5 Institutional Arrangements of Technology Policy and Management of Diversity: the Case of Digital Switching System in France and in Italy[1]

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5.1 Introduction

The importance of the development of a Digital Switching System (DSS) lies in its positive effect on the entire telecommunication network. DSS has provided greater reliability and speed, and enabled the introduction of new value added services, all of which have benefited the entire economic system. This chapter focuses on the development of DSS in France and Italy. We analyze how the 'organization' of a public research and development (R&D) programme can influence the relative success of a policy. By organization we mean coordination of the actors involved, and also the different technological options involved in innovation in telecommunications, which emerge, and should be publicly supported. Based on previous theoretical development, we state that the organization of a mission-oriented programme (such as the DSS) depends mainly on the learning ability of the policy maker and its proximity to the participating firms and institutions. Moreover, the management of technological diversity may have important impacts in terms of timing, costs, competition, technological diffusion and lock-in phenomena. The purpose of this chapter is to use this

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dynamic framework and evolutionary concepts to assess the relative success of the French and Italian DSS public programmes.

To understand the importance of DSS development and, thus, the critical role of technology policy, we will briefly set it within the broader context of technological developments in telecommunication, i.e. the paradigm shift from electromechanical to digital technologies. Between the mid 1950s and the end of the 1980s, the telecommunication industry was at the centre of a technological revolution with the shift from the electromechanical to the digital paradigm. Electronic devices were gradually introduced in the three main sub-sectors of the telecommunication industry: transmission, switching and terminals. This chapter focuses essentially on the switching part of the network.

The possibility of introducing electronics into the telecommunication network was first conceived in the 1940s. But it was not until after the Second World War that the Bell Laboratories in the US and the research laboratory of the UK Post Office began to work on an electronic switching system. The discovery of the transistor by the Bell Laboratories in 1948, as a by-product of this research, was a fundamental step. However, it was over 20 years before a completely digital switching system was realized. The main problem was the reliability of the electronic components. In England, the first ambitious attempt in 1962 to introduce a totally electronic switching system failed. The research path followed by the US Bell Labs was more successful. Instead of being oriented towards a completely digital switching system, Bell Labs incrementally introduced new sophisticated devices in a traditional electromechanical switching system: the first prototype of a semi-electronic switch (ESS 1) was installed in 1965.

To understand the technological choices made by Italy and France it is worth describing briefly the two main trajectories within the digital paradigm: the space division and the time division trajectories. A space division switching system is characterized by a physical connection between the entry and the exit of the signal. It is thus possible to follow the path of the signal through the space by the means of contacts that are generally electromechanical, but may also be electronic. This was the technological option adopted by the US and Germany. In a time division DSS the signal is "translated" into a digital code and then transmitted through purely electronic devices. In France and in Italy, time division was the preferred trajectory, but was arrived at by different routes (Libois 1983). The aim of this chapter is to compare the technological developments in France and Italy.

The evolution of the technology related to the introduction of digital switching had various consequences for both the service provider and the manufacturer. For the telecommunication service provider, the technological shift meant, first of all, a reduction in costs: these were the result of overall size, maintenance and numbers of personnel employed on installed lines[2]. This shift allowed improvements in the capacity of the switching systems and offered greater reliability and improved quality[3]. Finally, it opened up the opportunity for the introduction of new services and offered the possibility for digitized transmission of data and images in addition to voice (i.e., an ISDN - Integrated Services Digital Network). For the service providers it can be claimed that: "the advantages of electronic systems towards electromechanical ones undoubtedly exceed the risks connected to the management and organization of the technological conversion and the costs connected to the qualification of the personnel" (Bragho 1988).

For the manufacturing firms, this technological evolution meant a shift from a *labour intensive* technology (electromechanical) to a *competence intensive* one (digital). This shift involved a change in the number and type of people employed, the need for them to accumulate new competencies, and increased economies of scales, especially in R&D (Zanfei 1990). The progression from the electromechanical to the electronic paradigm involved a radical process of restructuring of the workforce, an increase in fixed capital investment, and the introduction of new flexible production technologies. Moreover, manufacturing firms were forced to accumulate upstream competencies in new and different fields, such as microelectronics and software, in order to develop and incrementally improve new products. Finally, the economies of scales in R&D increased. R&D investments need to be high in terms of the minimum efficient threshold, and they tend to remain high throughout the entire product life cycle, which eventually becomes shorter.

Thus, it can be seen that technology policies have a tremendous impact on the further development not only of an industry – in this case telecommunication – but also of the whole economy.

The two cases described in this chapter are the development of the E10 in France and the Proteo/UT family in Italy. The time period spans the 1950s to the 1980s for France, and the 1960s to the end of the 1980s for Italy. Based both on theoretical hypothesis and on empirical facts, we show that the relative success of the efforts in France can be explained by the ability of policy makers to appropriately coordinate the actors in the telecommunication innovation system, and the various technological options.

[2] For example, the passage from the Cross-Bar switch to the ESS 4 in 1976 in Chicago led to a saving of 25% in size and more then 30% in energy and maintenance (Libois 1983).

[3] The already cited substitution in Chicago leads to a five-fold increase in capacity.

However, political decisions related to competition entailed some failures, such as the demise of one national company. The Italian R&D programme, on the other hand, suffered from a lack of coordination between the actors involved. After a long period of experimentation, national resources were finally pooled and Italian firms cooperated with foreign companies. The delay in this collaboration induced high costs and significant delays in the development of the technology, thus explaining its relative lesser success, compared to France.

