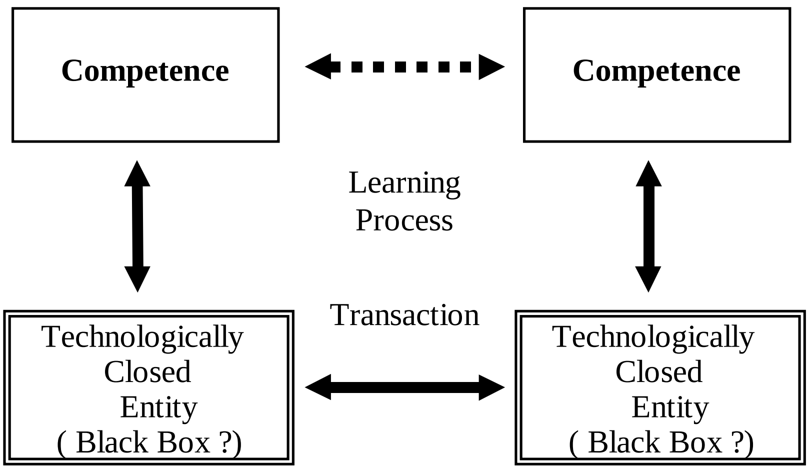

Figure 1. A Two-dimensional "Non-classical" Analysis to Integrate Learning and Transactions.

[8] This restriction is also underlined by Chandler (1992): "I find the earlier growth of the industrial firm difficult to explain fully in terms of transactions, agency and other information costs, so I find it hard to explain the recent process of expansion and contraction with these same concepts" (Chandler, 1992, pp. 98-99).

[9] The question of capabilities refers to the debate on the complementarity between TCT and evolutionary theory (cf. note 17 for more references.).

[10] This interpretation must be brought closer to Williamson's position on the institutional environment and close to North's research program.

All this advocates considering the “standard” TCT framework essentially as a “static”, normative approach. Learning and technologically strategic choices are not integrated within this “standard” analysis. In recent papers, Beije (1996) and Noteboom (1996) underline the difficulties raised by the introduction of dynamics together with a TCT analytical framework. Beije (1996) introduces key concepts for understanding the technological dimension. That is, technological learning implies taking into account competence – as mentioned above – but also strategies and path-dependency phenomena. In this way, the relative advantage of a governance structure no longer depends only on its capacity to minimize transaction costs, but also on its ability to make technological learning easier, and to capture private rent from innovation as well.[11] Finally, from the point of view of technology analysis, the analytical framework of “standard” TCT alone is therefore essentially “static”; in this sense it is not possible to take into account the process of technological evolution itself, and the technology remains an “exogenous” factor. This kind of argument is still valid when we move on to the institutional environment.

2. 3 Taking into Account the Institutional Environment

The institutional environment is defined by Davis and North (1971) as “a set of fundamental political, social and legal ground rules that govern economic and political activity (rules governing elections, property rights and the rights of contracts are examples of the ground rules)”.[12] More specifically, Schotter (1981, p. 11) defines a social institution as “a regularity in social behavior that is agreed to by all members of society, specifies behavior in specific recurrent situations, and [is] either self-policed or policed by some external authorities”. For North (1991), institutional elements consist of “constraints” which structure political, economic and social interactions. Such interactions may be either formal rules (constitutions, law, property right) or informal constraints (taboos, custom, traditions and codes of conduct). The relative features of the various forms of coordination for transactions (i.e. costs of governance) are dependent on the characteristics of the institutional macro-environment (Williamson, 1993a, 1996). Thus, modifications in the institutional environment may alter the relative performances of governance structures which organize these transactions.

The Three Levels (at least) of the Global System: Institutional Environment, Governance Structures and Individual Agents

The influence of the institutional environment on governance structures may be illustrated by Williamson’s diagram (Figure 2: Strata Diagram – Williamson, 1993a). The relationship between the individual (agents) stratum and that of the governance structure denotes the influence of individual behavioral characteristics (limited rationality, opportunism) over the choice of governance structures. Williamson recognizes the significance of specific evolutionary dynamics for the institutional environment, on the one hand, and for governance structures, on

[11] Noteboom (1996) further develops the issue of bounded rationality in the cognitive sense. Cognitive capacities depend on subjects, but also on environments. As a result, preference formation and innovative capacities must be endogenous and the way in which agents seek to learn matters.

[12] Op. cit. p. 133. Davis and North define “an institutional arrangement as an arrangement between economic units that govern the ways in which these units can cooperate or compete”. The governance structure is typically such an “ institutional arrangement ”.

the other hand.[13] But for Williamson, these dynamics must relate to two different levels of analysis. On the one hand, the institutional environment concerns the global macro-relationships between agents and activities. On the other hand, governance structures concern the micro-economic level of transactions. As a consequence, governance structures and the institutional environment would emerge and evolve differently with respect to intentionality (Williamson, 1996, p. 5). Moreover, he considers the feedback effect of governance structures upon the institutional environment as of the second order (Williamson, 1993a). Given all these arguments, Williamson claims that these two levels must be studied separately.

The two higher strata may influence individual choices as well, for instance through certain forms of "social influence", "social customs" or "conformist" behavior (Jones, 1984; Akerlof, 1990; Bernheim, 1994). This effect of "endogenous preferences" (Bowles, 1998) denotes the influence of the institutional environment and governance structures upon an individual stratum. These effects, recognized by Williamson, of lower importance, are indicated as dotted lines in Figure 2 (endogenous preferences and strategies). The latter are frequently neglected by TCT, which focuses on the two main relationships (institutional and individual effects upon governance structures, indicated as a solid line). However, TCT refers frequently to secondary effects, but Williamson suggests that others' analytical frameworks are more appropriate for studying these relationships (Williamson, 1993a, p. 115).

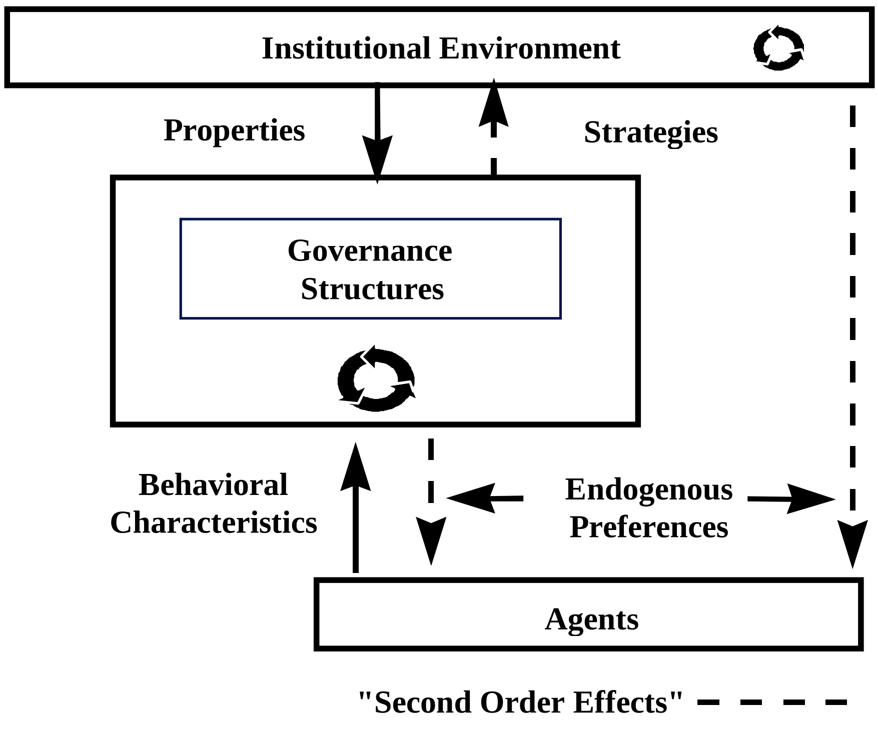

Figure 2. Strata Diagram.

Source: Williamson [1993a]

13 "Both the institutional environment and the institutions of governance have evolutionary origins, [but] the ramifications of each are different": Williamson (1996, p. 5, underlined by us).

