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Exploring the causes behind the persistence of French technological specializations

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Exploring the causes behind the persistence of French technological specializations

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Abstract

Responding to the research on the persistence of technological specializations, this paper puts forward a complementary explanation for the stability in the fields in which a country performs well relatively to other countries. The study investigates the French institutional and historical features that may explain the evolution of the relative technological strengths of French organizations since the end of the seventies. More precisely it focuses on the interplay between three related institutional factors, the relatively high commitment of the State, the prevailing role of French large firms and of the technical experts from the Grandes Ecoles in shaping France's innovation system.

Keys Words: Technological specializations, Institutions, large firms

JEL Codes: C10, L29, O38

1. Introduction

The literature devoted to the study of national technological specializations has shown that once established countries' technological specializations tend to persist over time, although with a diminishing intensity in the long run (Cantwell 1989, Pavitt and Patel 1990, Patel and Pavitt 1998, Nesta and Patel 2004, Laursen 2000). As predicted by the theory and despite deep external changes and internal structural transformations (Amable and Hancké 2001, Hancké 2002), French innovation system has displayed relatively stable patterns of technological specializations over the last 30 years. Existing research mostly relies on the path dependent nature of technological accumulation in order to explain this stability. Accordingly, the theory of technological accumulation argues that firms that have developed a competitive advantage in certain technologies will tend to strengthen this advantage, and to diversify in fields close to their existing knowledge base (Cantwell 1989, Dalum et al. 1998). Although the explanation based on technological path dependency brings some answers on the lock in into certain technological paths (David 1985, Arthur 1989, 1990) and the localized character of technical change it underestimates the role of institutional and historical country level determinants. As pointed by Patel and Pavitt (1998) and more recently by Nesta and Patel (2004) further research is needed to understand the institutional determinants of the stability in countries' technological patterns. Actually we need to go beyond the technology and firm based explanations of technological path dependency and to complement them by accounting for the role of national specific features of the innovation system. Such an exercise can allow to compare and to understand the relative importance of the different complementary levels of explanation for the persistence of countries technological strengths.

The first contributions on national innovation systems (NISs) have argued that specific historical features and different institutional set-ups matter in the way and the extent to which national firms generate and market innovations (Freeman 1987, Lundvall et al. 1992, Nelson et al. 1993). According to this literature the persistent international differences in technological performances reflect the diversity of NISs that have favored or hampered the development of countries along certain technological trajectories. Therefore we should expect firms with different national cultural background to exhibit different innovative behaviors according to the NIS from which they originate. More recently another stream of the literature has been devoted to the study of the fitness between the features of national innovation systems and the industries in which they are relatively more specialized (Tylecote and Conessa 1999, Goyer 2001, Vertova 2001 and Tylecote and Vertova 2007). Tylecote and Conessa (1999) have underlined the importance of the fitness between the national financial and corporate governance systems and the sectors in which the countries will specialize. Later, Vertova (2001) and Tylecote and Vertova (2007) have argued that only countries with a proper national system of innovation are likely to specialize in the highest technological opportunities fields.

Build upon this latter literature this paper argues that stability might arrive because the activities of certain industries fit better into the innovation system of a particular country. Taking France as a case study the paper mainly argues that nothing has really changed, and this, although the main actors of the French innovation system have been through deep organizational and structural changes. Indeed the French innovation system has remained strongly dominated by the large firms and a persistent, although more indirect, presence or intervention of the State in most of the sectors in which France remained relatively more specialized. Despite the change in their environment large firms have survived and their innovative and research activities still strongly reflect the pattern of French relative technological strengths.

Hence the purpose of this study is to explain the role of the State and large firms in the observed persistence of French technological specializations patterns between the end of the seventies and the mid-2000s. The remainder of the paper is organized as follows. In the Section 2 we present the empirical findings regarding the evolution of French technological specializations across technological classes between 1978 and 2004. Then we discuss the origin of French relative technological strengths focusing on the historical commitment of the French government in the design and the performance of technological activities after the Second World War. In Section 3 we argue that, despite major changes in the French industrial policy, including the gradual withdrawal of the French Government’s stakes from several large firms, the French state has remained relatively active notably through the funding and performance of research activities through its research agencies and establishments. Also, till the mid nineties the French state has been present in several key sectors notably through its majority or high participation in several large firms. However after 1995 it has intensified the progressive withdrawal, and has shifted its focus from large firms to small business enterprises (SMEs). Nevertheless, we observe that large firms remained dominant in the technological classes in which France's organizations are the most specialized. In Section 4 we focus on the persistent role of large firms in research and innovative activities in France. In these large firms the technical experts and engineers from a French particular institution, "les Grandes Ecoles", are still playing a crucial role in the design and management of the industrial and innovative strategies. We argue that in order to improve their innovative capabilities, former French national champions have operated important restructuring in their activities, with a greater focus on their strategic activities and a range of mergers and acquisitions. This process has led to the emergence of international champions in several major sectors in which France has maintained its relatively strengths. Section 5 concludes.

2. Patterns and origins of France relative technological strengths

2.1. Empirical findings on the evolution of French technological specializations

The Table 1 gives an overview of the classes with the highest patent shares in France for selected sub periods. These patent shares are computed using the SPRU longitudinal patent database[1] which gives the total number of patents granted by the United States Patent and Trademark Office (USPTO) across 34 technological classes for each country[2] and every year for the period 1978-2004. The Table 1 reveals that the set of French top patenting classes has remained quite stable, although with different rankings. Eight classes have remained in the top patenting classes for the whole period including organic chemicals, instrument and controls, drugs and bioengineering, general non electrical industrial equipment, telecommunications, non electrical specialized industrial equipment and chemical processes and miscellaneous metal products. In order to compare French pattern of absolute advantages with the whole sample's top patenting classes, we put in italics in the classes with the highest share of patent over all countries. It suggests that France's pattern of absolutes advantages have tended to move further away from the whole sample pattern. However as underlined in Appendix II the highest patenting classes in France do not systematically match with classes in which France appeared to be relatively specialized, this reflect the classical difference between absolutes and relative advantages. Between 1978 and 1983, France is relatively specialized in only four of its highest patenting classes including drugs and bioengineering, telecommunication, electrical and non-electrical industrial equipment. Moreover French organizations are relatively not specialized or only in average (index ranges between 0.95 and 1.05) in organic chemicals and instruments and control, two of the highest patenting classes. Thus in order to account for the different propensity to patent across sectors and countries the present study discusses the changes in France technological specializations or relative advantages.

[1] The data has been kindly provided to Mafini Dosso by Parima Patel during her research stay at Science Policy Research Unit (SPRU, University of Sussex, Brigthon, United Kingdom).

[2] The Appendix I provides more details on the original database, on the main specialization index used and on the different methodologies used to assess the persistence of technological specializations.

Table 1: Top patenting classes in France

1978-83	Share (%)	1988-93	Share (%)	1999-2004	Share (%)
Organic chemicals	8,46	Instruments and	8,35	Drugs and	12,99
Instruments and		control		bioengineering	
control*	7,48	Drugs and		Telecommunications	8,78
Drugs and		bioengineering	7,73	Computers,	
bioengineering	6,71	Organic Chemical	6,97	Calculators	8,03
General non-electrical		Telecommunications	6,56	Instruments and	
industrial equipment		General non-electrical		control	5,72
Telecommunications	6,68	industrial equipment		Organic chemicals	5,70
Non-electrical	6,64	Non-electrical	6,11	Chemical processes	5,41
specialized industrial		specialized industrial		Non-electrical	
equipment		equipment		specialized industrial	
Chemical processes	5,76	Miscellaneous metal	5,46	equipment	5,07
General electrical	5,48	products		General non-electrical	
industrial equipment		Chemical processes	5,11	industrial equipment	
Metal working	5,03	Computers Calculators	4,95	Dentistry and Surgery	4,26
equipment		Electrical devices and		Miscellaneous metal	
Miscellaneous metal	4,05	systems	4,18	products	3,72
products					
	4,02		3,74		3,69

*The classes in italics are the classes with the highest share of patents (with shares above 4.8%) over all the countries in the original sample.

The Table 2 presents the long run evolution of French specialization patterns across technological classes between the beginning and the end of the period. French organizations have remained relatively specialized in inorganic chemicals, bleaching, dyeing and disinfecting, drugs and bioengineering, plastic and rubber products, metallurgical and metal treatment processes, general non-electrical industrial equipment, induced nuclear reactions, power plants, other transport equipment, aircraft (incr) and telecommunications. These classes have been historically dominated by large firms and a strong presence of the state notably through its research centres as CEA (nuclear field) and IFP (French Oil Institute). Pavitt and Patel (1990) have provided the distribution of patents granted to France between large French firms (French or foreign control), state organizations and others firms from 1969 to 1986. Overall large French firms and state organizations account for more than 50%[3] of all patents granted to French organizations. In terms of concentration, the first twenty firms own almost 44% of patents granted between 1969 and 1989, and the first fifty firms own 55%. Their results suggest that these two types of organizations dominate the patenting activity in classes such as induced nuclear reactions (46% for state organizations), power plants (60% for French large firms), aeronautics (63% for French large firms), telecommunication (55% for French large firms), inorganic chemicals (66% for French large firms), bleaching and dyeing (69% for French large firms), metal working equipment (46% for French large firms), drugs (37% for French large firms), plastic and rubber products (61,5%) and general non electrical

[3] Table p 26, Pavitt and Patel 1990.

industrial equipment (46% for French large firms). The exclusion of the United-States from the sample reveals that French additional specializations areas also appear to be dominated by large firms and state agencies (chemical processes, hydrocarbons, mineral oil and mining and wells machinery and processes).

Table 2: Evolution of French technological specializations profile between 1978-1984 and 1998-2004

Specialization in	**De-specialization in**	**Stable specializations in** (variation of the index)	**Stable under-specializations** in (variation of the index)
Organic chemicals	General electrical industrial apparatus	Inorganic chemicals (incr.)	Apparatus for chemicals, food, glass etc. (incr)
Agricultural chemicals	Metallurgical and metal working equipment	Bleaching, dyeing and disinfecting (incr.)	Assembling and material handling apparatus (decr)
Chemical processes	Semiconductors	Drugs, bioengineering (incr)	Road vehicles, engines (decr)
Hydrocarbons, mineral oils, fuels, igniting devices	Instruments, controls	Plastic and rubber products (incr)	Mining and wells machinery and processes* (incr)
Materials (glass and ceramics included)		Metallurgical and metal treatment processes (incr)	Electrical devices and systems§ (decr)
Food and tobacco (processes and products)		General non-electrical industrial equipment (incr)	Calculators, computers (decr)
Non-electrical specialized industrial equipment		Induced nuclear reactions (decr)	Image and sound equipment (decr)
Miscellaneous metal products		Power plants (incr)	Photography, photocopy (incr)
Textile, clothing, etc.		Other transport equipment (exc. aircraft) (incr)	Dentistry, Surgery (incr)
		Aircraft (incr)	Other (decr)
		Telecommunications (decr)	

The computations are based on US patents taken from SPRU database; Decr and incr denote decreasing and increasing indexes between the beginning and the end of the period.
* Specialized in 1985-91 and 1992-98
§ Specialized in 1985-92

2.2 Origins of French technological specializations: the role of the state in the creation of innovative capabilities

2.2.a Relative Specializations in Colbertist classes

At the end of the seventies French organizations are relatively specialized in fields considered as Colbertist such as nuclear reactions, power plants, telecommunication or aeronautics (Pavitt and Patel 1990). These fields are characterized by a strong intervention of the state notably through state orders, funding and performance of research activities (state firms or state research agencies) and the orientation of technological activities. The leadership of France in these fields could be related to the implementation of the Grands Programmes (Large programs) in targeted areas. These programs and the policies of national champions have become very important under de Gaulle era. They partly reflect the willingness of French government to get independence and autonomy from US technological domination (Chesnais 1993). They basic structure implied the participation of a dedicated public research institute and large state or private industrial partners in charge of the industrial exploitation. Designed in a long term perspective and at the frontier of research, they are mainly oriented toward defense related fields or towards civil sectors as nuclear power industry, space technologies, aeronautics telecommunications or oil industry. They also include fields in which French organizations are not specialized as computers through the Plan calcul that has been the major French Grand Programme. These development and investment plans come with the creation of several state research institutes designed to improve scientific capabilities and whose strategic priorities were conceived mainly by the government. The organization of research in France rested for the most applied part on these mission-oriented institutes which have narrow links with the industry. Basic research was performed in the CNRS (National centre for scientific research) and few universities as Université Louis Pasteur, Université Paris IX Orsay, Grenoble and Toulouse universities. Most of universities were dedicated to teaching activities. The Table III.A in Appendix III present the major historical programs, their launching date, the related technological breakthrough, the main firms implied as well as the investments between 1962 and 1989.