The first part of the chapter focuses on the institutional set up of the telecommunication systems in each country. The analysis mainly compares the characteristics of the two information structures and highlights the coordination mechanisms used to develop the DSS. The specific institutional arrangements had some consequences for the dynamics of DSS diffusion. We then go on to analyze the policies in terms of coordination failures, diversity exploitation, and lock-in and diffusion effects. This allows us to assess the relative success of each country's policies.

5.2 Institutional Arrangements, Information Structure and Coordination

A technology policy is embedded in institutional arrangements, specific to each country, resulting from the particularities of its institutional history. One way to deal with the problems associated with these specificities is to compare (with some kind of implicit "ceteris paribus" assumptions) some "parameters" of the institutional structure. Following on from previous work (Foray and Llerena 1996), we have chosen to focus on the information structure and the coordination between the different actors in the national telecommunication system. Our purpose is not to achieve a precise description of the institutional mechanisms supporting technology policy; but to suggest that there is a clear link between the informational structure of, and the coordination mechanisms implemented by, a policy, and its degree of success. We first present the analytical framework used to define the relevant parameters, and then apply it to each case.

5.2.1 Information Structure and Coordination in Technology Policies: Analytical Framework

The aim of this section is to establish a link between the informational structure of the technology policy system and the mode of coordination of activities, in order to analyze the coherent and incoherent elements of a technology policy. For this purpose, we use the model developed by Foray and Llerena (1996), which restates Aoki's (1986) results, and compare two types of technology policy organization.

5.2.1.1 Informational Capacities of the Policy Maker

Foray and Llerena (1996) state that the policy-maker's informational capacity is determined *de facto* by the nature of the technology policy. Using the classification developed by Ergas (1987), they distinguish between mission-oriented and diffusion-oriented policies.

Mission-oriented policies correspond to radical innovation projects. Their main characteristics are the centralization of the decision making process and the pursuit of goals involving the implementation of complex systems. Frequently, one particular public agency is in charge of the programme. By their very nature, missions concern strategic technologies. The number of projects is limited, as is the number of actors involved. Mission-oriented policies often imply the creation of a new technology, a specific (i.e. large technical systems) or a new generic technology, without any *a priori* specification of the modes of use.

Diffusion-oriented policies are characterized by decentralization. Public agencies have a restricted role, entrusting responsibilities to professional bodies, or to cooperative research organizations. Public resources are widely spread throughout the systems, so as to reach small and medium sized enterprises (SMEs), the main goal being to diffuse the technology, and to ensure adaptation to the local and specific needs of individual firms.

In both cases, the *informational capacities* of the policy maker need to be differentiated. It can be supposed that in the case of diffusion-oriented policies, *de facto*, the policy maker has a very imperfect perception of the precise needs and characteristics of firms, and that there is probably a long delay between perception of a possible need and implementation of the relevant solution (i.e. the policy maker's reaction time). In the case of a mission-oriented policy, however, the policy maker has a clear 'vision' of what should be done (it is clearly a centralized design and decision process, with a precise definition of the technological goals to be achieved) and there is strong institutional proximity between the policy maker and the chosen firms ("National Champions").

5.2.1.2 Learning Capacities of the Policy Maker, the Firms and the Intermediary Institutions

The main learning characteristics of the local elements of the system (i.e. firms and intermediary institutions, such as technology centres) are represented by the initial ability of these elements to identify their needs, their learning rate, and the efficiency of horizontal coordination between them. More precisely, the ability to identify needs could be interpreted as an in-house research capability, relevant for defining the absorptive capacity of firms. The coordination skill refers more specifically to a firm's and institution's ability to slot into cooperation networks. These parameters help to determine the appropriate mode of coordination of diffusion-oriented policies, since the informational capacities of the policy maker are *de facto* low in these types of policies.

The learning ability of the policy maker is its ability to accumulate past experience and know-how. The rate at which it takes into account historical events demonstrates capacity to define a coherent system within a mission-oriented policy (i.e. coherence between the policy and the mode of coordination). The learning ability of the policy maker will induce the relevant coordination mode since the selected firms are characterized by significant learning abilities and the informational capacity of the policy maker is given (i.e. high).

The Aoki model allows the relevant coordination mode (vertical or horizontal) to be defined for a given set of values of parameters characterizing the institutional arrangements of the technology policy. The main results of the model can be summarized as follows (see Aoki 1986; Foray and Llerena 1996).

In the case of a *diffusion-oriented policy*, since the informational capabilities of the policy maker are by definition low, horizontal coordination will be more effective than vertical when the learning rate, the initial knowledge and the coordination skill of the firms are high. "In other terms, a diffusion-oriented policy with horizontal coordination needs a minimal technological capability or learning potential on the side of potential users" (Foray and Llerena 1996, p. 164). If the converse is true, then vertical coordination will be more appropriate.

In the case of *mission-oriented policies*, the policy maker has, by definition, a high information capability, and firms are characterized by a high learning rate, and significant initial knowledge and coordination skills, since the policy maker can choose the most relevant firms and research institutions. Which coordination mode is the most appropriate will crucially depend on the capacity of the policy maker to accumulate knowledge based on past experiences. If the technological competences of the policy maker are high, then the preferred mode of coordination would be vertical; if not, then horizontal coordination would be better.

Our purpose is to use and develop this analytical framework in the case of technology policies implemented in France and Italy. The DSS case is particularly interesting because this technology played a major role in defining the relative competitive advantage of firms in the telecommunication industry. In other words, the DSS programme can clearly be said to be a mission-oriented policy, with the explicit goal of developing a new device for the switching system based on new technological principles.