Williamson's argumentation on "second-order effects" is not fully persuasive, especially when the time perspective is long enough for significant backward effects not to be avoided. For instance, the accumulation of small events may create an effect of tension by accumulation which may suddenly be relaxed by a dramatic change beyond a certain threshold (Lordon, 1996). In the case of the governance structure, the history of business highlights that the feedback of organizations upon the institutional environment is sometimes negligible but may become more significant in other cases, with possible institutional break-up. For instance, Fliegstein (1990) shows how large American firms' structures can be viewed as a consequence of American institutional competitive rules (such as antitrust laws), on the one hand, but the behavior of these firms in order to find new way to bypass this institutional framework must be viewed as the main cause of the evolution of this institutional framework, on the other hand. The AT&T case, as studied by Mueller (1993), is a good example in the telecommunications field of such behavior. A governance structure which may generate such a tension would be stable in the short term (locally), and strongly unstable in the long term.[14] Elsewhere, one governance structure may be inefficient in a given institutional environment, and efficient in another. Hence, institutional reform may sometimes be suggested in order to intentionally modify – in a "strategic" way – the institutional environment in order to make a given governance structure more efficient.[15]

In a recent paper, Magnusson and Ottosson raise the question of the underdevelopment of the feedback effect of governance structures on the environment, and the difficulty of "standard" TCT in explaining the real (historical) process of institutional change. On the one hand, the action of actors on the institutions matters. "Clearly the actors will try to influence institutional arrangements according to their self-interest" (Magnusson and Ottosson, 1996, p. 361). On the other hand, because the actors are also bounded by the existing institutions, path-dependency phenomena may explain why evolution can also lead to a lock-in in inefficient institutions as well as governance structures. Because a real choice depends not only on transaction costs, but also on technological, market and institutional conditions, these authors argue that actors cannot measure *ex ante* the transaction cost for different kinds of governance structure, and TCT cannot by itself explain the transition between different regulatory modes. As a result, these authors claim that TCT "has been most valuable in developing economic history, but its use as an explanatory factor in itself is highly questionable"(id. p. 361). That is, a complete assessment of the scope and limits of the TCT analytical framework for relationships between the equipment manufacturers and operators in the public switching system market must take into account the complete set of factors (institutional, technological, organizational) which affect a transaction. Despite the complexity of the question, we shall try to propose a synthetic framework in order to summarize the (omitted) effects of technological and institutional factors within Williamson's original diagram.

[14] In another way, similar results can arise when the accumulation of small events drives a dynamic system into a "critical state" where there is no proportionality between incremental stimulus and the resulting effect, as in the case of avalanches.

[15] Transformations in the institutional environment may be committed intentionally for strategic reasons or instrumental ones. The position of R.H. Coase on the interest of selling Hertzian frequency by auction is a good example of such an approach (Coase, 1994). Coase proposes a set of arguments to demonstrate the superiority of the market over the administrative decisions of the FCC to organize this transaction. However, to make the sale by auction possible, it is previously necessary to create property rights over the Hertzian frequency spectrum. Thus, the intrinsic qualities of the market (as a particular governance structure) justify an institutional reform to make possible the use of the auction-market as an efficient solution for a transactional problem.

Technological and Institutional Factors: A Synthesis

In this way, Figure 3 amends Figure 2 by proposing complementary relationships. (2') represents the impact of individual choice on the set of technological options (innovations), on the one hand, and (2) represents the contribution of technology to the modification of the arbitration space of TCT, on the other hand. Both questions are usually seen as exogenous by the theory.

To summarize, TCT recognizes that evolution in technology and evolution in the institutional environment are important features for the problem of organizational choices. However, they are generally treated as exogenous by the "standard" approach of governance structures. These factors define a given transactional space where agents would arbitrate between the different institutions, the governance structures.

"Standard" TCT will be applied in the second part of this paper to public switching transactions for a given technological and institutional environment. With this constraint, TCT will be used as a static allocative theory of organization, and a history of organizational forms will be reduced to an assessment in a "static comparative" way.[16]

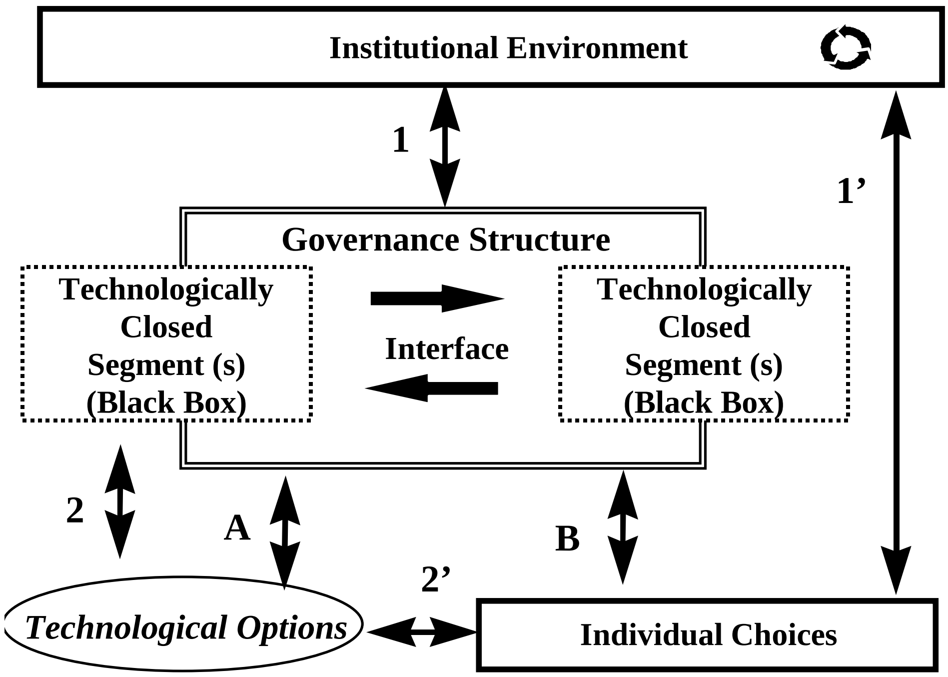

Figure 3. Synthesis

[16] Dynamic evolution is often referred to in recent papers, but little is proposed in practice. However, one may conceive extensions for the TCT standard research program. Lotter (1997), for instance, suggests a more "dynamic" approach for the evolution of transaction characteristics. Such an extension is suggested by Williamson himself, in a recent work. The problem is that it is not certain that this extension will be sufficient to make endogenous the technological choices and the dynamics of innovation. Another way is to suggest a complementary approach for TCT, like the evolutionary theory of a firm based on capabilities (Winter, 1991; Langlois, 1992; Foss, 1993, 1996; Langlois Robertson , 1995; Brousseau, 1996).

3. THE TRANSACTIONS BETWEEN EQUIPMENT MANUFACTURERS AND OPERATORS IN THE PUBLIC SWITCHING SYSTEMS INDUSTRY: CHARACTERISTICS AND ATTRIBUTES

On the basis of “technologically separable interfaces”, TCT analysis enables us to distinguish between three periods. In the first one, the switching electromechanical system is an unique technological entity, which gives rise to a single transaction between telcos and equipment manufacturers. In the second period, the switching system is split into two different technological entities: hardware and software, and two different transaction characteristics. *Exogenous* technologically separable interfaces appeared early with space-division electronic switches, as a consequence of the diffusion of computer industry characteristics into the telecommunication industry. But a separate transaction for software and hardware, respectively, appeared only with the fully digital switch (time-division). A third period began with the emergence of the Intelligent Network Architecture (INA), which led to more modular systems, opportunities for new technological separation and more standardized interfaces. By opposition to the previous stage, the definition of new technologically separable entities became mainly endogenous. In this section, we study the attributes of transaction for the two earlier periods, and provide hints for the transition towards the third period, to be completed in the last section.

3.1 From the First Switch to Electromechanical Generation

In the 1910s, the first automatic switch, invented by Alvin Strowger, simply imitated the actions of previous manual operators. The basic principles of this system were not to change for decades. Two main components had to be distinguished within the machine, one designed for action and the other designed for control:

A selector within the switching machine allowed a circuit to be temporarily created between an incoming line and an outgoing line.[17] In order to increase the capacity of this machine, these components were connected one to the other via a mesh and thus constituted a “connection network” with the function of switching the line.