In the seventies the French innovation system was centered on a core of large state and private firms with SMEs exclusively dedicated to them. The Government support to research as direct subsidies and repayable loans was almost exclusively captured by those large firms, leaving SMEs with almost no support or very few notably from the FRT (research technological funds). As underlined by Chesnais (1993) French national innovation system is characterized by a set of vertically structured and strongly compartmentalized sectoral subsystems often working for public markets and invariably involving an alliance between the State and public and/or private firms belonging to the oligopolistic core of French industry. Within this mission-oriented system the priority has been granted to large intensive and technological systems. These narrow relationships between the State and the oligopolistic core of large firms were typically found in the sectoral subsystems or meso-systems (Sefati, 2001, defense industry) related to the defense industry, the electronuclear field, the space industry and telecommunications equipment industry. Chesnais (1993) made a distinction between four subsystems[4]. The military sub-system concentrated more than one third of French state R&D funding distributed between nuclear research of the CEA and large firms through public R&D procurement and contracts. The strong commitment of the DGA (French government agency that conducts the development and evaluation programs on the weapon systems of the French military) in the various sub-systems reflect the importance of military objectives in the innovation processes. The agency was also in charge of the labor division between the industrial partners as Dassault Aviation and Aérospatiale (planes and helicopters), SNECMA (planes’engines), Aérospatiale and Matra (missiles), Thomson (defense telecommunication) and Dassault-Electronique (electronics). In the eighties the electronuclear subsystem was

[4] See Chesnais’contribution in Nelson et al. (1993) for a detailed presentation of these subsystems

organized around the CEA and Empain Schneider[5] and their industrial subsidiaries (Cogema, Framatome, EDF, Jeumont Schneider and Creusot Loire…). In this field CGE/Alsthom was in charge of heavy industrial electrical equipment (Figure 6.6 page 217, Chesnais). As in the hydrocarbons field (IFP), the state agencies in the nuclear field, the CEA (Commissariat à l'énergie atomique) owns a high share of the patents granted to French organizations between 1969 and 1986 (respectively 55% and 46%, Pavitt and Patel 1990). French space industry has been formed in the frame of the European Space Agency (ESA, 1975) in which CNES (French state research center) was strongly committed. French large firms as Aérospatiale and Thomson CSF (state firms) and Matra (Groupe Largadère) were the same implied in defense and aeronautics industry. In the telecommunications field the subsystem is structured around the CNET (state research centre in telecommunication), the DGT (department in charge of public procurements) and CGE Alcatel in the manufacturing sector (design and construction of telecommunication equipment). After Thomson (electronics and aeronautics) and Rhone Poulenc (chemicals), CGE was the third major innovative French firm as shown by its shares in patents granted in the US. The shares of the three companies in terms of patents granted to the US were respectively equal to 6.21%, 5.69 and 4.79% between 1975 and 1980 (Pavitt and Patel 1990, table p28). Looking at a finer level we observe that French technological strength in telecommunication reflect its relative advantages in telecommunication equipment (RTA=2.17), communication systems (RTA= 1.71) and to a lesser extent electrical transmission (RTA= 1.09).

In France the prevailing military objectives and the strong political will of national autonomy in the design of industrial strategies have led to the technological decline of France in some cases as computers (Plan calcul) and electronics (Plan composants) industries in which France has been lagging in the favor of countries as US and Asian countries as Japan and South Korea and later Taiwan. However in some fields these programs have led to great successes in high technology fields as aeronautics (Concorde, Airbus); thus reflecting a French know-how in achieving and leading large projects. Although the state participation brings some stability and allows for longer run horizon in the design of industrial strategy, it also tends to favor radical innovation fields as aeronautics, nuclear reactions or other transport equipment. This, according to Goyer (2001) has rendered French firms less able to develop capacities in incremental innovation-oriented fields. According to the author the particular structure of the French education has also favored this pattern of France industrial development. The dual education system and the prevailing role of the élites from the Grandes Ecoles narrowly linked with the State administrators have favored the design and development of large scale projects oriented towards specific technologies. The tight relationship between the State and the large firms has been founded on this élites network that often work for large state and private firms operating at the center of the major sub-innovation systems. On the other hand the availability of patient capital has also favored the undertaking and the successes of radical innovation projects. Indeed the technologies developed in these Colbertist fields require high and long run investments and related profits horizon that generally go beyond firms and shareholders time. The strong commitment of the State and a dedicated bank system have favored the long run investments in radical innovation-oriented projects. Besides the Fordist organization of French firms, that implies among others a strong hierarchical organization,

[5] Empain-Schneider will later focus its activities on electrical consumer goods and will become Schneider Electric in 1998.

standardized products and low-skilled works, has not favored the development of incremental innovations. Such innovations are more likely to result from work and cumulative learning that takes place in ordinary production activities and thus, have a greater component of a bottom-up approach while French system has generally favored a top-down approach of the innovation and industrial development. According to Goyer (2001) this organization has reduced the capacities of large French firms to develop innovations that could be generated in the various subdivisions of the firms.

2.2.b Other relative strengths of France

Besides these Colbertist classes French organizations show relative specialization in 1978-83 in classes as bleaching and dyeing, drugs, inorganic chemicals, plastic and rubber products, metal treatment, general electrical industrial equipment and semiconductors (Appendix II). French organizations also display relative average specializations scores in general non-electrical industrial equipment and food and tobacco products.
As shown by Pavitt and Patel's analysis (1990) the specialization of French organizations in semiconductors (57% for large French firms), bleaching and dyeing, plastic and rubber products and inorganic chemicals rested, to a great extent, on the activities of French large firms (respectively 57%, 69%, 61% and 66%). Thomson (and its subsidiaries as SECOSEM, SILEC, EFCIS) was the French national champion in the semiconductors field at the end of the seventies (Dosi 1983). At the end of the eighties the semiconductor activities of Thomson and the Italian group SGS have merged to STMicroelectronics. With its main innovative activities in bleaching and dyeing, l'Oreal has more than 2% of the patents granted in the US, and is ranked sixth over French all French organizations on the period 1981-86 (Table 3). In the chemicals field the French firm Rhone Poulenc owns almost 5% of patents granted between 1975 and 1986. Rhone Poulenc appears as a top patenting French firm, and operates in various subfields of chemicals as organic and inorganic chemicals and chemical processes (Table 3). In the Fortune 500 (1992 ranking) besides Rhone Poulenc, Air Liquide is ranked tenth according to profits amount and sixth if we look at the ratio of profits to sales. At a finer level we can observe that French relative strength in plastic and rubber product lies on the class of wheels (RTA=2.86). Michelin, the large French firm is ranked eighth in top patenting firms in the US in plastic and rubber products. In terms of economic performances Michelin was ranked seventh in the Fortune 500 (1992) as regards its ratio of profits to sales.

In the class "metal treatment" more than 60% of French organizations' patents have been granted to large French firms (46%) and state agencies (14%) between 1969 and 1989. In this field three firms are included in the top 50 French patenting firms (Pavitt and Patel 1990). Pechiney Ugine Kuhlman group owns more than 2% of patents granted in the US between 1969 and 1986 while Usinor and Sacilor only own respectively 0.14% and 0.11% between 1975 and 1980 and 0.22% and 0.21% between 1981 and 1986. As for the metal treatment class the innovative capacities of French organizations in classes as drugs, general electrical industrial equipment and general non-electrical equipment lie on large firms activities (respectively 37%, 46% and 46%) as well as other firms that respectively own 37%, 35% and 44% of patents granted between 1969 and 1986. However, according to Pavitt and Patel the high RTA in the drugs field does not reflect the performance of one or two large French firms but the combination of a former French firm (Roussel Uclaf) and the increasing activities of

French firms as l'Oréal, Rhone Poulenc and Elf Aquitaine. The French firms Valeo and CGE are respectively ranked 15th and 16th in the class of general non-electrical industrial equipment and general industrial equipment between 1981 and 1986.

Table 3. The rank of French large firms (French control) in the top patenting firms in the US between 1981-1986

Technological Classes	French firms and rank
Inorganic chemicals	Rhône Poulenc (12), PUK (17)
Organic chemicals	Rhône Poulenc (20)
Agricultural chemicals	Rhône Poulenc (19)
Chemicals processes	
Hydrocarbons, mineral oil ect…	Institut Français du Pétrole (IFP, 13)
Bleaching and dyeing	L'Oréal (6)
Drugs and bioengineering	
Plastic and rubber products	Michelin (8)
Non metallic mineral products, glass, ect…	
Food and Tobacco products	
Production of iron and iron ores	
Apparatus for chemicals, glass…	
General non-electrical industrial equipment	Valeo (15)
General electrical industrial equipment	CGE (16)
Non electrical specialized machinery	
Metal working equipment	
Nuclear reactors and systems	Creusot-Loire (2), CEA (5)
Power plants	SNECMA (17)
Motor vehicles	
Other transport equipment	F Salomon (15), LOOK (16)
Aeronautics	SNIAS (4), SNECMA (6), Thomson(19)

Table translated from table p 29, Pavitt and Patel (1990).

Our analyses reveal that French technological patterns of specializations have remained relatively stable[6] over the whole period. As predicted by the theory this stability is even greater in the shorter run (Cantwell 1989, Pavitt and Patel 1990, Patel and Pavitt 1998, Nesta and Patel 2004, Laursen 2000). The correlation coefficients of the distribution of French RTAs across technological classes equals to 0.55 between 1978-83 and 1999-2004, 0.91 between 1978-83 and 1988-93 and 0.62 between 1988-93 and 1999-2004. This stability mainly reflects the French organizations specializations (US included) in three kinds of sectors namely the Colbertist sectors including aircraft and space technologies, telecommunication, nuclear reactions, power plants and other transport equipment (railways and railway equipment). Besides France has hold relative advantages in other classes dominated by large private French firms (share of more than 55%) as bleaching and dyeing, plastic and rubber products and inorganic chemicals. Finally we have underlined some classes in which French technological specializations lie on large firms as well as other firms (large foreign firms and other firms), namely the classes of metal treatment, drugs and general non-electrical industrial equipment.

[6] See the methodological Appendix I.

However during the eighties and nineties French organizations have witnessed deep changes in their economic, financial, industrial and political environment. The arrival of Mitterrand in power translated into a wave of nationalizations in 1982 in several manufacturing sectors as electronics, power equipment, aluminum making, pharmaceuticals and chemicals as well as in some financial organizations (Common Government Program). These programs concerned large firms such as Thomson, CGE, Saint Gobain (building materials), Pechiney-Ugine-Kuhlmann (aluminium), Rhone Poulenc and large French banks as Compagnie Financière de Paris, Compagnie Financière de Suez as well as the Government shareholding in Matra, Dassault Aviation or Roussel Uclaf. At the beginning of the eighties French state sector accounts for almost one third of the employment and one fourth of the turnover of the national industry and exports (Larousse Encyclopedia). However the budgetary restrictions led French government to give up most of the reforms and sectoral plans, and to gradually privatize the firms that have been nationalized in 1982.

The withdrawal of French government has progressively ended the competitive devaluation and expansionist policies, the public procurement or the subsidized loans. The French and international environment have led to a competitiveness crisis of large French firms that where, partly given their Fordist organization, ill-equipped to compete at the international level. This new environment and constraints led to an internal restructuring process that has, according to Amable and Hancké (2001), Goyer (2001) and Hancké (2001), been conducted by large French firms. It mainly entailed a greater autonomy from the State, a decrease in unions' power, a reorganization of work and workers skills and the transformation of industrial relations with suppliers and subcontractors. The modernization of supplier network was mainly achieved through the implementation of just-in-time system, and an upgrade of suppliers technological and organizational capabilities organized with state and regional institutional resources. These latter resources includes schools and training programs, regional technical universities, CRITT (regional centres for innovation and technology transfer), local employment and development agencies and the Ministry of Industry's regional offices.