5.2.2 Relevance of Coordination Modes in France and in Italy

France and Italy have different institutional arrangements in relation to their technology policies, and especially for DSS. In France, there is a powerful specialist centre (CNET, National Centre of Telecommunication Studies), which is close to the policy maker, and which is able to capitalize on knowledge, know-how, and political expertise. According to our analytical framework (i.e. the ability of the policy maker to accumulate knowledge is high), vertical coordination seems to be appropriate. In contrast, in Italy there is no institution with the capabilities to develop such competences. Therefore, horizontal coordination should have been effective, but did not really emerge. Table 5.1 presents the technological evolution of DSS in each country.

5.2.2.1 The French Case: a Mission-Oriented Policy with Centralized Coordination

In France, especially during the first phase[4] (1958-1974), the development of DSS was marked by the creation of a "specific organizational device" (Quelin 1992), with CNET, the research laboratory of the French PTT, playing a central role. In 1958, after the opening of a new switching department in Lannion, CNET formed an alliance with Socotel, the pool of the French manufacturers of switching equipment. Under this arrangement the two French subsidiaries of ITT (Compagnie Générale de Constructions Téléphoniques – CGCT – and Le Materiel Téléphonique – LMT), the French subsidiary of Ericsson (Société Française de Téléphones Ericsson-SFTE) and the two French manufacturers, AIOP and CIT-Alcatel, collaborated to conduct research on the new technological paradigm of electronics.

Two projects were initiated. The first, Socrates, involved Socotel and CNET. It aimed at the development of a digital switching system following the space-division trajectory (incremental innovation). The second,

[4] This first period ended in 1974 with the election of V.G. D'Estaing to the presidency of the French Republic, whose government recognized that important changes were occurring in the telecommunication industry and intervened to weaken the role of CNET.

Aristote, involved only CNET and Société Lannionnaise d'Electronique (SLE), a new company opened in Lannion by Cit-Alcatel. The Aristote project chose to start directly on the time-division trajectory (radical innovation).

Table 5.1. Technological evolution of the Italian and the French digital switching systems

Year	Technological evolution of the Italian digital switching system	Technological evolution of the French digital switching system
1958		Creation of the Switching Department of CNET Creation of Socotel Project Socrate and Aristote
1967		Platon and Pericles
1970	Beginning of Proteo	First E10 installed
1972	Proteo CTA installed	E10-A (improvement in program capacity and components)
1979	Proteo CT-2 (improvements in memory) Beginning of UT	
1980	TN-16 and TN-5	E10-B (new circuits, modular architecture, improvements in program capacity)
1981	UT10/3 prototype	
1983	UT10/3 industrialized	
1985		ALCATEL E10 (new access unit for network compatibility - ISDN level)
1987		First ISDN trial
1989	UT100/60	
1992	First ISDN trial	

Source: Our elaboration on Chapuis Joel (1990)

The reasons for this division of labour were twofold. One was technological: the technological advance of manufacturing firms in the space-division technology. Given their greater experience in terms of the electromechanical paradigm, these firms were thought to be in a better position to gradually introduce electronic control and management systems within a crossbar switch. On the other hand, CNET, in the previous ten years, had accumulated vast experience doing basic research on electronics, especially transmission, and was thus better suited to developing a new electechnology contributed to the objective of building French independence in this strategic field. It was clear that if the time-division project proved successful, French manufacturing industry would be in a monopoly position vis-à-vis foreign subsidiaries. In fact, the group of researchers working on Platon (the successor to the Aristote programme on the time-division solution) had the explicit task to "realise the prototype of totally electronic switch and then to pass immediately to the industrial phase" as quickly as possible (Libois 1983, p.158). The consequence of the "exclusive" French efforts on time-division technology, if successful, would be to push ITT and Ericsson out of the market.

Socrates was followed by a new project, Pericles, while Aristote was followed by Platon, the project that finally led to the installation of the world's first time-division switch. The Platon prototype, later known as E10, was installed in Lannion in 1970 followed six months later by a new and bigger prototype. Between 1970 and 1972, work continued in Lannion to progress from a prototype to an industrial product. In 1972, the E10A was ready to be produced and sold commercially. During the inauguration of the time-division switch in 1972, the Ministry of PTT confirmed the importance of the new technology for the modernization of the French network in announcing that the E10 would cover 2% of the French switching market by 1973, and 10% by 1975 (Libois 1983). Moreover, in 1973, the new Ministry of PTT confirmed support for the time-division technique, predicting further development of the system in order to serve bigger towns (Libois 1983).

It is important to underline the crucial role played by CNET in this first phase. CNET had two main responsibilities: R&D and control over equipment. This dual function gave CNET the advantage of being able to interact both with the service supplier and with manufacturers with relative autonomy. Also, during this period CNET had a very charismatic leader: Pierre Marzin (Griset 1995). Through a combination of personal contacts and trust, CNET developed a dense network of relationships with industry (facilitating technological transfers), with policy makers (accelerating the funding of projects), and with academia (strengthening the flows and exchange of knowledge and personnel).