This “connection network” was driven by instructions from the command subsystem of the switching device. The latter accomplished the “intelligent” function: to establish the communication and to administrate the system. In more recent electromechanical switching systems, the command subsystem drove a relay which opened or closed a circuit. This role was to perform logical operations at a low level of complexity. These components are not naturally programmable. *In this context, it is practically impossible to easily upgrade the command subsystem, which integrates the general specifications of the network.*

Network Specificity

Unlike a milling machine or a lathe, of which certain models may be used indiscriminately in numerous contexts, a public switching device may not be deployed outside the public telecommunications network without lack of efficiency. The latter must be considered as a specific system. For a telecommunications operator, the control of the whole switching system generates an important market power over competitors wishing to be interconnected to this network.

[17] The path established between two lines is a physical one (spatial): metal contacts make the connection. With the transistor , they were replaced by electronic gates.

However, a secondhand market exists for switching devices. The obsolete equipment may be deployed again in the less developed countries under the following conditions: the host network must have the same characteristics as the original network, which implies technical lags. It is also necessary to mention the case of regional American companies which have common technical characteristics, given their common past within the Bell System (Western Electric equipment).

Uncertainty Over the Telco-Equipment Supplier Relationship

During the era of electromechanical switching, operators were often in a local monopoly for telephony services. The uncertainty about transactions resulted principally from considerations about the continuity of supply (uncertainty about the long-term survival of the supplier) and about problems technical by nature.

Table 1. Asset Specificity for Electro-Mechanical Switches

Nature of the Specificity	Switching Equipment
Site Specificity	No
Dedicated Assets	Yes, network as “specific system”
Specific Human Resources	Specialized teams for switching system

3.2 Digital Technology: A New Technological Separation, Coming from Computer Industry Design

The emergence of the so-called “digital paradigm”[18] in telecommunications has gradually transformed the production framework and especially the structure of this industry, in the field of public switching. In particular, the introduction of electronics has gradually modified the attributes and the number of transactions. Since the end of the sixties, switching systems have been extended to become a specialized type of computer.[19] The “intelligence” of telecommuni-

[18] Some authors, including Abernathy and Utterback (1978) and Dosi (1982, 1984) have extended to technological practices the use of the concept of “paradigm”, used initially in fundamental sociology research by Kuhn (1970). Dosi (1982) thus defines a *technological paradigm* as: “ a ‘pattern’ of solutions of selected techno-economic problems based on highly selected principles derived from the natural sciences, jointly with specific rules aimed at acquiring new knowledge and safeguarding it, whenever possible, against rapid diffusion to the competitors ” (Dosi, 1988, p. 1127). According to this analytical proposal, an innovation is considered as “radical” when the potentialities that it conceals eventually lead to the fundamental transformation of the dominant design. *Radical innovation* constitutes the core of a new “knowledge base”, intended to increase with new solution rules, associated with new products and new methods of production. In telecommunications, digitization may be analyzed as a radical innovation (Brousseau, Petit and Phan (eds.), 1996; Dang Nguyen and Phan, 1998). In this paper, we do not develop the role of governance structures in the emergence of digital technology (time-division switching) which have been previously analyzed by Quelin (1992).

[19] Telecommunications engineers rapidly understood the advantages of replacing cabled automata guaranteeing the automatic switch control functions via programmed software activating a calculator. In 1949, the first development project of such a machine, Eco, was launched at Bell Labs. In 1957, at the first ISS (International Switching Symposium), Bell Labs announced the SPC (stored program control), a switch controlled by means of electronics. It was only in 1970 that CNET, in collaboration with CIT, developed the first prototype of a

cations networks has become more flexible and they have a higher capacity, as a result of the generalization of electronic computation and the implementation of software inside the switching equipment. Since the early generations of electronic switching,[20] the "software" component has assumed an increasing role within the core of telecommunications systems. This increasing importance of software led to a proportion of 50% of the total cost of the switch by 1988, and between 70% and 75% by 1994.

From the TCT point of view, *the possibility of separating hardware and software* may be understood as *the opening of a previously technologically closed entity*. It was not previously possible to develop the control subsystem and the connection network in a switch separately. A new technological interface in the TCT sense will appear as a result of this innovation. Therefore, the potentiality of a new transaction level between network operators and suppliers of switching systems also appears. The importance of this transaction is enhanced by the possibility of upgrading the software part of the switch.[21] As a consequence, transactions over public switching systems may first be located at two levels: the hardware level and the software level (software platform), with attributes different from the TCT sense. This technological architecture was not "thinking strategically" in the telco-equipment area, but it is clearly transposed from the computer industry, as an exogenous feature.

Without interface standardization, the asset specificity dedicated to these two transactions results mainly from the specific nature of the network itself. This specificity results from the technological path historically followed by manufacturers in the related sector. Market fragmentation and the existence of local monopolies do not contribute to a costly standardization process for the equipment produced by the manufacturer. Nevertheless, the importance of transaction on software will be increasingly enhanced by the possibility of upgrading the software part of the switch, which allows a different frequency of transaction between hardware and software, and an endogenous incentive toward more standardization and more modularity.

The Path Dependence of Specificity

After the "digitization" of the control subsystem, then of the switching device (time-division), the switching device has remained specifically dedicated to a given public telecommunications network. These have great capacities, which distinguish this kind of equipment from private equipment (PABX). In the latter, administrative functions are less sophisticated and do not have, or have a very simple, invoicing function. Finally, they establish circuits (physical or virtual), that distinguish the public switching system from the material used in the data network (such as routers and packet-switches) which appeared with the development of telecomputing).

With digitization, the technical characteristics of public networks have become more diversified. This results from past choices in switching systems: the division into national protected markets, the differentiated technological paths resulting from past strategies and the industrial

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totally electronic switch, integrating a logical circuit connection function. This time-division switching system, called the E10, was then the largest computing system of its time (Libois, 1983; Chapuis and Joel, 1990).

[20] Space-division, stored program control (SPC): cf. Chapuis and Joel (1990, Chs.. VI & VIII).

[21] By analogy with micro-computing, this operation resembles the upgrade of software to a new version on a personal computer.

policy of the "national champion" in some European countries and Japan. Such a division has contributed to the enforcement of the specific dimension of public network systems.[22]

Frequency of Transaction

The frequency of transactions relating to public switching equipment is determined by the growth of the network, by the duration of material, or more recently by its obsolescence. More specifically the latter enforces the need for building a long-term relationship between the operator and his suppliers. During the electromechanical period, switches had a very long duration, sometimes longer than forty years. This implies a low frequency for the renewal of the whole stock of switching equipment.[23] With the digitization of controls, the duration of the switching equipment has been considerably reduced. However, the possibility of upgrading the software components makes it possible to maintain duration long enough for the hardware. With the absence of standardization, the initial choice for a specific system and a particular supplier therefore tends to limit the scope of possible future opportunities – that is, in particular, the opportunity for an operator to choose another supplier. This type of constraint contributes to the creation of exclusive relationship conditions with a supplier of switching systems.[24]

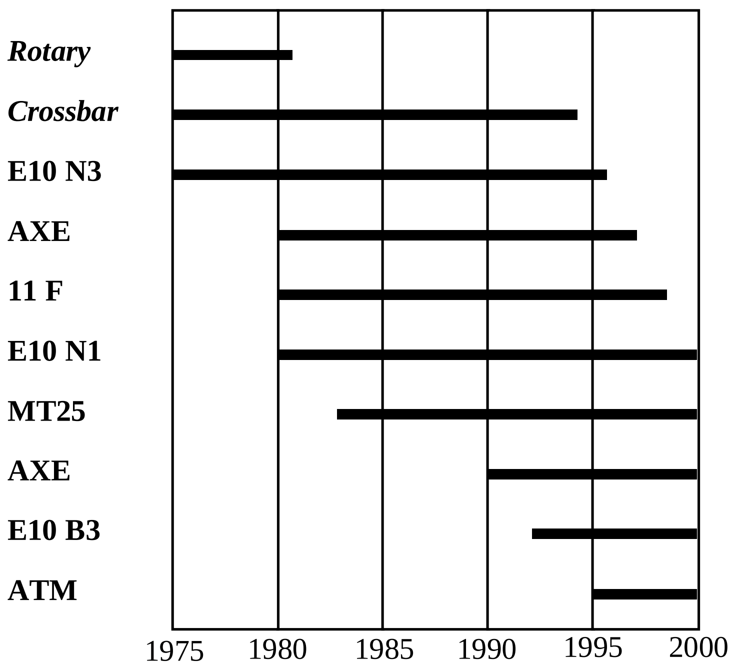


Figure 4. The Generations of Subscriber Switches in France (Duration by System).