Regarding the public research system, the status of state and administrative institutions have been changed to EPST [7] (Scientific and technological Government-funded research organizations as CNRS (National Center for Scientific Research), INRIA (research institute in computer science), INSERM (health and medical research) or EPIC (Commercial and industrial Government-funded research organizations as CEA (nuclear power), CNES (space), ONERA (aerospace), IFP (hydrocarbons)…). These new status allow the centres to form subsidiaries and to cooperate on specific projects with scientific and industrial partners within public interest group (created in 1982) or scientific interest group (created in 1996). The interest groups have been implemented notably to favor the exploitation of French government research results.

Despite these changes the technological specialization pattern of French organizations has remained quite stable. In the following sections we explore the determinants of this stability. Given the stable technological specializations of France (see Table 2) we focus on three French-specific historical and institutional factors namely the persisting, although decreasing, importance of the State, the prevailing role of large firms in research and research activities

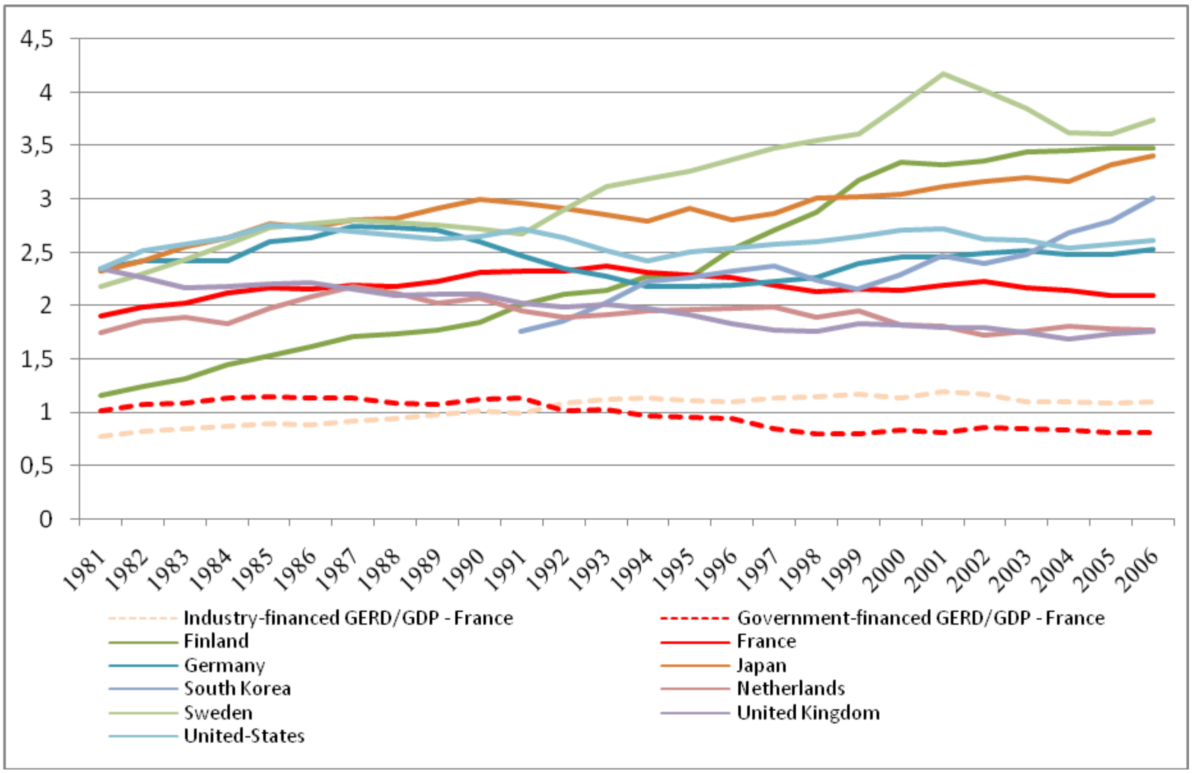
[7] Law on research orientation, JORF 1982.

and the role of the élite system from the Grandes Ecoles in the design and the orientation of research and innovative activities of large state and private firms.

3. The gradual retreat of the French State from innovative and industrial activities

In this section we focus on the evolution of the pattern of the public research funding between the eighties and the mid 2000s. The Figure 1 shows that the French R&D effort has increased over the whole period, although it has started declining since the mid-1990s. By the mid-2000s, as in United-Kingdom, it has remained below several OECD countries and below the Barcelona objective of 3%; revealing the relative low commitment of France in the funding of research and innovation activities. The figure also reveals that in the beginning of the nineties the industry effort has overcome higher than the Government's effort in R&D funding. By mid-1990, more than 50% of the researchers operate in the public sector while the private sector researchers account for only 45% of the total number of researchers. In 2007, these proportions are inverted notably because of a more pronounced increase in the private sector that account for about 56% of total researchers (full time equivalent, OST 2010).

Figure 1. R&D funding as a percentage of GDP



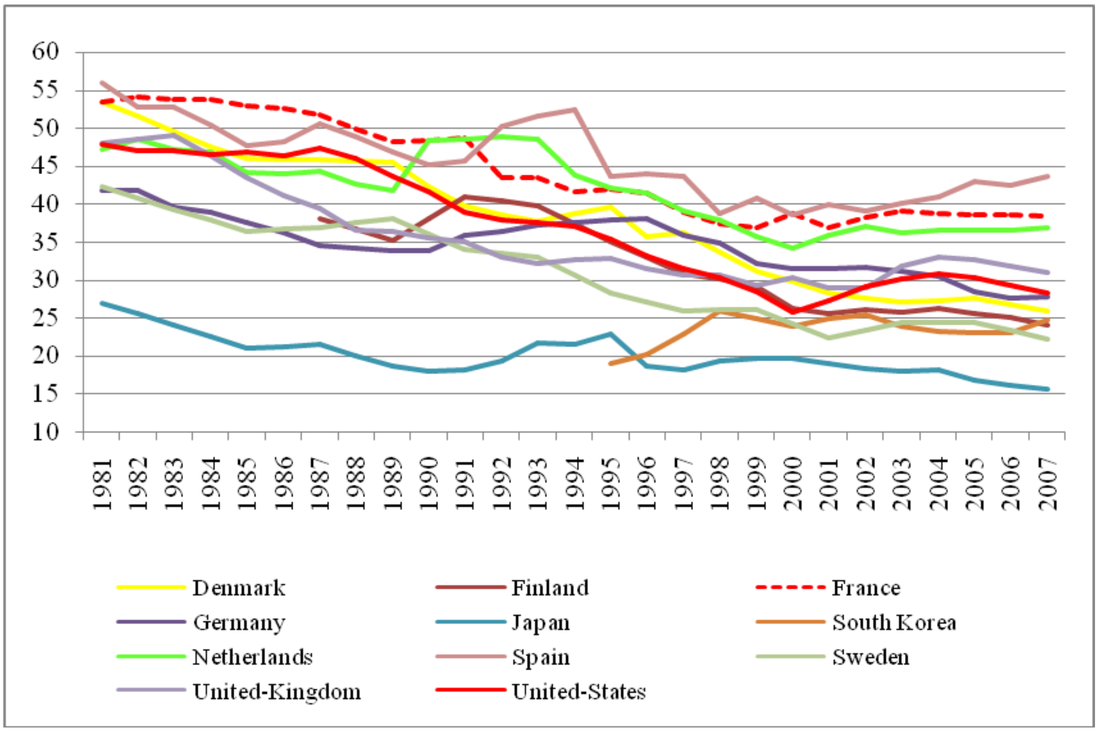
Graph made from Main Science and Technology Indicators 2010, OECD database.

The analysis of the distribution of national expenditure on R&D[8] (all French or foreign firms performing R&D in France) between business and administration sectors (government, higher education and non-profit organizations) shows that the share of administration sector has been decreasing since the beginning of the nineties (from 51.3% in 1992 to 43.7% in 2002).

[8] Figures from « Bureau des etudes et recherches statistiques sur la recherche ». 1992 is the 1st year available.

However the figure below reveals that the government share, although decreasing as in most innovative countries has remained quite high as compared to other selected countries. Although the goal of the two third of R&D funded by industry has not been achieved by the mid-2000s, the ratio of administrations share to business share tends to be stable in the 2000s. In terms of GERD (gross expenditures on R&D) and within the administration sector the share of the State has gradually decreased since the last two decades, especially in the defense sector (from 20.4% in 1992 to 6.1% in 2007). On the contrary in the civil sectors, the EPSTs performed share (CNRS and Institutes excluded) have slightly increased. The most important increased has been operated in Universities which now account for more than 30% of the R&D performed by administration sector (against 22% in 1992). Given that French Universities remain in their majority state organizations and that the EPIC's RD expenditure is included in business expenditure the weight of the French Government appears to be underestimated. Therefore although it has reduced its commitment, the French government remains a major actor in the performance of R&D notably through the EPST, the EPIC and the Universities.

Figure 2. GERD financed by Government (%) – International comparisons



Graph elaborated with the data of the OECD, Main Science and Technology Indicators 2010.

Although it has been decreasing during the nineties, the Government direct funding of BERD (Business expenditures on R&D) tends to be stable since 1998[9] (around 10%). Moreover it has remained quite high, and has overcome since the beginning of 2000s the US Government funding of BERD (MSTI, OECD 2010). During the nineties Government funding remained[10]

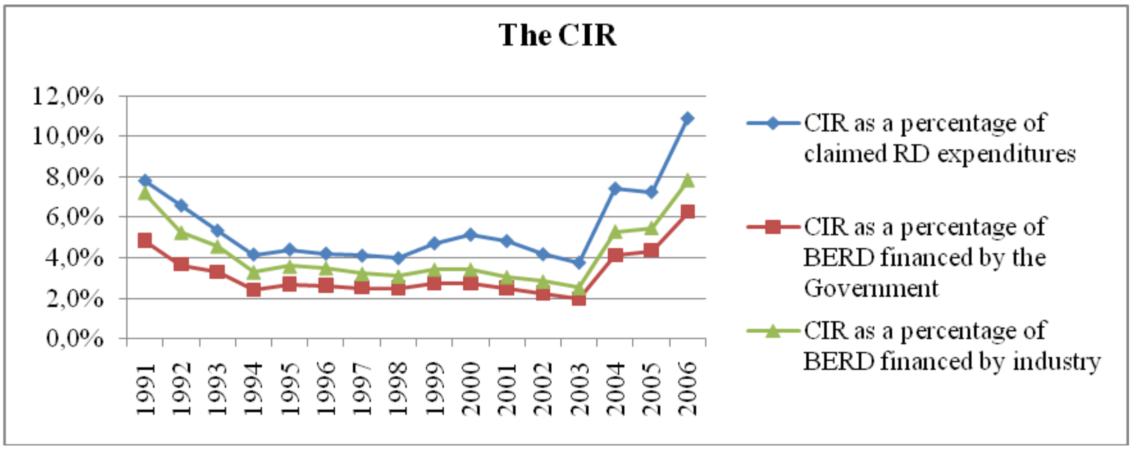
[9] OECD MSTI 2010-1. Government funding of BERD includes contracts with Government administration and Government incentive credits, CIR (tax research credit) excluded. Funding from government firms are not included as they are already taken into account in Industry funding.

[10] The data are taken from the Bureau des etudes et de la recherche statistiques sur la recherche

highly concentrated notably in four industries including space and aeronautics (42% in 2001, 36% in 1997), medical, precision and optical instruments (15.8% en 2001, 26.9% en 1997), radio, television and communication equipment (13,8% en 2001, 14,1% en 1997) and manufacture of machines and equipments (13.1% in 2001). Regarding the large programs most of them have disappeared or have been considerably cut down as in aeronautics during the nineties. In 2006, they account only for 21% of R&D budgetary credit allocations and for 17% in 2008. They are concentrated on space technologies (that accounts for more than 50%[11] of allocation to large programs), power and aeronautics (the Appendix 3 present a summary of the current large programs).