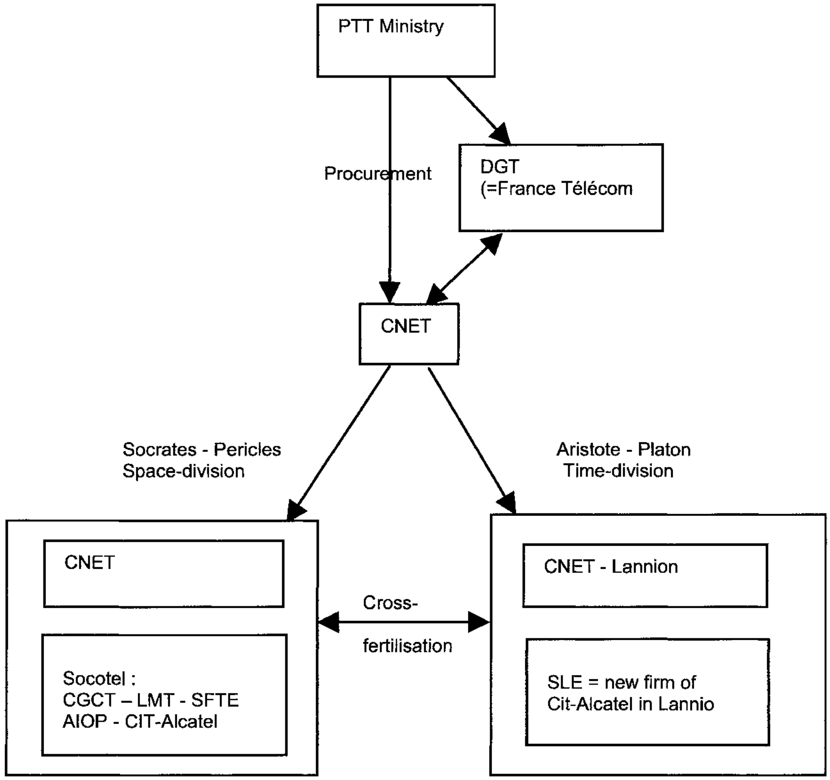

Fig. 5.1. The Organisational Design of the DSS Policy in France

A crucial aspect of the technological developments was the involvement of all the suppliers acting in the French market and the division of labour between the different members of Socotel. One of the bonuses of this division of labour in the two series of projects was the opportunity for the two groups to interact, given the presence of CNET researchers in both projects. For example, the manufacturers' experience in relation to the reliability of the switch promoted adoption, in the Socrates prototype, of the principle of "load sharing" i.e. the simultaneous use of two (or more) parallel computers to control the switch. This principle was later adopted in the design of the DSS architecture in the Platon project.

5.2.2.2 The Italian Case: a "Mission-Oriented" Policy with a Lack of Coordination

In Italy, there was no such centralized process or closeness to the policy makers' decision process, and horizontal coordination (between sub-sets of firms and institutions) emerged. "Competing" solutions, promoted by competing "networks of firms" or "competing actors horizontally coordinated", were produced; but indecision about the adoption of early technology and industrial choices resulted in loss of opportunities and a lag in the adoption and diffusion of DSS.

The first phase of development of DSS spanned the period between 1960 and 1980. In the course of these twenty years, three main actors (Sit-Siemens, Telettra and CSELT) were involved in research on digital switches. Despite some attempts to reach agreement (between Sit-Siemens and Telettra and between Sit-Siemens and CSELT inside the STET[5] group), and despite the strong complementarities that existed among the different players, most of the research was isolated. We briefly describe below the three axes of this research.

In the early 1960s, a small group of researchers in Sit-Siemens started working on a prototype for an electronic PBX (Private Branch Exchange). At that time Sit-Siemens was producing the majority of its equipment under licence from the German company, Siemens. Based on this first prototype, a project for the development of an electronic public switching system was conceived. The research project was conducted completely *intra-muros*[6]. The top management in STET were part of the decision process, but no participation from the vertically integrated service provider was planned. In 1969, a first draft of the project was presented to SIP, in order to obtain the approval of the service provider concerning the architecture and the main characteristics of the switch. SIP's R&D department approved the main characteristics[7].

Even though no formal arrangements were put in place in relation to the future market, the vertical integration within the STET group, and the historical dominance of SIT-Siemens in the Italian market for switching

[5] STET is the Italian holding company for telecommunications. It includes the service providers (SIP for local calls, Italcable for international calls, and Telespazio for satellite), the national research centre (CSELT), and the main national manufacturing firm (SIT-Siemens).

[6] An early participant in the research asserted that the project was conducted almost in secrecy for fear of reaction from the German licensor. Interview with a Sit-Siemens engineer - January 1992 (Trenti 1992)

[7] Interview with the General Director of CSELT, working at that time at the SIP R&D Department (Torino, 4/7/97)

equipment, gave Sit-Siemens a great advantage. The decision to directly "jump" into the time division trajectory was taken on the basis of its initial success in France (Llerena, Matt and Trenti 2000a,b). The project was extremely ambitious for a firm with no autonomous technological capability and no experience in the new electronic paradigm. Sit-Siemens specialism was in switching systems and not transmission, which introduced electronics into telecommunication equipment. The new digital system presented a specific architecture formed by a central transit switch and linked with peripheral small switches. The full design was never realized. Instead, one small prototype of the peripheral switch was installed in Milan in 1972. The service provider was involved only in the installation phase. The prototype did not become operative until two years later. During the 1970s, other prototypes were installed (in Rome, Pordenone, Florence and Messina in 1975), but were not activated until the end of the decade.