Source: Telecommunications, 1992

[22] Cf. Fransman (1992) for an example of an evolutionary approach to R&D at AT&T, BT and NTT. On public policy and industrial strategies, cf. Dang Nguyen (1983); Quelin (1992); Sally (1993). On national systems of R&D in telecommunication , cf. Grupp and Schnöring (1992).

[23] In 1980, there was still a Strowger switch in BT's network which had been working since the 1920s.

[24] TCT interprets this phenomenon as a "fundamental transformation" (Williamson, 1985, p.61). Certain operators tried to get around this problem by opening up the market to a supplier, but such a policy was contested for the complexity that it created for the administration of the network.

Uncertainty Related to the Functional Dimension of Hardware and Systems

With digitization, technical uncertainty increased (i.e. uncertainty about the effective performance of the equipment). Uncertainty increased about the survival of the supplier in the long term, given the large investments in R&D required and the necessity to maintain and to periodically upgrade software. Moreover, with liberalization, telecommunications operators were to be faced with increasing (real or expected) competition on the market.

Digitization has not radically changed the nature of the transaction concerning the hardware part of the switching system, even if some attributes had to evolve. In particular, asset specificity related to the systemic nature of the network remains the crucial factor. The main innovation results from the emergence of a new transaction concerning the software component. The latter allows a greater frequency in the renewal of functionalities related to the switching system, by upgrading software. This innovation has led to more significant important changes in the nature and the evolution of asset specificity at the software level.

Specificity

A range of switches have the characteristics of a specific physical asset from the viewpoint of transactions linked with software. Until very recent times, switching software was “tailor-made” to satisfy the needs of an operator. Moreover, this software was developed by manufacturers with the help of proprietary languages, which reinforced their “capture” of the operator by the manufacturer. This logic can be found in the early development of software for intelligent network platforms : the slowness of the processes of standardizing programming interfaces proved the reluctance of equipment manufacturers to abandon proprietary systems for open, modular structures.[25]

The technological characteristics particular to the network strengthen this effect even more. The specificity of a system can be conveyed in the writing of the software. In the absence of standardized interfaces, switching software cannot be deployed again towards a different system. Collaboration between the specialized services of the operator and the equipment manufacturers concerning the specifications of this proprietary software also constitutes a specific human asset which it is difficult to deploy without avoiding important learning costs.

Frequency as a Competitive Advantage for Fast Movers

A new transaction may occur when purchasing new equipment equipped with more efficient software and new functions. It is then necessary to upgrade the software of the older equipment.

Another type of upgrading occurs at regular intervals. This is partly linked to the commercial policy of the operator. It means introducing into the network the intelligence necessary to

[25] This problem is classical in the computer industry, where the eighties were marked by a massive decrease in closed proprietary systems to the benefit of modular systems. But the latter remained largely proprietary within each module. With TCT’s “Dynamics” proposed by Langlois, Robertson (1995), taking these “modular systems” into account allows other factors to be integrated into the analysis, such as the demand for modularity and “upgradability” which this suggests, although the analysis framework of “standard” TCT only covers one of the aspects of the problem.

carry out new functions and to supply new services on the market.[26] The introduction of a new release for a whole network is a long and complex operation – software in a modern switch represents over a million instructions – and above all, the operator is tied to the supplier(s) already present in the network, who alone is(are) able to upgrade their software.

Today, the time necessary to implement a new version of the software throughout the set of switches in a classic telephone network is still very long, although it is tending to decrease.

Table 2. Comparison of Switching Software Development Times (1993).

Operator	Design and Specification	Industrial Development	Testing	Introduction in the Network	Total	Version Frequency
FT (VN3)	18 months	30 months	12 months	12/18 months	72 months	12 months
DT (S12)	8 months	14/16 months	1 months	3 months	26 months	6 months
AT&T	12 months	11 months	1 months	6 months	30 months	6 months
MCI	6 months	18 months	3 months	3 months	30 months	1 2 months
Bell Atlantic (RBOC)	6 months	18 months	3 months	12 months	39 months	12 months

Sources: ENST-Bretagne; L'Echo des Recherches: Kubiak.and Baptiste (1995)

Depending on the operators and the manufacturers, the process is split into different phases of variable length which reflect various factors difficult to isolate: efficiency of the process, capacity of the equipment to evolve, the number of functions and of services per version, etc. In the above table, these times are given for AT&T, who manage a long-distance network, and for Bell Atlantic, a local, general operator.

Uncertainty from the New Institutional Framework

Uncertainty is profoundly linked with the liberalization of the operator's market. A competitive risk is associated with times which are too long to develop switching software, in particular at services level. It is the "time to market" which allows the more reactive operators to benefit from a temporary rent which can be transformed into a permanent advantage when "club effects" are decisive in attracting customers (for instance for new mobile networks). With the

[26] In France, the first upgrade (or "Digital Version" = DV) dates from 1987, when the introduction of the *Numéris service* (ISDN) made it necessary to update the switching network. Three other operations of this type were then planned in order to improve the services entrusted to ISDN (DV2, DV3, DV4). In the innovation "technology push" model which characterized telecommunications operators in the pre-competitive period, the implementation of a "DV" was limited to collaboration between the specialized services of the CNET (France Telecom's research center) and the manufacturer. The commercial services were gradually involved in defining the new versions of switching software. The requirements and specifications of the DVs were established by the operator, but the development was ensured by the manufacturer. In this distribution can be found the provider-customer roles close to specialized sub-contracting. Given the precursor role of Alcatel in Digital (time- division) switching, the complete DV cycle had lasted 6 years in France by 1992. This long delay has decreased dramatically with new generations (Kubiak and Baptiste, 1995).

growing liberalization of the market, upgrading software has become a test with which to measure the capacity of operators to withstand the competition of new service providers, who might act either from other public infrastructures or from private equipment.

This risk casts doubt on the very existence of this kind of transaction in the future. This question brings us back to that of the place of intelligence in telecommunications networks. The question is raised both from a technical point of view (the competition of Internet-type networks, where the intelligence is located at the users' end) and from an economic point of view (opening up of networks and request for the interconnection of competitors). For the moment, however, the intelligent network architecture enables a partial solution to be found to the problem of the length of switching software development cycles.

A Need for Integration

Table 3 summarizes the characteristics of specific assets relative to transactions linked with public switching. This degree of specificity is high, but a trend towards a reduction has begun since the beginning of electronic switching.

Table 3. Asset specificity for Digital Switches

Nature of the Specificity	Switching Equipment (Hardware)	Software
Site Specificity	No	No
Dedicated Assets	Yes, Network as "Specific System"	Yes, • proprietary systems • enforced by the effect of the network as a specific system.
Specific Human Resources	Specialized teams to maintain and upgrade the available function (Decrease with harmonization effort of the supplier)	

In conclusion, the specificity of assets appears as the most decisive characteristic for analyzing transactions in public switching. Empirical observations seem to confirm the results of the theory. In industrialized countries, the privileged relationships between telecommunications operators and the equipment manufacturers are the most frequent governance structures. The United States have even seen more than a century's effective integration in the Bell System. However, digitization and liberalization have also opened up new opportunities which are expressed as falling incentives for this specificity, and therefore a potential questioning of integrated governance structures.