Besides the research performed and the direct funding the French government also provides an indirect support for R&D and innovation. One of the major instruments of French tax support, the CIR (research tax credit) has recently known continuous changes regarding its rates, its upper threshold, and eligible expenditures. In 2004, the CIR is based on the increase of R&D expenditures (45% in 2004, 40% in 2006) and the claimed volume of R&D expenditures (5% in 2004, 10% in 2006). In 2008, the CIR is based on the claimed volume of R&D expenditures. It is equal to 50 % of R&D expenditures up to 100 million of euros. By 2010, the rate has been decreased to 30% given the high cost of the measure. After a strong decrease in the early nineties the CIR has been stable for more than 10 years, representing more than 4% of BERD financed by Government and about 3% of BERD financed by firms. During the nineties its share has been quite low regarding the declared R&D spending. However the strong increase observed after 2004 comes from the rise of the upper threshold and the consideration of R&D expenditures. Before 2004, the CIR was mainly based on the average of the increase of R&D spending in the last two years..

Figure 3. the evolution of CIR (tax research credit)



Personal elaboration from Bilan du *CIR au titre de l'année 2006*. BERD values are taken from the Bureau des études statistiques sur la recherche, Research and Higher Education Ministry.

This support is mainly received by SMEs that account for almost 80% of the total beneficiary firms in 2006. They received 42% of the CIR for 20% of claimed expenditure. Within the manufacturing industry the first beneficiaries sectors are the electronics and electrical industry, aeronautics, pharmaceuticals and chemicals. These industries (except electronics

[11] Data from Bureau des Etudes Statistiques sur la recherche.

industry) are related to the stable technological strengths of France as shown in the previous sections. In these expenditures, staff expenses (researchers and technicians allocated to R&D) and operating costs (75 % of staff expenses) account for more than 75% of the total claimed expenditures.

The recognition of the importance of SMEs in terms for the economic development as led the French Government to develop several other funding measures to promote research and innovation activities. At the beginning of the eighties several reforms implying the deregulation of fees related to stock market and the creation of the Second Marché have been implemented to increase funding sources of SMEs. However only large firms have benefit from these reforms as few SMEs were eligible mainly because of required standards in terms of information and the related costs (Cieply 2001). Between 1985 and 1995 several international, national, regional or local organizations dedicated to SMEs were implemented. However their scope remains quite limited, and most of them have for long remained focused on few regions as Ile de France, large cities as well as on few areas and projects. They were not of a sufficient size in terms of funding resources to decrease significantly the existing gap between large firms and SMEs. Since the mid-1990s new initiatives have been developed such as an increase funding of regional councils through loans to medium and low growth firms and an increase funding from non-profit venture capital organizations. They also implied the creation of the nouveau marché in 1996 dedicated to young and high growth potential firms with a high level of risk and strong investments needs. The BDPME (development banks for SMEs), created from the merger of CEPME (loans for equipment) and the French company of risk insurance, provide SMEs with long term loans or joint loans with classical banks.

At the beginning of the nineties the French Government still owned majority shareholding in several large firms in sectors such as the aeronautics (Aérospatiale, Snecma), the car industry (Renault), the chemicals (Rhone Poulenc) or the steel industry (Usinor-Sacilor). Many former nationalized French firms were privatized or have seen the Government shareholding gradually decreased. Also the number of firms controlled by the Government has decreased by one thousand from 2500 in 1996 to 1600 in 2002 (Recme[12]). However in 2002 the Government still owns a majority shareholding in firms such as Thomson SA, COGEMA, SOFRATOME, Framatome ANP, Compagnie Française des Mines, Charbonnages de France, SNECMA, Labinal and in other financial and non-financial services. Moreover it also kept a high shareholding in major French firms as France Telecom, Gaz de France, Alstom, Renault or Thalès. Since 2004, all the shares of Government are managed by the APE (French Government shareholding agency). The agency represents the Government in general shareholders' meeting. The table 4 below provides the government shareholding in the quoted companies in 2003, 2004 and 2005.

[12] Database from INSEE (French national statistical office).

Table 4. Evolution of Government shareholding in quoted companies between 2003 and 2005

Quoted Companies	Sector	Government Share in 2003	Government Share in 2004	Government Share in 2005
Air France (1)	Air Transport	54%	44,6%	18,5% (Air France-KLM)
APRR	Motorways exploitation	al.	al.	70,1%
Alcan	Aluminium	0,10%	0%	al.
Alstom	Railway transport and power production equipment	np.	21,40%	21,1%
Arcelor	Steel industry	0	0%	al.
ASF	Transport Infrastructure	50,4%	50,3%	50,4%
Bull	Computers	16,3	3,5%	Np
CNP	Insurance	1,2%	1,2%	al.
EADS (1-3)	Aeronautics-Space	15,1%	15,1%	15,1%
France Télécom (4)	Telecommunication	58,7%	42,2%	34,92
Gaz de France	Gaz	al.	al.	82,5%
Renault	Cars	16,6%	15,6%	15,6%
Safran	Aeronautics- Space	al.	al.	36,0%
Sanef	Transport Infrastructure	al.	al.	75,6%
Snecma	Aeronautics (Engines)	np.	65,7%	Groupe Safran
Thalès (5)	Aeronautics- Space (electronic systems)	31,3%	31,3%	31,3%
Thomson	Electronics	20,9%	2%	2,04%

Source: Personal table established from reports on *L'Etat Actionnaire* (Government shareholding in companies) 2004,2005 of APE (French Government Shareholding Agency)

np: non-provided (but companies on the list)

al: absent of the list (maybe no more quoted or withdrawal of the Government)

(1) included free stocks of shares for employees

(2) Some shares are own by ADF

(3) Greatest share is own via SOGEADE

(4) Included shares own by ERAP (5) Owned by Thomson SA

Finally the French Government has also been very active in protecting French firms from takeover attempts (e.g. Danone, 2005) notably by favoring specific partners for the mergers (Sanofi-Synthélabo and the German Adventis). Besides the Government also, as in Alstom case in 2004, may enter as a temporary shareholder to help in the restructuring process of the company. However in Alstom case the issues go beyond France as the company has some 110 000 employees across 70 countries including 62 000 over Europe.

In the last two decades we have witnessed a progressive, although sometimes partial, withdrawal of the Government from large firms' shareholding. Regarding the R&D funding the Government reduced commitment has not been compensated by the private sector increased funding, thus leading to a relatively low national effort of R&D. Moreover the French state has remained very active in the traditional areas of technological specialization, e.g. nuclear power, space and aeronautics, and has kept a majority or significant shares in companies operating in these sectors. In the next section we focus on the main structural changes in French large firms and we discuss their importance in the overall research and innovative activities.

4. The persisting leadership of restructured large French firms in research and innovation activities.

Between the eighties and the early 2000s, the withdrawal of French State has been gradual and partial. It has taken place mostly in favor of large firms. Over the period 1987-2005 six sectors, typically dominated by few large firms, accounts for almost 75% of R&D spending (Motor vehicles, Pharmaceuticals, Space and aeronautics, Basic chemicals and Radio, television and communication equipment and apparatus, Medical, precision and optical instruments). In addition the Table 5 below confirms that these R&D expenditures are highly concentrated within large firms. The firms of more than 5000 employees perform more than 40% of R&D while they account only for 1% of firms or organizations in the beginning of 2000. In 2003, they still account for one third of R&D spending. In 2000, they receive more than 41% of public funding while small firms (less than 1000 employees) that account for more than 90% of firms receive only 15% of the Government funding. Since 2003 the decrease in the share of R&D expenditures of large firms has taken place in favor of less than 500 employees firms that performed 11% of R&D in 2002. In 2005 these latter firms accounted for almost 28% of R&D expenditure. The cut down in Government funding to large firms (more than 5000 employees) has benefited to firms of more than 2000 employees (but less than 5000) which received more than 40% of Government funding in 2004. However Government funding for SMEs' R&D is still limited as well as their spending in research activities. Indeed if we consider firms of more than 500 employees (1000 employees) Government funding accounts for only 11% (15%) in 2000 and 16% (19%) of total Government funding in 2004.

Table 5: Concentration of R&D expenditures by firm size (2000-2005)

Total employees (full time equivalent)	2000					2001					2002				
	% of firms or organizations	Gross RD expenditures		Public funding		% of firms or organizations	Gross RD expenditures		Public funding		% of firms or organizations	Gross RD expenditures		Public funding	
		M€	% total	M€	% total		M€	% total	M€	% total		M€	% total	M€	% total
< 500	86,3%	3 933	20,3%	248	11,0%	**87,7%**	4 378	21,1%	273	12,9%	**88%**	4 722	22%	285	11%
[500 ; 1 000[	6,8%	1 744	9,0%	91	4,0%	**5,9%**	1 890	9,1%	98	4,6%	**6%**	2 330	11%	154	6%
[1 000 ; 2 000[	3,6%	2 291	11,8%	52	2,3%	**3,2%**	1 651	7,9%	39	1,9%	**3%**	2 082	10%	174	7%
[2 000 ; 5 000[	2,1%	3 416	17,7%	834	36,9%	**2,2%**	4 418	21,3%	558	26,5%	**2%**	4 115	19%	417	17%
≥ 5 000	1,2%	7 964	41,2%	1036	45,8%	**0,9%**	8 446	40,6%	1142	54,1%	**1%**	8 590	39%	1468	59%
All firms	100%	19 348	100%	2259	100%	**100%**	20 782	100%	2110	100%	**100%**	21 839	100%	2498	100%

Total employees (full time equivalent)	2003					2004*					2005				
	% of firms or organizations	Gross RD expenditures		Public funding		% of firms or organizations	Gross RD expenditures		Public funding		% of firms or organizations	Gross RD expenditures		Public funding	
		M€	% total	M€	% total		M€	% total	M€	% total		M€	%total	M€	% total
< 500	90%	5 290	24%	405	17%	90%	5 641	25%	418	16%	88%	6 732	28%	390	15%
[500 ; 1 000[	5%	2 173	10%	86	4%	5%	2 153	10%	67	3%	6%	2 100	9%	74	3%
[1 000 ; 2 000[	3%	2 047	9%	310	13%	3%	2 747	12%	310	12%	4%	2 847	12%	273	11%
[2 000 ; 5 000[	2%	4 323	20%	770	32%	1%	4 069	18%	1 148	44%	2%	3 406	14%	1 027	40%
≥ 5 000	1%	7 812	36%	873	36%	1%	7 914	35%	676	26%	1%	8 825	37%	804	31%
All firms	100%	21 646	100%	2444	100%	100%	22 523	100%	2 619	100 %	100%	23 911	100%	2 567	100%

Elaborations based on the data of Bureau des Etudes Statistiques sur la recherche -chiffres- La R&D dans les entreprises- Taille des entreprises exécutant la R&D » (French statistical office for the studies on R&D). M€ stands for millions of euros - Methodological Change in 2004.

The withdrawal of French Government has come up with the transformations of the structure, the strategies and the corporate governance of French large firms.

Regarding the shareholding structure the retreat of the French State has favored the development of system of cross-shareholdings (Morin 1996, Goldstein 1996, Morin and Rigamonti 2002) organized around a hard or stable core of organizations. It represents a coalition of shareholders tied through temporary and defined cross-ownership (Morin 1996). Such a model qualified of financial core results from the establishment of capital-based alliances between large financial and industrial groups. According to Morin and Rigamonti (2002) these alliances have enable large groups to control the coordination of the resources and the evolution of industrial structures. This model has peaked after the second wave of privatizations in the nineties. On the one hand it reflects the desire of large quoted French firms to control their shareholding structure in order to protect the groups and their ruling staff from takeovers. According to Goldstein (1996) the establishment of such a system has also been favored by the desire of policy makers to preserve the stability of the control after the privatization process. On the other hand it also enabled large groups to ensure necessary resources for their development; thus shaping the frame of economic regulation of their funding sources and the restructuring required for their growth. The banks appear as central actors in this system organized around three poles. The first pole is organized around the Société Générale, the AGF and Paribas and includes large firms as Rhône Poulenc, Schneider, Total and Alcatel Alsthom. The second pole relies on BNP and the Compagnie financière de Suez, and includes large firms as Saint Gobain and Elf Aquitaine. The last pole includes Axa and UAP that own shares in the two other poles.