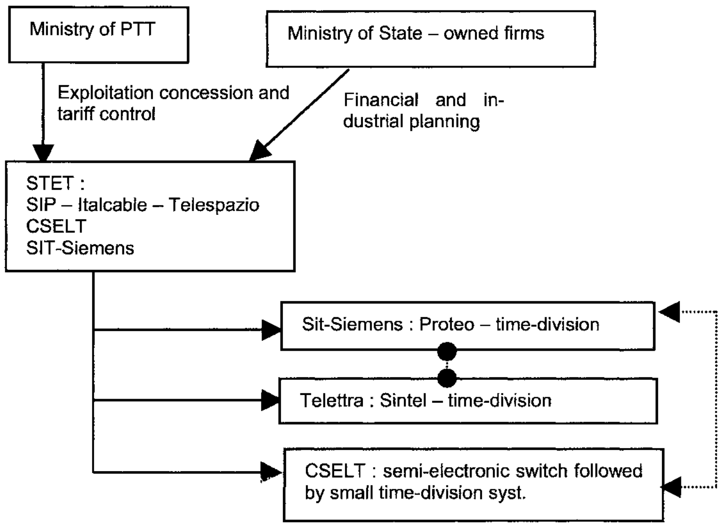

Fig. 5.2. The Organisational Design of the DSS policy in Italy

From the early 1960s, the second Italian supplier of telecommunications equipment, Telettra, historically specialized in transmission technology, had been conducting research on electronic switching (Sintel project). Telettra was convinced about the inevitability of the microelectronics paradigm infiltrating the whole range of telecommunications equipment. Therefore, Telettra researchers "felt the hazard of being excluded from the world of future communications" (Bellman 1976). Unlike Sit-Siemens, Telettra had already accumulated competencies in electronics thanks to their historical specialization in transmission technology. However, Telettra had no practical experience in electromechanical switching and did not enjoy the historical market share in the switching sector of Sit-Siemens. During the first decade of research, efforts were focused on acquisition of the knowledge needed to solve switching problems, and on training up researchers in the new paradigm, working on small time-division switches and on hardware and software equipment[8]. In the early 1970s, a second phase of research began aimed at the production of marketable switching products (Bellman 1976). The initial Sintel project on development of a complete time-division switch was considered to be too ambitious. Research focused on two main products: the DST1, a space-division switch with an electronic cross-point network and a distributed control; and the DTN1, a transit switch with a time-division switching network and stored-program control, an outcome of earlier research on the Sintel system. The DST1 was first installed in the Italian telephone network in 1975 while a bid to provide the international switch in Verona was awarded to the DTN1. The DTN1 was due to be installed in 1977, but installation was postponed and the switch was not finally installed until 1979[9]. The Telettra digital switching equipment was later modified (AFDT1) to accommodate the voice and data transmission network of SIP.

In the meantime, CSELT was conducting research on electronic switches. The aim was primarily to acquire a competence in the new paradigm and to respond to the needs of the service provider. Various products were developed. In 1967 a small semi-electronic switch was successfully put into service. During the 1960s, answering a specific need of SIP concerning the documentation of traffic, a prototype for a small time-division switch (TECA) was developed. Then, in 1971, the prototype of a small time-division switch and stored-program control with advanced feature (GS - Gruppi Speciali) was installed in Mestre (Venice) just one year after the successful Platon product in France. Further improvements to the GS switch were developed and installed during the 1970s (CSELT 1994).

This brief description of the research carried out in the 1960s and 1970s highlights the lack of coordination among the three actors involved. Given the shortage of high skilled personnel in the Italian National System of Innovation (NSI), the novelty of the technology, and the complementarities between the three actors, this lack of coordination is particularly signifi-

[8] One of the first versions of the system (Sintel III) was presented in an international symposium in Boston in 1972. The Sintel III featured two main characteristics (a time-division switching and a stored programme control) in order to be economically attractive and technologically valid (Bellman 1972).

[9] Interview with the Vice-President of Italtel, at that time R&D Manager at Teletra (Milano, 25/6/97).

cant. During the 1970s (in 1972, 1976 and 1978) Telettra and Sit-Siemens tried, without success, to coordinate their R&D activities and the development of the digital systems[10]. Moreover, even inside the same group in STET, coordination between Sit-Siemens and CSELT was poor. CSELT was only involved in the improved version of a Proteo switch (CT-2) installed in 1982 for which its Turin laboratory provided an advanced component (Chapuis and Joel 1990). Taking the French case as a benchmark, where the R&D laboratory of the service provider was given the task of coordinating national research, it is suggested that CSELT had the technical expertise to become the catalyser of the Italian efforts, as demonstrated by its technical success in the digital switching. However, CSELT was never given a clear commitment to develop a national technology and transfer it to national firms (lack of political decision).

5.3 Coordination and the Management of Diversity

Based on these cases it is interesting to see how a given coordination mode, or a coordination failure, can influence the mechanisms of selection of technologies. This section will analyze in more detail some dynamic properties of coordination modes. In the French case, vertical coordination induced an internal exploitation of controlled development of the technological alternatives (diversity). In the Italian case, lack of coordination produced a tendency to postpone final choice, leaving the diversity of solutions unexploited. Finally, policy makers chose to exploit external diversity, by employing a process of national coordination and cooperation with foreign actors to achieve catch-up. As a result there was delayed diffusion of the new technology in Italy, i.e. a relative failure of the policies and policy organizations implemented in this country, compared to France.

We first look at the contradictions faced by policy makers in their decisions about the appropriate technological option in a pre-paradigmatic phase. We then describe how French and Italian policy makers managed the technological diversity. Finally, we assess the relative successes of both policies, based on analytical elements and some simple statistics.

5.3.1 Analytical Elements

Each policy faces paradoxes, especially in the early phases of the new paradigm. David (1987) has highlighted three difficulties encountered by

[10] In 1976, Telettra passed into the control of FIAT.

policy makers in technology selection: (1) "*the narrow policy window paradox*" underlines the limited time period in which public intervention is possible; (2) "*the blind giant quandary*" shows that the possibility of intervention is necessarily localized at the beginning of the development process - the period in which the policy maker has little information concerning the relative efficiency of competing emerging technologies; (3) "*the angry orphan*" underlines the problems related to early adopters that are finally eliminated by the policy maker choices.

In other words, once the policy maker selects a technology, there is greater opportunity for the characteristics of this technology to be demonstrated and greater chance of its being adopted. If an inferior technology is chosen, the system is very likely to become locked into this technology. The probability of this phenomenon is amplified by the existence of increasing returns. To avoid this, the policy maker should subsidize different options until there is sufficient information available for a decision to be made as to which is the best. This, however, is not a fool-proof solution since technology improves as the result of diffusion, and trajectories are difficult to assess *ex-ante* Thus, the technology chosen might ultimately be the most inferior. For practical and financial reasons, the policy maker will have to put an end to experimentation at some point and back the technology that is believed to be the best at the time.