3.3 Liberalization and Falling Incentives for Asset Specificity: Towards the End of Integrated Governance Structures?

The liberalization of networks has deeply modified the institutional environment of public switching.[27] TCT shows that the old governance structures are tending to become more and

[27] Cf. Brousseau, Petit and Phan (1996), for a review of these changes and their consequences.

more inadequate with this environment, which is more oriented towards the market. However, the emergence of new structures largely depends on strategic, technological and institutional choices, on which "standard" TCT can only cast a little light, because it partly considers them as "exogenous". First of all, the emergence of digitization was favored by governance structures with a high degree of control, as underlined by Quelin (1992). Asset specificity was first reinforced by the characteristics of transactions associated with the software. But a trend has since been observed towards a drop in specificity. This largely comes from explicit arbitration where asset specificity plays a strategic role. However, in the absence of interface standardization, interfaces are sufficiently specific to dissuade operators from radically changing the nature of their relations with equipment manufacturers. In the USA, organizational adjustments are nonetheless being outlined, turning towards governance structures closer to the market.

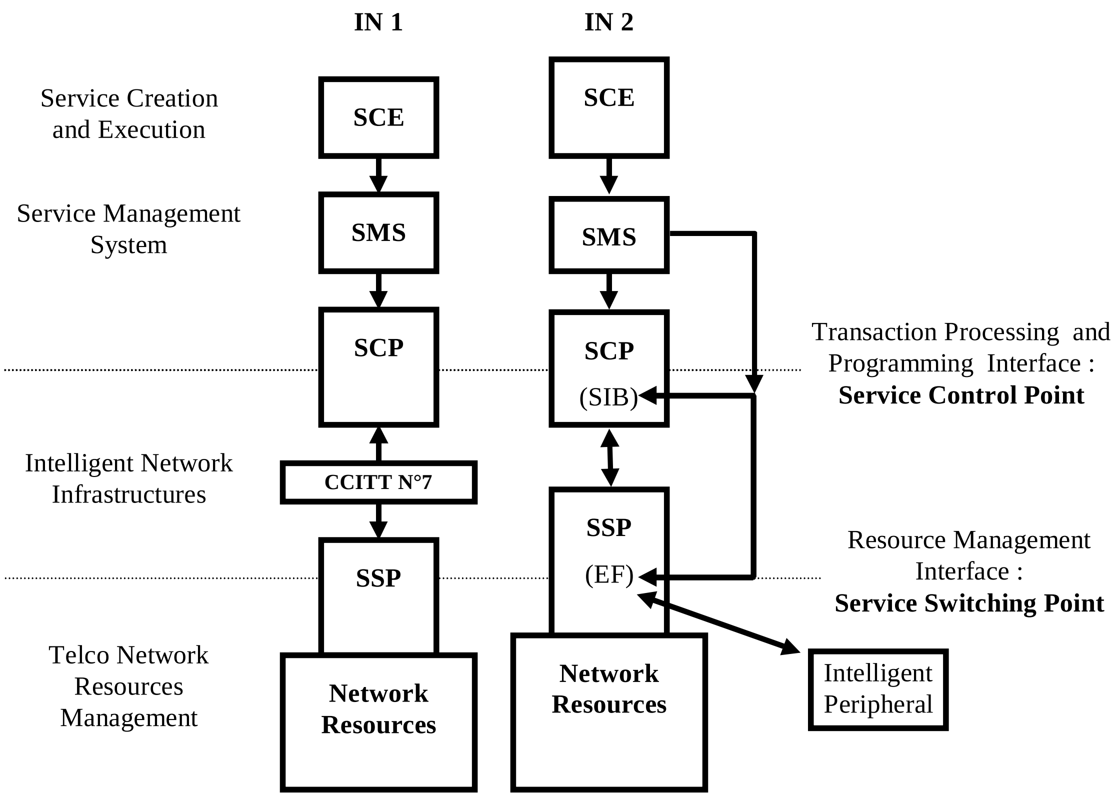
Intelligent Network Architectures

Inside an analog/electromechanical telecommunications network, the signaling (numbering, demand for circuits, signal for free or busy circuits, taxation) conveys a low volume of information and performs together with transmission on the same channel. In this period, it was not technically pertinent to separate transmission and signaling. This technical constraint is today no longer valid. The signaling circuit (so-called "CCITT Number 7") is different from the communication circuit. The opening of this technological entity, formerly closed, has numerous consequences.

Intelligent Network Architectures (INAs) allow a new stage to be reached in the modularity of telecommunications systems. These architectures extend the separation between hardware and software by dedicating a specific system to the process of the information and another to the supplying of services. Contrary to the solution that consists of making some specific switches more specialized for network services, INAs first separate the control function and the services facilities into distinct levels, driven by a separate signaling network (CCITT Number 7). That is, an intelligent network is made up of configurable components in order to satisfy the customer's demands more easily. This is possible through a modular architecture which separates the different network functions (signaling, administration of the network, services provision) from the transportation of information itself, and as a result makes the supply of service independent of the underlying infrastructure. In a second step (IN2) modularity is increased by providing three different interfaces, with the possible opening up to customer services facilities, as an intelligent peripheral through a "Services Switching Point". For some cases, service provision may be performed by an ordinary work-station located beyond the "Services Control Point", that is, constituting a specific case of modularization within the software component itself. See also Box 1.

In all interfaces, a standardization question is raised for the different levels of transaction considered. According to Man-Sze and Eirwen (1993), the motivation for the standardization of such interfaces varies among players' interests and the different areas of standardization. Everybody has an interest in standardization for resource management interfaces. Telcos are looking for a decrease in equipment cost, and equipment suppliers are looking for an increase in the market area. If telcos and software providers have an interest in standardizing programming interfaces, hardware providers have a low incentive to do this, in order to keep the telcos as captive customers. At the higher level, only customers and software suppliers have an incentive for standardization. The motivation of the equipment supplier to refuse standardization is the same as previously (to keep the telcos as captive customers). For the telcos, standardization at the service level is an incentive for both competitors and customers to request interconnection to the network; the greater the level of diversity, the greater the local monopoly barriers. Finally, the attribute of transaction greatly depends on the standardization policy, so the design of new separable interfaces in the INA process clearly appears as an *endogenous strategic choice*, and not as a given exogenous, purely technical fact.

Box 1: Intelligent Network: Increasing Modularity



In 1984 Ameritech began work on a concept of total separation between service features and switching process. Bellcore further developed the concept of INA by 1985-1986 which gave the IN1 concept, a centralized architecture based on the existing telephone network. Connection with service information was to be located at Service Control Points, with access from switches provided by CCITT N° 7 Signaling System. This IN1 was deployed by the RBOC during 1986-1992. During this period, Bellcore studied a new conceptual framework, IN2, and carried out an interim solution named IN1 +, by 1988. IN2 introduced more modularity, with SCP's Service Independent Building Block (SIB) and Elementary Function at the level of the service switching point. In addition, more interfaces were designed for the services and a new system, called Intelligent Peripheral, provided a platform for deploying services assistance capabilities. There exist three interfaces between the elements of the system: first, the resource management interface, located between network resources and IN infrastructures; second, a transactional interface located between the intelligent network and service facilities; third, another interface between the service management system and the services design functionality (creation and execution).

The Drop in Asset Specificity

The digital paradigm is expressed via the great increase in fixed costs in the telecommunications equipment industry. R&D expenses have risen considerably with the abandonment of purely electromechanical technologies, overtaken by digitally controlled (SPC) space-division technology, then by time-division switching. Equipment manufacturers had to face the problem of increasing fixed costs. They diversified their production in order to benefit from economies of scope, and looked for economies of scale in production.

In the framework of the exclusive relationship between operators and manufacturers, systems were set up to get part of this constraint borne by the operator (support via market studies or in the procedures for signing public markets which could be seen through an increase in dedicated specific assets). With the liberalization of the services market and the loss of monopoly income, the operators became more reluctant in giving their support to manufacturers.

In order to extend series, and to deliver to increasing numbers of public customers, the manufacturers then tried to overcome the effect of specific systems associated with each national network. Harmonizing ranges between switching systems then became necessary (Quelin,, 1992). The development of competition at an international level was thus accompanied by a strong movement of concentration in the industry. Equipment manufacturers, of whom there were 36 in the world in 1975, were only 12 in number in 1990.

Furthermore, under competitive pressure, manufacturers were gradually compelled to abandon the logic of proprietary systems, in the same way that large computer manufacturers had to do in the not so distant past.[28]

With the development of INA the specific nature of networks was to decline. However, specificity in INA is still important today, and manufacturers are trying to keep this specificity as high as possible. Only the next step in technological change, with the Internet, could significantly reduce this specificity.