Besides this specific shareholding system, the composition of the board of directors that mirror them led to the concentration of strategic information, and thus a great influence power on the large groups and the related industrial structures, into the hands of few managers (Goldstein 1996, Morin and Rigamonti 2002). The members of the board of directors generally present a common academic and professional path and the job market for directors in France is the same for both state and private firms. They have often achieved their academic studies within the same schools and their careers in government departments followed by higher positions in the state and private firms. One particularly well-known feature of the French capitalism rests on the central role of élites from the highly selective Grandes Ecoles that provide education for the future chief executives and the Grands Corps[13] of the State (Chesnais 1993, Coriat and Taddei 1993, Golstein 1996, Morin 1996, Hancké 2002, Cytermann 2007). This stable group of higher Education schools (names in 2010) includes schools as Ecole Polytechnique, Ecole *Nationale d'Administration, Ecole des* Mines-Paris Tech, Ecole Centrale-Paris, Supélec-Gif sur Yvette, Télécom Paris Tech, Ecole

[13] The Grands Corps consists in State bodies of higher civil servants that recruit mainly through the ENA (Ecole Nationale d'Administration) and the technical Grands Corps. Historically we distinguish five Grands Corps that have been established during the 18th and the 19th century and include Corps des Ponts et Chaussées (bridge and roads), le Corps des Mines (mines), le Conseil d'État (State council), la Cour des comptes (revenue court), l'Inspection générale des finances (auditing department of Treasury). G16 list gathers the associations that represent civil bodies of higher civil servants is available on
http://www.hautefonctionpublique.org/g16/index.html .

des Ponts Paris Tech-Marne la Vallée, ISAE Toulouse (former Supaero). Technical bodies recruit mainly through Ecole Polytechnique or the X. This persistence in the ruling class rest on a common historical feature within schools, the network of formers students that fully works in France and have reproduced itself over centuries. They give students from these schools a privileged access (full directory[14]) to the relevant information on former students. This system also rested on premium partnerships between the Grandes Ecoles and large firms that often recruit before graduation and provide subsidies to the schools or the student associations. On the contrary and compared to the Grandes Ecoles the Universities which are for most not selective (at least for the 1st cycle) have only few relationships with firms. Thus programs are not suitable for industry needs. The selection process of directors also contributes to make the transfer of large firms' control harder. The privatization has not affected this social recruiting dynamics. On the contrary they have grafted themselves on this élite system, and have fostered with capital relationships their central position and their independence from the State capital and takeovers. The élite system has been reproduced outside the State frontiers (Hancké 2002).

However after the mid-1990s the emergence, the affirmation of French and foreign institutional investors in large firms' capital has weakened the financial core model. These changes in the cross-shareholding system is due to an increasing international dimension in the design of strategies, to the weakening of major financial actors as UAP, Suez or Paribas and also to growing complains from the foreign institutional investors. The shareholding of institutional investors as Anglo-Saxon pension funds has gradually moved the objectives towards the creation of value for the shareholder, financial profitability that come with a a posteriori and incentives-based control. This decline according to Morin and Rigamonti could partly be explained by the choices of UAP Axa and the Crédit Lyonnais to limit their shareholding to Paribas, BNP and CGE for the former and in Suez and the Lyonnaise for the latter. These operations have also allowed large firms to finance their international development.

These changes in the shareholding structure have come with a range of mergers, acquisitions and sales of activities that have modified the structure of groups as well as their strategic orientations. Facing an increasing international competition the large French firms have further focused on their strategic activities, and have proceeded to various mergers and acquisitions. The CGE, later Alcatel Alsthom and then Alcatel, has gradually focused its activities on telecommunication equipments. Between 1996 and 1999 Alcatel sold some of its activities or cut down its shareholding in several activities that included for instance the divisions of nuclear power (Framatome), transport, trains, heavy engineering equipment (GEC Alsthom) and shipbuilding. The changes in the firms' frontiers have continued in the 2000s notably with the more recent merger that led to the formation of Alcatel-Lucent (2006). Thomson also narrows its set of activities. It acquired CGE electronics activities and sold its telecommunication activities to CGE. In 1992, Thomson is committed only in three sectors namely the professional electronics (Thomson Consumer Electronics), the defense electronics

[14] Public directory only provides the name, the degree and the year of graduation.

(Thomson-CSF[15]) and the home appliances (Thomson Electroménager). The major sales have concerned the retreat from civil telecommunication and from medical activities in the eighties. These latter activities have been sold to General Electric which has also sold its electronics activities to Thomson. Thomson's semiconductors activity has been merged with the Italian firm IRI-Finmeccanica leading to the formation of SGSThomson in 1987, later ST Microelectronics (1998). Between 1987 and 1996 Thomson CSF has followed an external growth strategy by acquiring the defense electronics activities of Phillips in 1989 and has taken over Sextant Avionique (former avionics activities of Thomson-CSF and Aerospatiale). Thomson CSF that became Thalès[16] in 2000 has taken over the British Racal Electronics.
In the chemicals industry Rhone Poulenc has also proceeded to an important number of sales and acquisitions, and has focused its activities on pharmaceuticals, agrochemicals and fine chemicals activities (Cantwell and Kotecha 1997). Between 1986 and 1996 the firm has acquired the agrochemicals activities of the US companies, Union Carbide and GAF SSC (chemicals). In 1991, Rhone Poulenc bought the pharmaceuticals company Rorer (Rhone Poulenc Rorer). According to Cantwell and Kotecha (1997) the strategy pursued by Rhone Poulenc was part of a large restructuring of State chemicals industry, which has been designed to solve structural problems faced by the company. These problems were partially due to the conglomerate strategy of the company. Despite its size, Rhone Poulenc was not particularly strong in one field (see Cantwell and Kotecha, 1997). In 1994 Rhone Poulenc also acquired shares in Rhône Merieux[17] (animals' biology and animals' health activities). In 1997 Merial was formed through the merger of the animal health businesses of Merck and Co., Inc. and Rhone Merieux. Between 1996 and 1999 Rhone Poulenc sold its speciality chemicals (Rhodia[18]), bulk chemicals as well as fibers and polymers activities (Goyer 2001). Goyer (2001, p 147) provides the core activities and the peripheral business sold between 1996 and 1999 by large French firms as Alcatel, Danone, Elf, Paribas, Pechiney, Rhone Poulenc, Suez-Lyonnaise des Eaux, Vivendi and Saint Gobain.

Overall large French firms have tended to abandon their conglomerate growth strategies whereby corporate development has mainly relied on the extension of existing resources into related areas (Chandler 1962). The case of large French firms tends to confirm the works of Whittington et al. (1999) on European firms on an earlier period (1970 and 1993, United Kingdom, France and Germany) suggesting that conglomerate is a relatively transient phenomenon[19]. Indeed the work of Goyer shows that between 1982 and 1998 the contributions to net sales and the contributions to operating income of the first two activities of the top 44 large French firms (financial firms excluded) have been increasing respectively from 35% in 1982 to 69% in 1998 and from 39% in 1982 87% in 1998. This process of

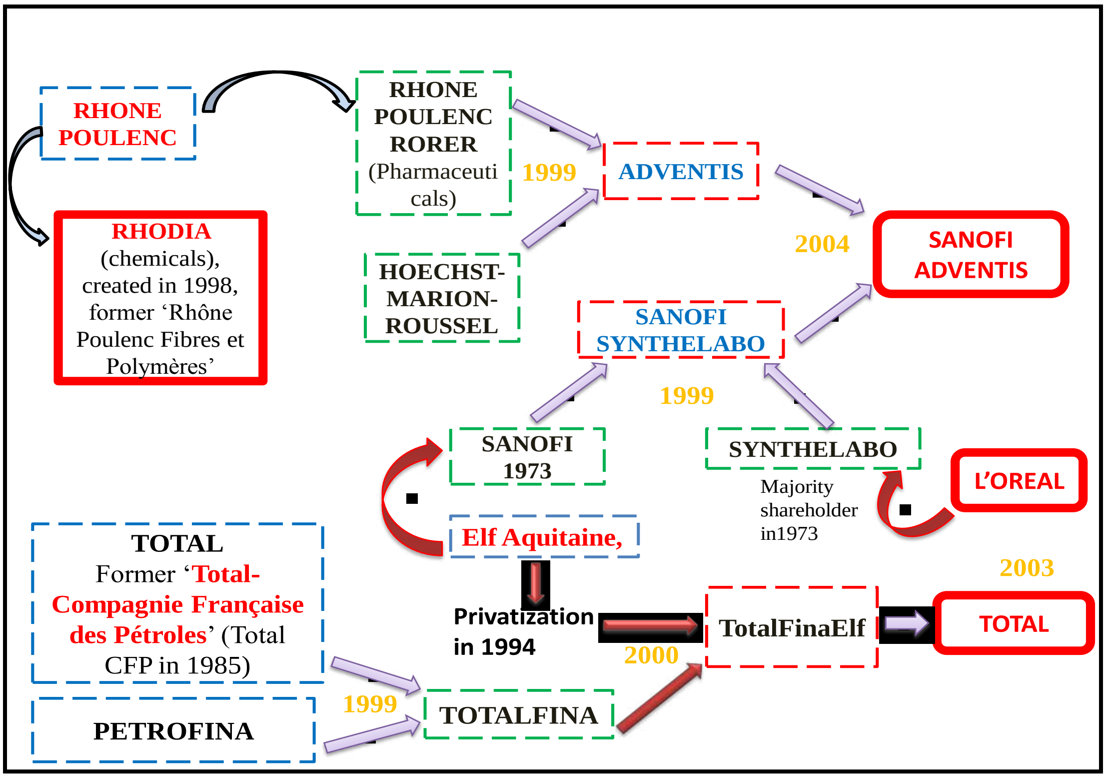
[15] Thomson-CSF comes from the merger of electronics activities of Thomson-Brandt, former Compagnie Française Thomson-Houston-Hotchkiss-Brandt, with the Compagnie Générale de Télégraphie Sans Fil (CSF) in the sixties.
[16] Detailed stories of mergers and acquisition available in the 2000 reference document of Thales.
[17]Detailed chronology available at http://fr.merial.com/company_history/index.asp
[18] Rhodia's Reference document 2007: the organization and the current name of Rhodia date back to January, the 1st 1998, and come from a range of restructuring operations led by Rhone Poulenc and its subsidiaries.
[19] It is important to underline, relying on Kay's paper (2002) which reinterprets the results of Whittington et al among others, that we do not deny the fact that conglomerate may be a more persistent strategy. However, the data on French large firms suggest that this conglomerate strategy has been unstable in France as well shown by the case of Rhone Poulenc.

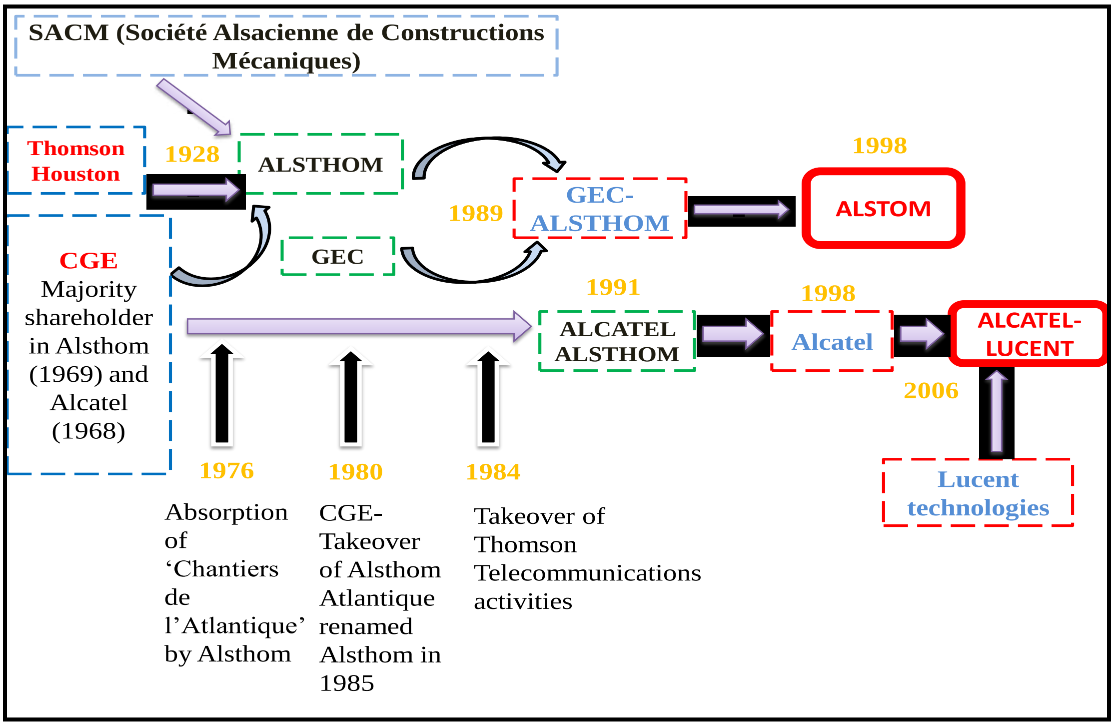
external growth has come together with an increased internationalization of French large firms' technological activities (Cantwell and Kotecha 1997). According to the authors it reflects the effects of international acquisitions, that once achieved, have led to a transfer of patents granted from the subsidiary to the parent company. This external growth-based strategy mainly reflected the firms' decisions to increase, to focus their capabilities, and to become more competitive in their fields of comparative advantage. The large French firms have employed these strategies to favor the replication of their model of specialization rather than developing new fields of competencies.