According to Cowan (1991), these three paradoxical situations evolve in different ways depending on whether the focus is on the degree of increasing returns, which shortens the competition period, or on the level of uncertainty, which extends this period. Increasing returns will tend to limit the window of opportunity and increase the cost of interventions to keep it open. But decreasing the period preceding lock-in will limit the number of orphans. A certain level of uncertainty will encourage policy maker to extend the experimentation period, which will increase the number of orphans. It will also heighten the "blind giants quandary", because the characteristics of the technologies and their future performance are ignored.

To manage these problems it is necessary "to build organizational systems, involving a coordinated set of decentralized experimental projects, mechanisms and procedures for exchanging and distributing information produced in the course of these projects, and a centralized procedure of assessment to decide the timing for switch (to the standardization phase)" (Foray and Llerena 1996, p.171). Our aim is to illustrate via the case studies how such coordination could influence the selection mechanisms and deal with the paradoxes.

5.3.2 The French Case: a Successful Technology, but a National Orphan

During the second period of development (1975-1983), the French situation was characterized by important political changes. After the election of V.G. d'Estaing to the Presidency of the Republic, the role of CNET in French industrial policy was called into question. Criticisms of CNET concerned its near monopoly of the financial means and decision function, which reduced the flexibility of the telecommunication industry. Moreover, the technological leadership of CNET was considered to be a major factor in explaining the high dependence and lack of entrepreneurship among French manufacturers (Griset 1995). Thus, in 1975 a change was made in the "leadership" of the telecommunication sector from CNET to DGT (i.e. the French Ministry in charge of telecommunication). The aim was to modernize the network and to obtain lower equipment prices, introducing more competition and control in a market dominated by SOCOTEL, considered by DGT to be a cartel. This change in policy had important consequences for digital switch development.

In 1975, DGT decided to publish an international tender to equip the Parisian network. DGT, after a long and difficult decision process, decided not to equip the entire Paris network with time-division technology. The decision was made to share the market between two space-division systems (the Metaconta of ITT and the AXE of Ericsson) and one time division system: the E10. At the same time, Thomson created a "second French pole" for switching equipment (space-division) with the acquisition of LMT (ITT) and SFTE (Ericsson). Space-division technology was given priority in the planned modernization of the French network, while time-division technology was relegated to the ancillary role of equipping the rural and low-density parts of the network.

Three years later, in 1978, the choice of space-division technology was itself called into question. Use of time-division technology was seen as the only way to achieve the objective of modernizing the French network, and to sustain the planned evolution towards telematics. Thomson, which was supplying the space-division system, was no longer able to sustain competition with CGE (later Cit-Alcatel), which had already developed the technology with the fundamental help of CNET. In 1983 (after the election of François Mitterand, a socialist president, in 1981), the telecommunication department of Thomson was sold to CGE, which had been recently nationalized.

In other words, the announced strategy of the 1960s to push the foreign subsidiaries out of the French market, was suddenly halted by the 1975 decision to opt for space-division technology. There are two possible interpretations of this change in policy. Each differently assesses the role of government technology procurement in the development of a national technology.

On the one hand, the choice of space-division technology can be seen as being completely incoherent. According to Griset (1995), "this strategy was a major failure and delayed the international development of the French industry". The decision to give Thomson the leadership for the space-division technology represented the starting of a "French-French competition", producing losses in terms of years of development and financially to several billions of francs. The positive climate created by CNET, and the success of the technology transfer strategy, was disrupted by the intervention of government procurement, aimed mainly at creating a competitive environment[11].

On the other hand, the choice of the space-division technology can be seen as facilitating a gradual modernization of the network. From this perspective, the time-division technology was not sufficiently well developed to be used to equip bigger towns (Libois 1983). Moreover, it was costly and risky. The "dilemma" between protecting the "national champion" and gaining from competition with other suppliers while waiting for the mature phase of the national technology, was resolved with the creation of a second "national champion" for space-division technology. In this sense, we could say that government procurement was used to enhance variety, allowing competition between two different technological trajectories at an early phase of development (Cohendet and Llerena 1997). The three year delay in the full adoption of the E10 in the French network, coupled with its installation in rural networks, might have helped CNET, which was still responsible for technological improvement[12], to gradually improve the performance and the reliability of the system. In this interpretation, the decision to sustain a "bridge technology" (the space-division trajectory) was not as totally incoherent as in the previous interpretation. The knowledge about time-division technology, totally new to the market, was insufficient to allow DGT to follow this trajectory from the beginning. At that time, no other country had attempted mass introduction of time-division switching in the network. Even if, inside CNET, there was great optimism about the

[11] According to an observer at the time (*Le Monde,* July 30, 1976) quoted by Griset (1993), government intervention should have been suspended and reconsidered, because "competition is a good thing if it does not turn into anarchy".

[12] For the whole of 1970s, Cit-Alcatel was responsible only for the production and the marketing of the new system, while technological improvements were still conducted under the umbrella of CNET.

development of microelectronics and semiconductors, DGT had no guarantees that the E10 would have the capacity to handle high traffic nodes.

However, with the support for time-division technology in 1978, CNET's plans were finally realized. Government procurements started to diffuse the new technology, which was ready to be sold and installed. According to Libois (1983), after 1978, the situation became clearer and the superiority of the solution provided by CNET was proved by the prodigious development of semi-conductors and by the introduction of microprocessors. The French Director General of Telecommunications (DGT) confirmed, at a conference held in Paris in 1979, that "the development of time-division switching has become a reality demonstrated by the already taken or imminent decisions in most of countries" (our translation) (Libois 1983). In 1980, time-division switches accounted for 70% of the procurement of DGT. In 1982, the orders for E10 amounted to 8 million lines, of which 2.5 million had already been installed.