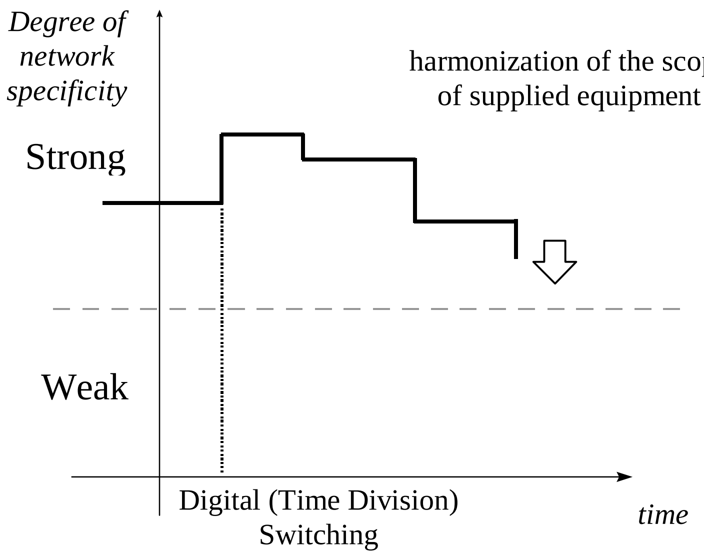


Figure 5. Evolution in the Degree of Specificity in Transactions about Equipment.

[28] Specifically, the high development costs associated with proprietary languages led them to migrate towards standard markets (Unix, C++).

It should also be added that public switched networks are going to be faced with increasing competition from "IP" databases (based on the Internet Protocol) for providing telecommunications services. At the end of the 1990s, real-time services appeared on the Internet (IP telephony, videophony). This world-wide network could not be ignored. Designed to interconnect heterogeneous networks, it is built from standardized equipment, routers, produced by a fast-expanding competitive industry, for which asset specificity is not a significant variable .

The choices made by those involved in the industry with the diffusion of the digital paradigm are in favor of less specific assets to support public switching transactions. This could be the case particularly if the regulator decided to impose the openness and the standardization of interfaces in the framework of the opening of INAs, or if an equipment manufacturer decided unilaterally (but successfully) to abandon proprietary systems and join an open system strategy, playing both on club – or "network" – externalities and on technological developments.[29] Each of these innovations could result in a profound change in characteristics linked to transactions.

According to TCT, these changes in characteristics should then be expressed by a search for regulation structures more adapted to operating transactions. In many cases, this could be closer to the market. But the standardization of "technological separation interfaces" is the condition necessary for the market to become an efficient means of coordination. Without this, specific assets remain high and the temptation toward vertical integration remains strong, which is contradictory to the will to promote competition, even more so as there are not very many equipment manufacturers on the market. The forms of such an evolution themselves remain open. This evolution may be stimulated "upwards" (regulation[30]) or "downwards" (deviant innovative strategy), associated with "*de facto*" standardization via the market.

4. THE EVOLUTION OF GOVERNANCE STRUCTURES: THE AMERICAN CASE

The *"Ancien Régime"*[31] *of* telecommunications favored the development of close relations between operators and manufacturers in the sector, which could even go as far as vertical integration. That was the specific case of the United States where AT&T remained an operator integrated in the production of equipment from its origins until 1996. Similarly, GTE, the principal independent network operator on a local level in the USA, kept an integrated activity producing public switching equipment until the end of the eighties. For several decades, the diffusion of the *digital paradigm* and the process of liberalization, whose own logic did not exclude a strong degree of interdependence, progressively changed the technological and institutional environment of governance structures. The only American example makes it possible to fruitfully confront what can be learned from TCT with the facts, and therefore to assess the scope and limits from a historical perspective.

[29] This strategy was successfully used by Sun Microsystems in the eighties, when it newly entered the workstation market, and it rapidly became the leader. This success is largely due to the exploitation of network (club) externalities linked with "open" systems, with the consumers' demand for diversity and "upgradability" and their preference for a modular system, and, finally, to Sun's capacity to remain the leader technologicallya after much innovation (Garud and Kumaraswamy 1993).

[30] Implementation may then be affected in either a cooperative (normalization) or a decentralized way (standardization through the market – or self-organized).

[31] Cf. Phan (1996) for an economic analysis of this "*Ancien Régime*" of telecommunications (the old-fashioned plain telephone service organization: integrated, monopolistic, electromechanical).

4.1 The Integrated Model

From its creation in 1878, American Bell was a manufacturing company. At that time, the telephone service was indissociable from the telephone itself, and Graham Bell held the patent rights. After having ousted the monopoly of the Western Union Telegraph from the market, the new company was to prosper from 1879 to 1894 under the legal protection which Bell's patents conferred on it. In 1881, the Bell system reinforced its production potential by acquiring the electrical materials subsidiary of its ex-rival (Western Electric). After a period of competition, between 1894 and 1934, AT&T was to transform its advantage as a precursor into a local monopoly situation regulated by the public authorities (Mueller, 1994).

"The company will establish (...) its domination over the whole of the sector ('local' services, trunks, equipment) by controlling strategic patents and by acquiring associated patents, by consolidating its control over the local operating companies and especially by becoming owners of the long-distance transmission network." (Simon, 1991)

The special nature of assets thus results from the initial conditions of the emergence of telephony, where the service (voice communication) was strongly linked to its technical support (the telephone). But it also very largely results from technical and strategic decisions taken later with the aim of strengthening AT&T's position as a monopoly. The legal environment in the United States was hostile to concentration and to vertical integration (the Sherman Act). The integrated governance structure between the operator and the manufacturer was attacked in court as early as 1910. T.N. Vail, the head of AT&T, was to set up as a system the principles of *unity*, *integrity* and *universality* of the network, and to plead for the creation of a monopoly regime controlled by the public authorities (Simon, 1991; Mueller, 1994; Phan, 1996).

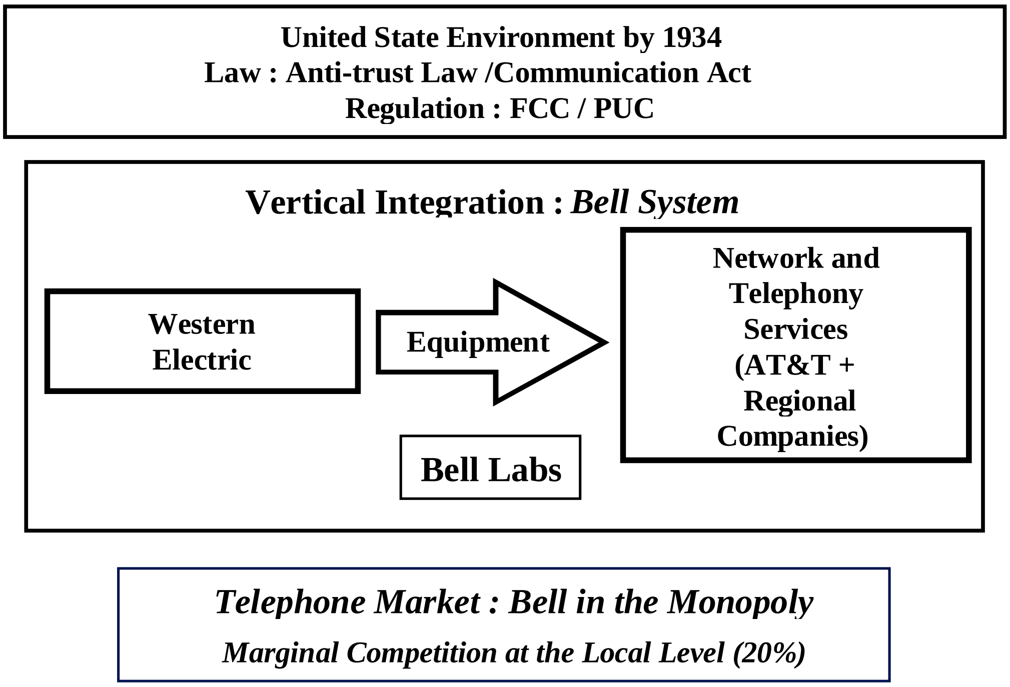


Figure 6. Vertical Integration within the Bell System.