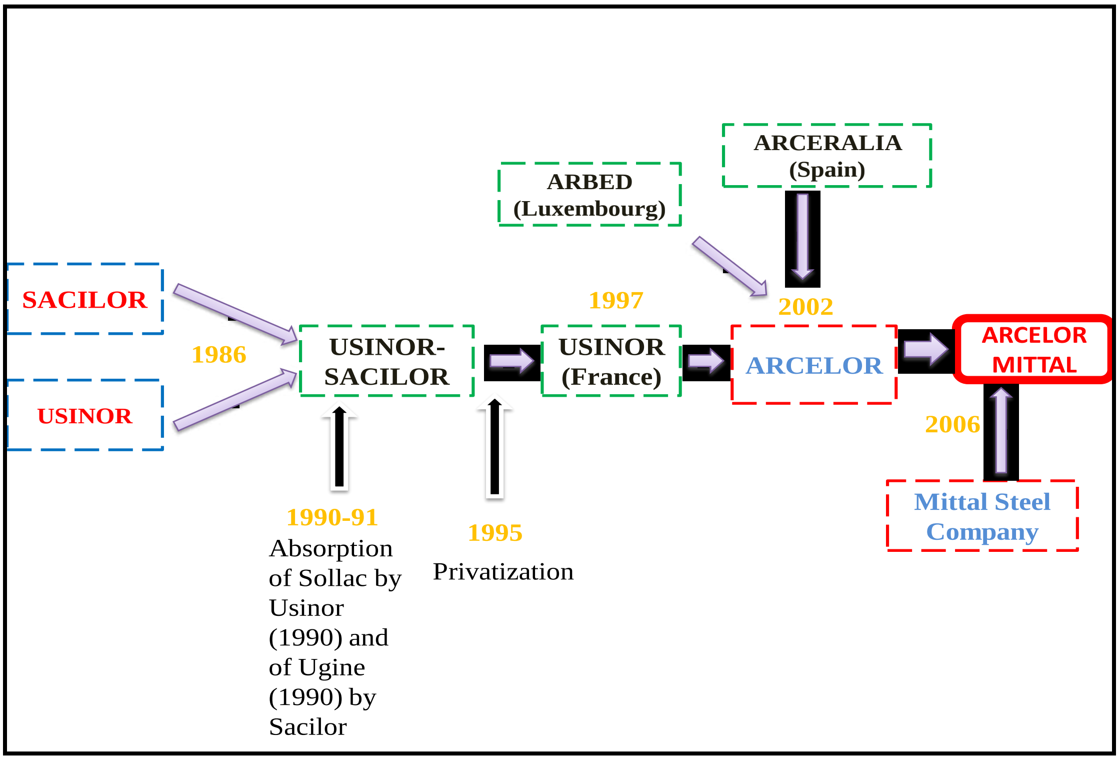
In the figures below we have attempted to map the most important features of the trajectory of former French national champions that have now become international champions. These figures are based the annual companies' reports, the compilation of public information available on the companies' web sites and several other official sources.

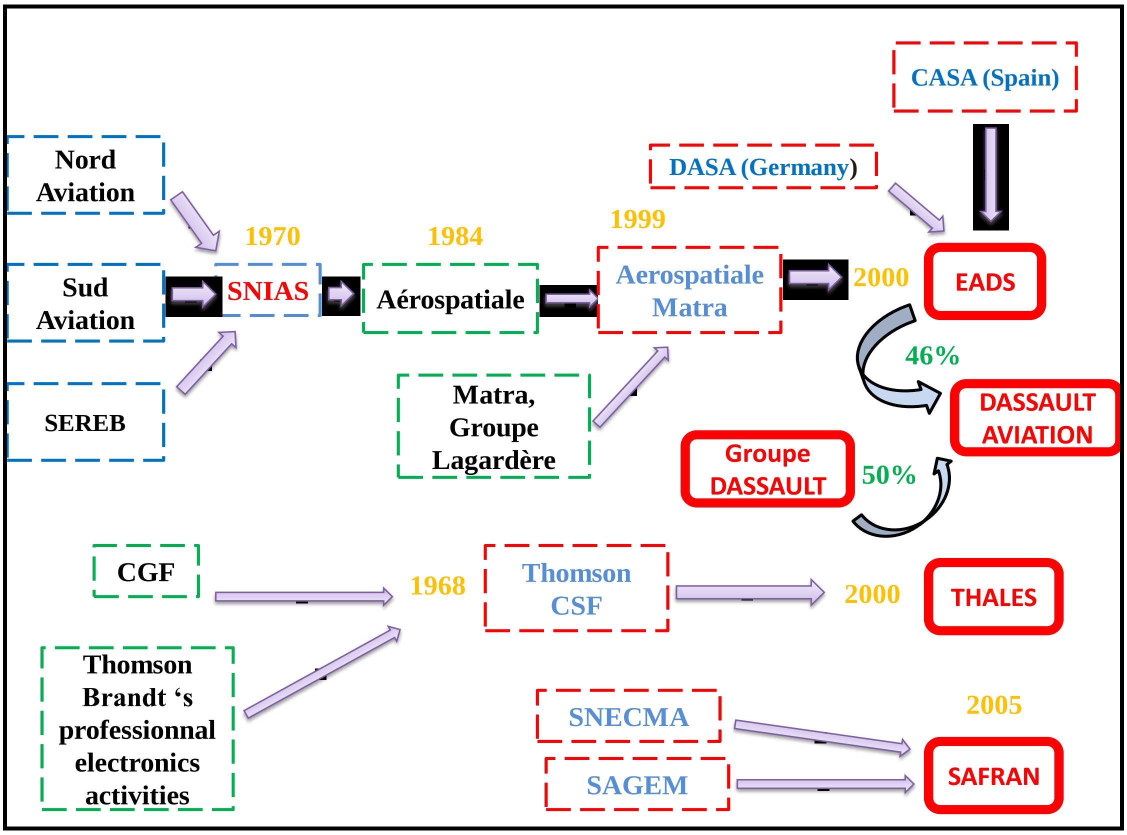
Figure 4. From French national champions to international champions

Personal Elaborations




SACM (Société Alsacienne de Constructions Mécaniques)
Thomson Houston
1928
ALSTHOM
CGE
Majority shareholder in Alsthom (1969) and Alcatel (1968)
GEC
1989
GEC-ALSTHOM
1998
ALSTOM
1991
ALCATEL ALSTHOM
1998
Alcatel
ALCATEL-LUCENT
2006
Lucent technologies
1976
1980
1984
Absorption of 'Chantiers de l'Atlantique' by Alsthom
CGE-Takeover of Alsthom Atlantique renamed Alsthom in 1985
Takeover of Thomson Telecommunications activities


ARCERALIA (Spain)
ARBED (Luxembourg)
SACILOR
USINOR
1986
USINOR-SACILOR
1997
USINOR (France)
2002
ARCELOR
ARCELOR MITTAL
2006
Mittal Steel Company
1990-91
Absorption of Sollac by Usinor (1990) and of Ugine (1990) by Sacilor
1995
Privatization



Curved arrows represent a relation of total or partial ownership. For instance, in the graph right above EADS owns 46% of Dassault Aviation and the Groupe Dassault owns 50% of Dassault Aviation.

5. Conclusion

The stability of French organizations' technological patterns reflects their persisting specialization in three kinds of technologies. The Colbertist technological fields include aeronautics and space technologies, telecommunication, nuclear reactions and power plants and other transport equipment (railways and railway equipment). Besides France has also maintained its relative strengths in technologies dominated by large private firms (bleaching and dyeing, plastic and rubber products and inorganic chemicals) as well as technologies in which large firms and other firms (large foreign firms and other firms) have been identified by Patel and Pavitt (1990) as the main patent holders (metal treatment, drugs and general non-electrical industrial equipment). In the light of the observed persistence of France's technological specialization pattern, our paper has suggested that, it is like nothing has changed, and this although the deep structural changes that have occurred in French large firms, their environment and the gradual retreat of the State from research as well as economic activities. Our study argues that the relative high, although decreasing, commitment of the French State and the replication of initial technological advantages by large French firms through a further focus on their strategic activities and a range of mergers and acquisitions have favored the persistence of French technological strengths. These structural changes have come with a further internationalization of French large firms' technological activities, thus leading to the emergence of international champions in several sectors in which French has maintained its relative strengths (pharmaceuticals, telecommunications metallurgical and metal treatment and aeronautics). In a nutshell rather than developing new areas of expertise, large French firms have abandoned their initial conglomerate strategies whereby corporate development was pursued through further diversification in related areas (Chandler 1962). Thus, as suggested by Whittington et al. 1999), and in the case of French large firms it seems that conglomerate strategies have been relatively unstable. Then the paper goes on by arguing that the persistent role of the élites from the Grandes Ecoles, in tight relationships with the State administrators notably given their common academic paths, may also have favored the large firms that have, at least till the mid-2000s, remained the most important beneficiaries of the public funding for research, and have kept a prevailing role in the technological development in France.

However during the last decade the French government has improved and issued several measures directed towards SMEs. Among them the major tax incentive, the research tax credit or CIR has been continuously reinforced and is now based only on the volume rather than the increase in firms R&D expenditures. Although it remains quite limited as compared to the overall business expenditures in R&D, SMEs represent the vast majority of beneficiaries. In addition several venture capital related measures have been implemented or encouraged. However, so far it has only lead to a limited increase in their research expenditures. Besides French large organizations are now facing an increasing international competition notably in some of its main fields of relative strengths (electricity, nuclear power, other transport equipments, etc). Indeed the State is pursuing its gradual retreat from several large firms

(EDF, Gaz de France, Areva). Moreover the French government has initiated, although with some lag, several programs in fast-growing fields as biotechnology or nanotechnology, and has recently further moved towards a more systemic approach in the innovation policy design and implementation. Although the French innovation system is still affected by its traditional mission-oriented structures this turn is very likely to affect the stability of the French traditional model of specialization in the long run. However at the political level the result of these changes will depend, among others, on the coherence and the stability of the recent French innovation policy, the development of SMEs innovative activities as well as the future strategies of French large firms.

References

Abi-Saab P., M. Bonneau and Favre F. (2003), "Dépenses de recherche et Développement en France en 2001, premières estimations pour 2002", Note de recherche 04.02, de la Direction de l'Evaluation et de la Prospective (DEP), Ministère de la Jeunesse, de l'Education et de la Recherche.

Acs Z.J. and D.B. Audretsch (1989), "Patent as a measure of innovative activity", Kyklos, volume 42, Fasc 2, p. 171-180.

Amable B. and B. Hancké (2001), "Innovation and Industrial renewal in France in comparative perspective", Industry and Innovation, volume 8, n° 2, p. 113-133.

Amable B., R. Barre and R. Boyer (1997), *Les systèmes d'innovation à l'ère de la* globalisation , Economica, France.

APE (Agence des Participations de l'Etat) (2005), *L'*Etat actionnaire: rapport 2004, Bibliothèque des rapports publics de la Documentation française. Available on http://lesrapports.ladocumentationfrancaise.fr/BRP/044000533/0000.pdf

Archibugi D., J. Howells and J. Michie (1999), Innovation Policy in a Global Economy, Cambridge University Press, United Kingdom.