The role of the national market was fundamental for Cit-Alcatel to enhance performance of the system. New versions of the E10 were developed in 1980 and 1985. The last version (Alcatel E10) was at the basis of the first ISDN trial in 1987. The success of the E10 in the national market had given Cit-Alcatel an important competitive advantage in the field of electronic switching. The process of digitalization of the French network was a key way to prove to foreign clients the reliability of the system. At the end of the 1980s, the E10 was in use in 40 international markets.

5.3.3 The Italian Case: Late Coordination and Delayed Choice of Technology

In Italy during the 1970s, the two service providers, SIP and ASST, continued to buy and install electromechanical switches. Only ASST chose to buy semi-electronic switches while SIP decided to skip the semi-electronics phase and wait for fully electronic switches. SIP's decision was based on an evaluation that showed that electronic switches were better suited to equip bigger transit nodes than the semi-electronic switches in the ASST network. Moreover, the move to an electronic switching system was seen by SIP as a way of reducing the number of suppliers. Given the rigidity in the supply of electromechanical switches, it was very difficult for SIP to change the historical shares in the switching market[13]. The Italian switching system was initially seen as a way to simplify the market and

[13] Interview with the General Director of CSELT, working at that time at the SIP R&D Department (Torino, 4/7/97)

sustain the vertical integrated "national champion". The development process was long and difficult, highlighting the problems related to the Proteo system. The presence of a second Italian supplier, Telettra, was not considered as a possible alternative (only ASST attempted to install a Telettra switch, which experienced a two year delay).

The result was that SIP was "waiting for the Proteo" (Morganti 1980). The Telettra system was chosen only to equip the national voice and data-transmission network, pushing Telettra to develop a specific switch for this purpose. The first trial for the voice and data-transmission network (Rete Fonia Dati - RFD) started in 1976. At the end of the 1970s, the network was ready for service. However, the RFD was not activated until 1984, because of prolonged battles between the Ministry, SIP and ASST over tariffs and charges.

At the end of the 1970s, and after the late and the partial failure of the Proteo system, SIP was aware that achievement of a "unique system" would be difficult and was still a long way off. For this reason, SIP decided to establish, enshrined in specific documents, the characteristics of the switching systems to be purchased in the future. These specifications were laid down as a way to allow the installation of different systems in the Italian network[14].

The role of policy in this period must be interpreted with caution. Two particular issues had been the object of criticism and debate: to pass directly to the fully electronic switch, or to wait for the Proteo.

The suggestion to leapfrog the semi-electronic phase was criticized for the reason that trialling the semi-electronic systems could have enhanced the capacity of SIP in handling the new microelectronics paradigm (Pontarollo 1989). However, as in other countries (for example, Canada), technological leapfrogging was the path chosen.

The "waiting for Proteo" strategy might be considered as being "providential" for the vertical integrated manufacturer (Cozzi and Zanfei 1996). The Proteo I experienced many technical problems during the 1970s, and it was thus considered too risky for SIP to install. This delay in modernization of the network gave Sit-Siemens the chance to develop a new product (see below). However, the decision to push Telettra to develop a specialized switch for the voice and data-transmission network, together with the difficulties encountered by Telettra in installing its digital switches, show that government procurement was not used in this period as an instrument to coordinate the already scarce national technological resources.

[14] Interview with the General Director of CSELT, working at that time in the SIP R&D Department (Torino, 4/7/97)

At the end of the 1970s, while Telettra was successfully equipping the voice and data-transmission network, Proteo finally entered the industrial phase, notwithstanding certain technical difficulties. A group of engineers from Sit-Siemens was sent to Dallas to cooperate with a US company, the Advanced Business Communication (ABC), in order to develop a new generation switch. The decision to collaborate with a foreign partner was motivated by the difficulty of hiring skilled personnel in Italy, especially for software (Chapuis and Joel 1990). Progress in the next two years was rapid: the first prototype of the new system (Proteo II) was installed in Milan in 1981.

One year later, an agreement was signed between Telettra, GTE and Italtel to build a complete switching system, finally pooling national resources. The distribution of roles inside the system saw Telettra supplying a peripheral switch, GTE a transit switch, while Italtel (the new name for Sit-Siemens since 1981) supplied the new switches, which became known as UT10/3. In the same period, responsibility for the switching system passed from Telettra's R&D department to Italtel. Industrial production began in 1983 and production of the old system was terminated in 1984. The UT10/3 evolved very rapidly in this period from an isolated switch to a family based on a modular architecture (Linea UT). The initial architecture of UT10/3, proposed by ABC, was completely reviewed to reach a truly modular solution that allowed low cost and an almost flat curve for the cost per subscriber (Bellman 1987).

The Proteo/Linea UT system development, which began as an isolated project, was strongly marked in this period, by one major organizational device: the search for external technological competencies, both at national (the Telettra R&D) and at international levels (ABC). After the difficulties encountered during the 1970s, the UT was developed in a relatively short time. The system was ready to be sold in 1984, but full development to satisfy the demands of the Italian market was not achieved until 1987 when "Piano Europa" was finally approved[15]. There was thus a three-year delay in the launch of the national procurement plan . This delay could be interpreted as an inability to sustain "the national government procurement" in line with the new system, the Linea UT, which was by far "more reliable and better performing" than the Proteo (Cozzi and Zanfei 1996).