From 1934, the institutional framework in which AT&T operated stabilized. The company, which controlled the whole of the long-distance service (AT&T Long Lines) and 80% of local telephony, underwent two levels of control: that of the Federal Communication Commission, created by the Communications Act, and that of the Public Utilities Commission at State level.

During the half century which separated 1934 and 1984, AT&T was to pay the price of defending its monopoly and the integrity of its network in lawyers' fees and propaganda. The company managed to maintain this *status quo* by invoking "universal service", with the backup of regulators and of certain large administrations (Simon, 1991), sometimes having to renounce certain important matters, as shown in the Consent decree of 1956.

4.2 The Imbalance between the Institutional Framework, Technological Evolution and Governance Structures

In 1982, after the third antitrust lawsuit against AT&T, the American Department of Justice and the operator came to a compromise about separating the long-distance activity from the local operations of the network. This decision aimed to enable a competitive situation to be established in the long-distance market. Seven regional companies (the RBOCs) in a severely regulated local monopoly were to be created by this split-up. This became effective in 1984. At the end of this agreement, AT&T kept the long-distance service, remained integrated in the equipment sector with its subsidiary Western Electric, and obtained the authorization to enter the computing markets.[32]

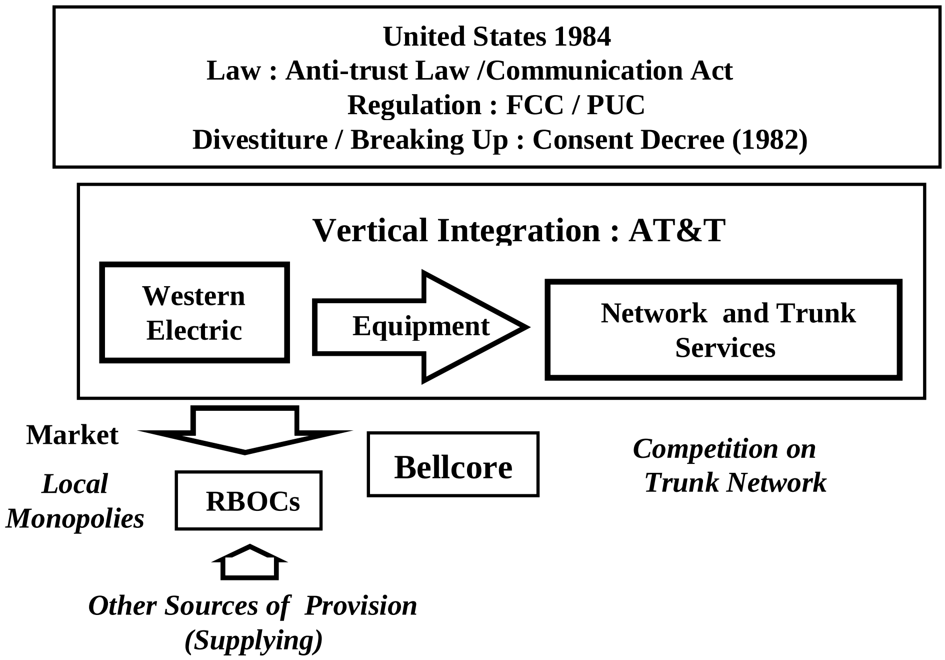


Figure 7. Vertical Integration after 1984.

[32] Controlling the "long lines" and vertical integration have been the key to AT&T's success since the beginning of this century. AT&T's managers then found themselves in what DangNguyen and Phan (1997) have called the "backward-looking dynamics" of expectations.

This compromise in 1984 created an unstable situation from a transactional analysis point of view. Thus, the features of switching transactions for local networks are always characterized by a network specificity, which was strengthened over time in the Bell system. Nevertheless, the market became the governance structure imposed during these transactions. To satisfy the requirement of these particular transactions, Bellcore, the laboratory common to the RBOCs created in 1984, had an interfacing role in the new regulation structure, to avoid the risk of market failure, and especially to coordinate the technological choices and technical norms between RBOCs.

From then on, the RBOCs were threatened with being locked in the relationship with AT&T, as the latter supplied them with network equipment (Filoche, 1997). As TCT claims, when objectives differ between firms, the risk of opportunistic behavior increases, and with this risk, so do the transaction costs. Because the RBOCs ceased to belong to the Bell System, their marketing policies and/or investment choices no longer depended on a sole decision maker. To coordinate the objectives of the parties involved would thus enable the situation to stabilize, but such a complete alignment of objectives was hardly conceivable in the new competitive framework. Everybody could equally demand particular evolution in material or specific functionalities for switching software.

With the emergence of Intelligent Network Architectures, a growth in the modularity of software functionalities was seen in the USA. In particular, certain operators designed service-creation platforms on workstations connected to "Service Control Points" with the aim of developing services autonomously, in relation to equipment manufacturers. So, MCI selected vertical integration after the in-house development of this service function; Bell Canada and Bell Atlantic experimented with mixed methods which combined in-house development, associations with software engineering companies and sometimes the outside purchase of off-the-peg software solutions.[33] This evolution placed the acquisition, control and development of competence, rather than the features of the transaction itself, at the center of the operators' strategy. For previously mentioned methodological reasons, this type of problem has not given rise to significant developments in the TCT framework.

Faced with this new trend towards modularization and with the explosion of the software market, AT&T decided in 1995 to re-focus its activities on services and abandon the production of public equipment. This second break-up of AT&T became effective in 1996 and the manufacturing activities of the operator were brought together in a new, legally independent company, Lucent Technologies.[34]

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[33] Derian (1991); for example, at the beginning of the eighties, Bell Canada bought a turnkey billing platform from GTE data systems, and a services platform from MCI.

[34] AT&T broke up into four different companies according to their basic competence and without any significant financial connections: one company has kept the name AT&T (for long-distance and mobile telephony, phone cards, Communications Services Group, AT&T Universal Card Service Corp., AT&T Solutions, AT&T Wireless Services); one company, Lucent Technologies, oversees all manufacturing activities (Network Systems Group, Global Communications Systems, Consumer Products, Paradyne and Microelectronics); there is one company for computing equipment (AT&T GIS (ex NCR)); and there is one finance company, Capital Corp.

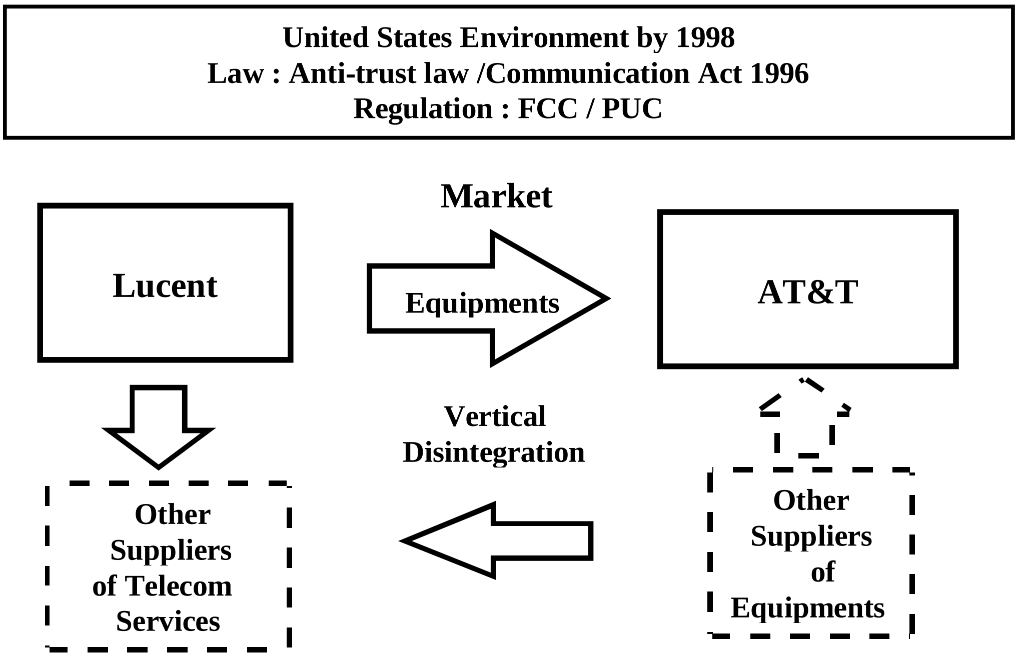

Figure 8. AT&T's Second Break-up.