Arthur W.B. (1989), "Competing Technologies, Increasing Returns and Lock-in by Historical Events", Economic Journal, 99, 106-131**.**

Arthur W.B. (1990), "Positive Feedbacks in the Economy." Scientific American, 262, 92-99.

Balassa B. (1965), "Trade liberalization and revealed comparative advantage", The Manchester School of Economic and Social Studies, n° 33, p. 99-124.

Beffa J-L. (2005), Pour une nouvelle politique industrielle, Collection des rapports officiels, janvier 2005.

Bureau des études statistiques sur la recherche (2001), "Recherche et Développement en France en 1999 et 2000". Note d'information 01.50 (novembre) de la Direction de la Programmation et du Développement (DPD), Ministère de l'Education nationale.

Cantwell J. (1989), Technological innovation and multinational corporations, Basil Blackwell, Oxford.

Cantwell J. and U. Kotecha (1997), "The internationalization of technological activity: the French evidence in a comparative setting", in Howells J. and J. Michie, Technology, Innovation and Competitiveness, Edward Elgar, United Kingdom.

Chandler A. D. (1962), Strategy and Structure: Chapters in the History of the American Industrial Enterprise. MIT Press: Cambridge,MA.

Chesnais F. (1993), “The French National System of Innovation”, in R. R. Nelson (ed.), National Innovation Systems: A comparative analysis, p. 194-229, Oxford University Press, New York.

Cieply S. (2001), “Bridging capital gaps to promote innovation in France”, Industry and Innovation, volume 8, n° 2, p. 159-178.

Coriat B. and D. Taddei (1993), *Made in France: l'industrie françai*se dans la compétition mondiale, Le Livre de Poche, France.

Cytermann J-R. (2007), Universités et Grandes Ecoles. Problèmes politiques et sociaux n° 936, La Documentation Française, Paris.

Dalum B., K. Laursen and G. Villumsen (1998), “Structural Change in OECD Export Specialisation Patterns: De-specialisation and 'Stickiness”, International Review of Applied Economics, 12, p. 447-467.

David P. (1985), Clio and the Economics of QWERTY. American Economic Review, 332.

Dosi G. (1981), *Technical change and survival: Europe's semiconductor in*dustry, Sussex European paper, n°9.

Dosi G. (1999), “Some notes on national systems of innovation and production, and their implications for economic analysis”, p. 35-48, in Archibugi D., J. Howells and J. Michie (eds.), Innovation Policy in a Global Economy, Cambridge University Press, United Kingdom.

Edquist C. (1997), Systems of Innovation: Technologies, Institutions and Organisations, London and Washington, Pinter.

France Télécom, (2009). Document de Référence 2009. Available at http://www.orange.com/media/doc-finance/fr/doc-reference/att00015095/DDR2009completCL28042010_17h06.pdf

Freeman C. (2004), “The ‘National System of Innovation’ in historical perspective”, Cambridge Journal of Economics, 19, p. 5-24.

Gasquet M. (2008), “Le credit impôt recherche”, Agence Nationale de la Recherche, available at http://media.enseignementsuprecherche.gouv.fr/file/Aide_a_la_recherche_-_devpt/06/8/BILAN_CIR_2006_31068.pdf.

Golstein A. (1996), “Privatisations et contrôle des entreprises en France”, Revue économique, vol. 47, n°6, Les privatisations un état des lieux , p.1309-1332.

Goyer M. (2001), “Corporate governance and the Innovation system in France 1985-2000”, Industry and Innovation, volume 8, n° 2, p. 135-158.

Griliches, Z. (1990), "Patent Statistics as Economic Indicators: A Survey", Journal of Economic Literature, volume 28, issue 4, p. 1661-1707.

Groupe EDF, Electricité De France, (2009), Document de référence 2009. Available at http://finance.edf.com/fichiers/fckeditor/Commun/Finance/Publications/Annee/2010/ddr/EDF_DDR2009_V2_vf.pdf.

Hancké B. (2002), Large Firms and Institutional Change Industrial Renewal and Economic Restructuring in France, Oxford University Press, Oxford, UK.

Hicks D., T. Breitzman, D. Olivastro and K. Hamilton (2001), The changing composition of innovative activity in the US - A portrait based on patent analysis. Research Policy, 30, p. 681-703.

Jaffe A.B. (2000), The U.S. patent system in transition: policy innovation and the innovation process. Research Policy. 29 (4-5), p. 531-557.

JORF, Journal Officiel de La République (July, 16th 1982), Loi d'orientation et de programmation pour la recherche et le développement technologique de la France (Loi n°82-610 du 15 juillet dite Loi Chevènement). Available at http://www.legifrance.gouv.fr/affichTexte.do;jsessionid=F1073F56D24C838D3FF5C73DC7A7EBB4.tpdjo08v_1?cidTexte=JORFTEXT000000691990&categorieLien=id

Kay N. (2002), "Chandlerism in post-war Europe: strategic and structural change in France, Germany and the United Kingdom, 1950-1993: a comment", Industrial and Corporate Change, volume 11, number 1, p. 189-197.

Laredo P and P. Mustar (2002), "Innovation and Research Policy in France (1980-2000) or the Disappearance of the Colbertist State", Research Policy, 31, p. 55-72.

Laursen K. (1998), "Revealed comparative advantage and the alternatives as measures of international specialisation", DRUID working paper, n°. 98-30.

Laursen K. (2000), "Do export and specialisation patterns co-evolve in terms of convergence or divergence on dynamics of trade performance 1971-1991", Journal of Evolutionary Economics, volume 10, p. 415-436.

Lundvall B.-A. (1992), National Innovation Systems: Towards a theory of innovation and interactive learning, London, Pinter Publishers.

Mairesse J. and B. Mulkay (2004), "Une évaluation du Crédit Impôt Recherche en France, 1980-1997", INSEE, Série des documents de travail du Centre de Recherche en Economie et Statistique (CREST), n°43.

Morin F. (1996), "Privatisations et dévolution des pouvoirs, le modèle français du gouvernement d'entreprise", Revue Economique, vol. 47. N°6, Les privatisations un état des lieux (Nov. 1996), p. 1253-1268.

Morin F. and E. Rigamonti (2002), "Evolution et structure de l'actionnariat en France", Revue française de gestion, 2002/5 – n° 141, p. 155 à 181.

Nelson R. R. (eds.) (1993), National Innovation systems: a comparative analysis, Oxford University Press, New York.

Nelson R. and K. Nelson (2002), “Technology, institutions, and innovation systems”, Research Policy 31, p. 265-272.

Nesta L., and Patel P. (2004), “National patterns of technological accumulation: Use of patent statistics”, p. 531-551, in Moed H. F., W. Glänzel, and U. Schmoch (eds.), Handbook of quantitative science and technology research , volume 24, Dordrecht: Kluwer.

OECD, Organisation for Economic Co-operation and Development (2010). Main science and technology indicators (MSTI). volume 2010/1. Paris:OECD.

OST, Observatoire des Sciences et Techniques (2010). Indicateurs de science et de technologies. Rapport établi sous la direction de G. Filliatreau, Economica, Paris.

Pavitt K. and P. Patel (1990), “L’accumulation technologique en France: ce que les statistiques de brevets tendent à montrer”, *Journal Revue d’Economie Industrielle,* volume 51. Organisation et dynamique industrielle, p. 10-32.

Patel P. and K. Pavitt, (1998), “Uneven (and divergent) technological accumulation among advanced countries: evidence and a framework of explanation”, p. 55-82, in Archibugi D. and J. Michie. (eds), Trade, Growth and Technical Change, Cambridge University Press, United Kingdom.

Rao P.M., V. K. Vemuri and P. Galvin, (2004), “The changing technological profile of leading ICT firms: evidence from US patent data 1981-2000”, Industry and Innovation, volume 11, n° 4, p. 353-372.

Sefati C. (2001), “The adaptability of French armaments industry in an era of globalization”, Industry and Innovation, volume 8, number 2, p 221-239.

Soete L.L.G. (1981), “A general Test of the Technological Gap Trade Theory”, Weltwirtschaftliches Archiv, volume 117, p. 638-666.

Tylecote A. and E. Conesa. (1999).Corporate governance, innovation systems and industrial performance. Industry and Innovation, volume 6, number 1.

Tylecote A. and G. Vertova (2007). Technology and institutions in changing specialisation: chemicals, motor vehicles in the United States, United Kingdom, and Germany. Industrial and Corporate Change, volume 16, issue 5, p. 875-911.

Vertova G. (1998), Technological similarity in national styles of innovation in a historical perspective, Technology Analysis and Strategic Management, volume. 10 , n°4, p. 437-449.

Vertova G. (2001), National technological specialization and the highest technological opportunities historically, Technovation, 21, p. 605–612.

Whittington, R., M. Mayer and F. Curto (1999), “Chanderism in post-war Europe: strategic and structural change in France, Germany and the UK, 1950–1993” Industrial and Corporate Change, 8, p. 519–550.

Zeebroeck, N., B. Potellsberghe de la Potterie and W. Han (2006), Issues in measuring the degree of technological specialisation with patent data. Scientometrics, volume 66, number 3, p. 481-492.

Appendix I: Data and methodology for the measurement of persistence of technological specializations.

I.A Data

We use the SPRU patent database[20] to investigate the evolution of the technological specializations of France between 1978 and 2004. The database provides the total number of patents granted by the United States Patents and Trademark Office (USPTO) by country for each of the 34 technological classes in every year. However patents cannot be directly and permanently matched with innovative efforts or outcome. The value distribution of patents is skewed as many patents have no industrial application whereas a few are of substantial market value. Many inventions are not patented or inventors may protect the inventions using other methods, such as secrecy, lead time, for instance. Indeed the propensity to patent differs across countries and industries. Nevertheless and despite these reservations patents have been widely used as a alternative proxy for technological change in the literature as they are a good proxy for innovative activities over all (Acs and Audredsch 1989; Griliches 1990; Cantwell and Kotecha 1997; Patel et Pavitt 1998; Jaffe 2000; Hicks et al. 2001, among others). Moreover patents statistics are available for long time periods and many countries, thus enabling to achieve international comparisons.

To avoid traditional concerns about home market bias towards the United States that arises when using USPTO data, we also perform our analyses excluding the United-States. Given that the application to a foreign patent office is a more time-consuming and costly procedure we may reasonably expect that inventions with the highest expected profits will be patented abroad. Besides the United-States have historically been a primary place for patenting activities of world organizations because of the advanced nature of technology producers and users in the United-States and of the importance of the market for technology.

Because of the unequal propensity to patent we observe situations with relatively small number of patents or zero-patents. To solve this problem, the original dataset has been limited to a sample of the 20 most innovative countries[21] that concentrate more than 90% of patents granted in the United-States over the period 1978-2004[22].

I.B Measurement of technological specializations: the revealed technological advantage

[20] The data has been kindly provided to Mafini Dosso by Parima Patel during her research stay at SPRU.

[21] Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, Netherlands, South Korea, Japan, Spain, Sweden, Switzerland, Taiwan, United-States, and United-Kingdom.

[22] Previous works referred to this methodology: Cantwell 1989, Cantwell et Kotecha 1997, Pavitt and Patel 1990, Patel and Pavitt 1998, Vertova 1998, Nesta and Patel 2004, Rao et al. 2004.

First used by Soete (1981) the most common indicator to assess the degree of technological specialisation (or under or de-specialisation) of a country, a group of firms or a firm in a sector is the Revealed Technological Advantage (RTA). It is computed in the same way as Balassa's index of Revealed Comparative Advantage (RCA, 1969). For a country it is obtained as below:

$$RTA_{ij} = \frac{P_{ij} / \sum_{i} P_{ij}}{\sum_{j} \left(P_{ij} / \sum_{i} P_{ij} \right)},$$

where P_{ij} is the number of patents of country i in class j.

The RTA of France in a technological class is computed as the ratio of the patent share of French organizations in a technological class and the share of this class in the total patents of the countries in the sample. The distribution of RTAs across selected classes is used as a proxy for France technological profile. The country is said to be relatively specialised (respectively non specialized) in a technological class when the RTA is above 1 (respectively below 1). The country has neither advantage nor disadvantage when the RTA index equals 1. The revealed technological advantages of French organizations across the 34 technological classes are computed on the basis of a sample of 20 most innovative countries that concentrate more than 90% of patents granted in the United-States over the period 1978-2004. In order to control for the intrinsic volatility of the annual patent data and to take into account the cumulative dimension of technological change the RTAs are computed on the basis of cumulated years[23].