The digital switching system evolved rapidly. In 1987, a new and bigger switch (UT100), the upper end of the modular architecture, came on line. The industrial phase of UT100 began in 1989, the year of the Joint Venture between Italtel and AT&T, introducing new features and improvements to

[15] Despite SIP's low level of investment and procurement, in 1986, 335 switches were delivered and 294 were already in service.

the Linea UT. At the same time, the investment plan for the modernization of the network was finally approved. Starting in 1988, the level of investments steadily grew. Around 30% of investment was devoted to digital switches. The number of digital lines installed in the Italian network increased dramatically from 1,5 million in 1986 to 8,5 in 1990. In relative terms, digital lines as a percentage of total lines increased from 11,8% in 1986, to 33% in 1990. The diffusion of the Linea UT followed a similar exponential path.

5.4 Assessment of the Policies and Conclusion

In the French case, during the first phase (1958–1974), the existence of CNET, a strong and competent centralized research centre, promoted vertical coordination. CNET participated in the development of two different technological options: space-division technology, which involved mainly a pool of foreign subsidiaries; and time-division, a trajectory that involved a new company being established by the French Cit-Alcatel. The presence of CNET in both experimental projects favoured cross-fertilization, and the centralization of information, and allowed the policy maker to take appropriate decisions. The time-division technology was well supported and in 1972, it (E10 from CIT-Alcatel) was ready to be commercially produced and sold. In this first phase, appropriate coordination helped to decrease the "blind giant quandary" and to increase the probability of the most efficient technology being selected. During the second phase (1975–1983), political changes induced some strategic modifications. CNET lost its leadership in the telecommunication sector. The government wanted to introduce more competition in the French telecommunication sector and, in 1975, launched an international tender to equip the Paris network. The market was finally shared between space-division (ITT and Ericsson) and time-division (E10) switches. Space division was given priority and Thomson absorbed the foreign subsidiaries to form a second French pole. In 1978, time-division switches were considered to be the only solution to modernize the French network. Thomson could not sustain the competition and its telecommunication department was sold to Alcatel in 1983. The second period could be described as follows. The high level of uncertainty, especially in relation to the ability of time-division technology to equip large towns, induced the government to extend the experimentation period and to sustain the alternative technology, with the risk of generating an orphan. Finally, the superiority of the time-division switches and the French-French competition pushed Thomson out of the market (national orphan).

The political decision to extend the experimentation period brought increased costs and longer development time. These disadvantages could perhaps have been reduced if CNET had been given similar leadership and if a truly competitive situation in relation to foreign firms had emerged. In other words, the organizational system was *a priori* coherent to deal with some of the paradoxes during the first phase, but the choices made during the second phase entailed some shortages. Despite these limitations, France was the first country to introduce time-division switches in a substantial way into its network.

In the Italian case, during the first phase (1960–1980) horizontal coordination between competing suppliers would have been appropriate due to the absence of a skilled central research centre. Three competing projects (mainly time-division systems and a semi-electronic one) emerged. The lack of real coordination between the actors seems particularly disadvantageous given the shortage in high skilled personnel, and the complementarities of the actors. Moreover, the procurement policy did not work as an instrument to coordinate existing national experience. In other words, there was no coordination between the decentralized projects and no centralized procedure favouring public decision making. During the 1970s, prototypes were installed on local basis. The experimentation period was lengthy, the "blind giant quandary" was not reduced, and the risk of a national orphan was high. At the beginning of the second phase, Telettra successfully equipped a special switch for the voice and data-transmission network and Proteo (Sit-Siemens) entered the industrial phase. The development of the technology and its late success can be explained by two crucial events: the collaboration of Sit-Siemens with an American company (ABC) to develop a new generation of DSS, and the pooling of national resources (Telettra, GTE and Sit-Siemens signed an agreement to build a complete DSS). This new organization of competencies induced the emergence of a switching system family based on a modular architecture: Linea UT. This second phase clearly shows the positive impact of the horizontal coordination: it decreased the "blind giant quandary" by allowing firms to develop a new performing switching system, without a national orphan. But it did not compensate for the coordination failures of the first period and the negative impacts on the development of the DSS: very high costs of development and a tremendous loss of time. This organizational failure induced a less successful development than the French case.

One way to measure the relative success of each policy is to compare the digitalization of the telecommunication networks. Table 5.2 presents data concerning the digitalization of networks in the main industrialized countries from 1988 to 1993. France, thanks to the massive installation of the national switching system that began at the end of the 1970s, appears as the leading country: it had the highest percentage of digital lines over the period considered. The Italian data confirm the delayed diffusion, and the importance of the most recent investments and the efforts of SIP to modernize the network.

Table 5.2. Digitalization of the network 1988-1993 (% of digital lines on total lines)

	1988	1989	1990	1991	1992	1993
France	60.5	65.8	69.1	73.5	78.1	83.0
Italy	20.1	24.7	32.6	39.9	47.4	54.5
USA	35.4	41.6	48.1	54.4	60.9	68.1
Canada	40.0	45.0	50.0	55.0	62.0	68.0
Japan	17.4	24.9	31.9	38.9	46.4	53.3
Gemany	5.0	7.3	10.5	15.0	19.4	23.7
UK	23.5	31.3	39.7	41.1	53.6	59.4

Source: Zanfei (1990) from NBI and SIP Development Plan

This chapter has focused on the technological evolution and, in particular, on the introduction, of DSS in France and Italy. We elaborated on the institutional framework of the policies involved in terms of information and coordination structures, and also in terms of lock-in and diversity management. We proposed for both dimensions an analytical framework, which allowed us to analyze the elements of both histories and to assess the relative successes of the two experiences, which differed in nature and timing. Further research should be devoted to examining whether these two rather specific histories had some impact on the introduction of subsequent generations of technologies and products, such as Minitel and/or Internet, in these two countries.

5.5 References

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