AT&T's second break-up may be justified from a company point of view through its desire not to penalize its manufacturing activities in a situation where it was in competition with its customers (Rey and Tirole, 1996). It seems therefore that after 118 years of vertical integration, controlling equipment is no longer a key element of AT&T's strategy, and they are especially seeking to develop in the multimedia market or as a "global" operator.

This decision also seems to be coherent with the new American institutional context. In 1996, the Telecommunications Act brought into being the " decompartmentalization " of all the telecommunications markets anticipated by AT&T. The local monopolies of the regional companies are destined to disappear, like the restrictions made on the RBOCs in 1982 concerning their operating in services and manufacturing activities.

5. CONCLUSIONS

5.1 Lessons from a Practical Point of View

Transactional analysis enables three periods to be distinguished. At the time of electromechanical/space-division switching, the switching system can be seen as a unique technological entity, which gives rise to a single transaction between telecommunications operators and equipment manufacturers. The high degree of asset specificity has sometimes been reinforced by national strategies, protected by a local monopoly. In the American case, the strategy of AT&T has led to its vertical integration within the Bell System.

As soon as space-division electronics appears, the digitization of switches makes it possible to distinguish the hardware from the software component in the equipment, corresponding to a new technologically separable interface in the TCT sense. Transactions concerning software are to become the support and the main stake of asset specificity. Originating in highly controlled governance structures, time-division switching is first expressed by a reinforcing of this specificity. However, the spread of the digital paradigm, into which this technology is integrated, and the process of liberalization of telecommunications, direct the choices of those involved towards a decrease in asset specificity. In fact, the growing costs of R&D associated with the taking up of digital systems by equipment manufacturers induce them to multiply the number of clients and to harmonize their range of equipment. As a consequence, asset specificity has to be reduced. At the end of this period, public switching has become a global oligopolistic market, controlled by a few major companies and/or networks of alliances (Quelin, 1996). Vertically disintegrated operators, like RBOC**,** make the equipment supplier market more competitive, and favor the emergence of Intelligent Network Architecture at *Bellcore*. The latter begins an additional step in the process of more modular switches with new opportunities for technological separation. (However, the adjustment process of the governance structures seems largely disconnected from such a process. TCT has some difficulty taking into account these dynamic aspects, even though this theory makes it possible to analyze the final consequences of such a process.) "Vertical disintegration" is observed, as in the case of AT&T or of GTE, when the attributes of transactions are still characterized by high levels of specificity.

In fact, equipment manufacturers and operators have to arbitrate between short-term and long-term considerations. In the short term, it is in the interest of equipment manufacturers to maintain the specific nature of the assets associated with their proprietary systems, in order to keep operators dependent on them, while it is in the interest of the operators to take a flexible technological stance, in order both to make their existing investments pay and to avoid committing themselves to making costly or dead-end choices, while technologies of the future (like ATM switching or multimedia data networks) are far from being stabilized. In the longer term, equipment manufacturers will certainly have to decrease their costs and commit themselves to more modular and more standardized systems. But then they will be in competition with the manufacturers of computer networks and systems integrators. The operators will themselves have to make their networks evolve, but in the meantime, competition leads them to worry first about adapting their services to the needs of their clients.

5.2 Theoretical Lessons

The analysis of transactions in the public switching telecommunications industry confirms the limitations of TCT highlighted at a more general level by authors mentioned in the first part of this paper. According to Groenewegen (1996), TCT is adequate for comparative static analysis between governance structures. Moreover, the analysis confirms that TCT is able to identify the instability of the current situation. But, according to the theoretical arguments of Beije (1996), Noteboom (1996), Magnusson and Ottosson (1996), among others, this theory is experiencing some difficulties in describing the evolutionary process. That is no doubt why most research about these questions uses an evolutionary approach.[35] In fact, TCT provides a framework to compare governance structures across time and/or across space, for a given in-

[35] All these works underline the "historical" dimension of the process, caused by irreversibility factors. For instance, Fransman (1992) and Quelin (1992, 1996) underline the role of competence in the resulting technological trajectories. More specifically, Wolff (1996) analyzes the nature of the learning process related to the forming of competence, in the case of strategic alliances. For the latter author, the transaction cost approach, at least in its standard version, suffers from a certain number of limitations when we try to analyze the dynamics of telecommunications agreements. "They can all be attributed to the essentially static dimension of this approach" (Wolff, 1996, p. 458).

stitutional environment, along comparative static principles. We can thus put forward elements to justify the existence of different governance structures in different contexts. On the other hand, the explanation for the evolution of one structure towards another goes beyond the field of "standard" TCT. Wishing to use TCT in a morphogenetic way, if institutional evolution is considered as given, would lead to a functionalist interpretation of governance structures.

To integrate in the long run, it seems necessary to describe more specifically the feedback effect of governance structures on the institutional framework (in the short run, such an effect is considered to be of the "second order" by Williamson). It would also be necessary to better integrate the trade-off between technology and strategic adaptation behavior, i.e. to consider a field wider than the one which "standard" TCT refers to. Such a research program remains to be constructed. Several directions are possible. Lotter (1997) thinks that we can develop evolutionist dynamics by keeping transaction as a sole support for the analysis. Other authors claim that greater integration between TCT and the evolutionist research program, judged to be complementary, should append significant enhancements (Foss, 1996; Brousseau, 1996). For Chandler (1992) the facts observed by the historian of company organization refer to this approach more than any other.[36] The relative independence/interdependence that has been highlighted between the institutional-organizational level and the technological level could thus be treated by using the notion of "co-evolution" borrowed from biology (Nelson, 1994). However, these developments remain merely exploratory and at the program stage. Therefore, this study suggests that understanding the evolution of the relationships between equipment manufacturers and telecommunications operators would certainly be enriched by such contributions.

5.3 Further Research

Finally, the public switching manufacturer's ability to innovate in the 1970s and 1980s is known to be linked to vertical integration or vertical quasi-integration with telcos (Dang Nguyen, 1983; Quelin, 1992; Harris, 1993). In such "hybrid forms of governance", the distribution of competence between partnership matters. For instance, one may raise the question of the opposing cases of French and German hybrid forms of governance in relation to competence in digital switching technologies. In France, competence is mainly located at the CNET.[37] In Germany, the main location of competence is at Siemens. Is this asymmetric distribution of competence between partners more significant than transaction costs when explaining the role of governance structures in the emergence of digital technologies (i.e. Alcatel's early leadership)? Recently, Praest (1998) has used patents in the telecommunications equipment industry to analyze the effect of competence accumulation and strategic behavior at the level of the firm throughout industrial dynamics. No doubt further research about the telecommunications industry will make significant progress by using a pluralist approach.

Another issue that might open new avenues for research is the convergence between IP (Internet Protocol) data routed networks and switched networks. Given the congestion of the Internet and the necessity to price-discriminate among the users, it is likely that the routers will become more and more complex and integrate some of the features that one finds in telephone

[36] "... the evolutionary theory of the firm, which emphasizes continuous learning that makes a firm's assets dynamic, provides an understanding of why in the past and how new firms grew by expanding into new markets through the process of integrating production and distribution. I find the earlier growth of the industrial firm difficult to explain fully in terms of transactions, agency and other information costs, so I find it hard to explain the recent process of expansion and contraction with these same concepts" (Chandler, 1992, pp. 98-99).

[37] The research center of the former DGT – *Direction Générale des Télécommunications* – now France Telecom.

switches. From an equipment design point of view, this will lead to a greater similarity between the two types of products. This, on the other hand, will have some consequences for the industry structure. Hence the focus will be shifted to horizontal – or "lateral" – integration among public telecommunications equipment and private data network manufacturers, attested by the recent takeover of *Bay Networks* by *Nortel*, instead of the vertical quasi-integration. In addition, it is important to remark that IP is gaining ground in relationship with the building of a "post-telephony" economy (Fleurot and Sommer, 1999). This process shifts the frontier between telecommunications and the computer industry. In this context, vertical relationship has to be investigated in a complex and fast-moving environment.

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