However the RTA index ranges from 0 to the infinite. Hence the main problem arises when we compare the RTAs on both sides of 1 as it tends to give much more weight to values above one, when compared to values below one. Besides it also presents an inherent risk of lack of normality precisely because the index ranges from 0 to infinity with an average value of 1. Therefore in case of skewed distributions, the assumption of normality of the error term does not hold any more and thus leads to unreliable results. As suggested by Verspagen (1996) and further discussed by Laursen (1998) we also consider the Revealed Symmetric Technological Advantage[24] (RSTA) that ranges from -1 to 1. Thus besides checking for the robustness of the RTA-based results it allows overcoming the problems that may arise when we employ the RTA in our econometric analyses.

By construction the specialization indexes thus allows us to overcome the biases implied by the different propensities to patent between countries and classes that could arise when we compare absolute shares. Within a country the analysis of specialization indexes and shares raise two different questions. The analysis of patent shares is related to the question « What are the top patenting classes in France? » and the analysis of specialization indexes comes to

[23] Previous works referred to this methodology: Cantwell 1989, Pavitt and Patel 1990, Patel and Pavitt 1998, Laursen 2000, Nesta and Patel 2004, Rao et al. 2004, among others.

[24] RSTA= (RTA-1)/(RTA+1)

answer the question « What are the classes in which France patent relatively more than the other countries?”.

I.C *How to measure the persistence or stability of countries’* technological specialization patterns

We investigate the evolution of national technological specializations patterns at the country level. For every sub-period t a country’s position in the technological space will be characterized by the vector $RTA_{it} = [RTA_{i,1,t}, \dots RTA_{i,n,t}]$, where $RTA_{i,j,t}$ represents the RTA of a country i in a patent class or a sector j (1, …, n). The technology space is a multi-dimensional space, with each dimension defined by a unique technological area or sector. The computations are achieved using both the RTA and the RSTA which are constructed on the basis of different time spans on the whole period. For each country and sector, we account for the patent counts on different sets of sub-periods ranging between 3 and 8 years. Then, for each country, we look at the evolution of the national distributions of RTAs (respectively RSTAs) across all technological classes using parametric and non-parametric correlations; and autoregressive models. We consider three methods as follows:

The first method to assess more precisely the mobility within countries’ distributions of specializations is based on parametric and non-parametric correlations. For each country we compute the correlations of its specialization profile between the different sub-periods. For each set of sub-periods we achieve these correlation analyses between the beginning of the period, the mid-period and the end of the period to account for short and long term changes. We expect that in the short run the correlation coefficients will be higher, thus reflecting a lower stability of technological profiles in the long run (e.g. Cantwell 1989, Dosi et al 1990, Malerba et al. 1997, Laursen 2000a,b, Mancusi 2001, Huang and Miozzo 2004, Nesta and Patel 2004). As a robustness checks, we look at each country’s matrix of autocorrelations between all sub-periods and for each set of the selected time spans.

The second methodology explores the degree of stickiness or cumulativeness and the inter-temporal persistence of technological specializations at the country level. We focus on the autoregressive structure of national specializations vectors, and estimate the coefficient β in the following regression:

$$X_{it} = a + \beta_l X_{i,t-l} + u_{it}$$

where, X_{it} denotes the vector of RTAs (RSTAs) of a country i in a sub-period t, α is a constant and u_{it} are disturbances.

We perform for each country the well-known galtonian regressions (Cantwell 1989) between short and long run periods. In this frame, a β = 1corresponds to an unchanged pattern between the selected periods. If β >1 the country tends to become more specialized in fields in which it is already specialized, and less specialized where initial specialization is low. Such pattern thus corresponds to a strengthening of the specialization. This latter situation corresponds to a β-specialization while 0 < β < 1corresponds to a β-de-specialization, i.e. on average countries with low initial RTAs increase over time and the opposite for countries with an initially high RTA. β < 0 indicates that the rankings of classes have been reversed. However as underlined by Laursen (2000) and Meliciani (2001), $\beta > 1$ is not a necessary condition for an increase overall national specialization pattern. Referring to Hart (1976), we also compute the standard deviation and the ratio of the estimated parameter β and the square-root of the coefficient of determination of the regression (R). As shown by the author:

$$(\sigma_k/\sigma_{k-1}) = (|\beta|/|R|)$$

where, σ correspond to the variance of the specialization index in a selected sub-period.
If $\beta = 1$ the dispersion of the distribution is unchanged, while a $\beta > R$ ($\beta < R$) indicates that the degree of specialization has increased (decreased). $\beta > R$ can be termed α-specialization and $\beta < R$ can be named α-de-specialization (Laursen 2000). In order to overcome problems with the non-normal distribution of the RTA index, the regressions are achieved using the RSTA.

In the third approach we focus on AR(1) models. The AR(1) (l=1) coefficient captures the persistence[25] of the process; the higher the estimated coefficient β_1, the more persistent is the national technological specialization pattern. A similar model and the problems that might arise from its estimation have been further discussed in Chesher (1979) within the frame of a test of the law of proportionate[26] effects. According to this law a variable subject to a process of change is said to obey to the law of the proportionate effects if the change in the variable at any step of the process is a random proportion of the previous value of the variable (Chesher 1979). Chesher employs an AR(1) structure to model the growth of firms' size for a sample of British firms in the end of the 1960s. The estimation technique depends on the presence of serial correlation between the errors terms[27]. The standard ordinary least squares estimator $\hat{\beta}_{OLS}$ may be inconsistent if the disturbances are cross-time dependent. When $\hat{\beta}_1$ exceeds the unity, the inconsistency of the estimator tends to 0 as the age of the process increases. However when $\hat{\beta}_1$ is below the unity, the inconsistency tends to persist (Chesher 1979). Moreover as the number of sub-periods considered for the AR(1) model is quite limited in the best case (9 periods of 3 successive years), our results are very likely to lead to inconsistent estimated autoregressive coefficients. Then, for each country we successively consider the RTAs based on the sum of patents for the year n, n+1 and n+2 and the RTA based on the sum of patents granted in the n+1, n+2 and n+3, and so forth. We test for the autoregressive structure of this new series of data RTAs applying an AR(1) model. This new series can be considered as a moving average (MA) series in which the average is the RTA over 3 years. As an indicator of trend, the MA belongs to the family of filters and thus, allows obtaining a smooth series in which non-significant fluctuations are eliminated. Although there may be a lag between the evolution of the moving average and the initial indicator, the MA enables us to focus on the main trend in the process on a long time span. Contrary to the previously discussed methods, it enables to have an assessment of the relative stability of countries' specializations patterns considering the entire period. Due to the structure of the data used, we

[25] See Chesher 1979 for the estimation technique. Previous works that have used this methodology: Dosi and Grazzi 2006, Bottazzi et al. 2008.
[26] Building upon the classical work of Gibrat (1931).
[27] The presence of autocorrelation between the error terms is generally tested on the basis of Durbin-h statistic or its modified versions (Durbin 1970, Durbin et Watson 1971). Breusch and Godfrey's test allow testing for the autocorrelation in the errors terms for an order superior to 1 (Breusch 1978, Godfrey 1978).

expect the coefficients to be quite high. However the comparison of the coefficients allows achieving a further verification of the relative persistence of countries' technological profiles.

Appendix II: Initial technological specializations pattern of French organizations

Table II: Patterns of French technological specializations (1978-1983)

TECHNOLOGICAL CLASSES	RTA	Share of France[a]	RTA (US non-included)	Share of France (US excluded)
Induced nuclear reactions	3,09	10,42 %	2,88	24,88%
Aircraft	2,26	7,61%	3,41	29,45%
Bleaching Dyeing	1,86	6,26%	1,25	10,79%
Telecommunications	1,67	5,63%	1,70	14,72%
Drugs and bioengineering	1,66	5,58%	1,31	11,34%
Inorganic chemicals	1,38	4,66%	1,31	11,33%
Plastic and rubber products	1,29	4,36%	1,13	9,80%
Metal treatment	1,18	3,99%	0,97	8,38%
Other transport equipment	1,18	3,98%	1,28	11,08%
General industrial electrical equipment	1,14	3,83%	1,08	9,32%
Semiconductors	1,09	3,69%	1,07	9,25%
General non-electrical industrial equipment	1,06	3,57%	1,12	9,67%
Food and Tobacco products	1,05	3,55%	1,16	10,00%
Metal working equipment	1,01	3,40%	0,98	8,51%
Instruments and control	1,00	3,38%	0,94	8,10%
Road vehicles and engines	1,00	3,37%	0,67	5,78%
Chemical processes	0,97	3,27%	1,03	8,88%
Materials	0,97	3,27%	0,94	8,12%
Power plants	0,97	3,25%	1,05	9,08%
Organic chemicals	0,95	3,21%	0,88	7,61%
Electrical devices and systems	0,93	3,12%	1,08	9,33%
Computers, calculators, ect.	0,90	3,02%	0,94	8,15%
Non-electrical specialized industrial equipment	0,87	2,92%	0,83	7,15%
Assembling and material handling apparatus	0,86	2,92%	0,86	7,45%
Apparatus for chemicals	0,85	2,86%	0,81	7,03%
Hydrocarbon Mineral Oils, ect.	0,84	2,82%	1,83	15,80%
Miscellaneous metal products	0,83	2,79%	1,07	9,22%
Mining and wells Machinery and Processes	0,78	2,61%	1,51	13,07%
Textile, clothing, leather, wood products	0,77	2,59%	1,11	9,58%
Other*	0,76	2,58%	1,16	8,65%
Image and sound equipment	0,74	2,49%	0,60	5,20%
Dentistry and Surgery	0,69	2,32%	1,02	8,85%
Agricultural Chemicals	0,59	1,97%	0,57	4,97%
Photography & photocopy	0,29	0,97%	0,19	1,63%

a : in the total countries'patents in each technological class.

*Miscellaneous articles (jewelry, coffins),Building materials and statics structures, structures for roads and bridges (processes and engineering), Weapons and ammunitions, toys and entertainment....

Appendix III: Large programs in France

The following tables provide the main features of some major historical and current large technological programs implemented by the French governments (own translations).

Table III.A: Major historical "Grands Programmes" (Large programs) in France

Programs	Launching Date	Technological Breakthrough	Main industrial actors	Invested funds
Concorde	1962	Fly-by-wire flight Control System	Aérospatiale	3,9 Mds€ between 1970 and 1990
Plan Calcul	1966		UNIDATA, Bull	8 Mds€ as support to Bull
TGV (Fast Speed Train)	1969	Doubling of commercial speed	Alsthom, SNCF	2,1 Mds€ state investment for the launching of the 1st line of the TGV
Airbus	1970	Motoring, piloting, maintenance, cost	Aérospatiale, Airbus	3 Mds€ in repayable loans for Aerospace from 1971 to 1997 (all programs)
Nucléaire civil (Civil Nuclear)	1973	Nuclear power industry	Areva, EDF	
Minitel	1978	Telematics	France Télécom	1,2 Mds€ investments for Poste Télégraphe Téléphones company (PTT)
Plan composants (Components Plan)	1989	Miniaturization	Thomson and later STMicroelectronics	

* French public administration of postal services and telecommunications was formed in 1921 and was split in 1991 into La Poste and France Télécom. Mds stands for billion euros.

Table III.B: Main large programs in the early 2000s

Program	Activities	Public support instruments	French Government budget
Nuclear	Third genration nuclear reactor, EPR Participation in the international program ITER for nuclear fusion	Public resaerch and support to AREVA	550 millions € for Government RD expenditures (2003) 30 millions € of state funding to private RD (mainly AREVA)
Space	Earth Observing System (Envisat, Calipso, Champ, GMES, ect...) Space Observing System: cluster, Mars express Telecommunication : Galileo Transport spatial : Ariane V et ISS	State research(CNES, European Space Agency) partially externalized	Budget of 1,7Mds€ including 0,6 Md€ for ESA (2003) 150 millions € public funding to private RD
Aeronautics		Repayable loans to Airbus	Repayable loans that amount to 1,2 Mds€ for A380 (2004) Request for repayable loan of Mds€ for A350