Paper to be presented at the DRUID 2011

on

INNOVATION, STRATEGY, and STRUCTURE -
Organizations, Institutions, Systems and Regions
at
Copenhagen Business School, Denmark, June 15-17, 2011

Technology Policy Learning and Innovation Systems Life Cycle: the Canadian Aircraft Industry

Majlinda Zhegu
Université de Québec à Montréal
Management et technologie
zhegu.majlinda@uqam.ca

Johann Vallerand

vallerand.johann@uqam.ca

Abstract

This study aims to bridge the literature regarding organizational learning and the system of innovation perspective. This paper explores the co-evolution of industrial technology policy learning and the innovation systems life cycle. Firstly, the main findings on organizational learning attributes are presented. Secondly, the process of public policy learning is discussed. Finally, a life cycle approach for analyzing technology policy learning is presented for the Canadian aerospace industry. By discerning the complimentary factors among differing theoretical perspectives, this paper provides a better understanding of the process and evolution of technological policy.

Jelcodes:O32,M10

Technology Policy Learning and Innovation Systems Life Cycle: the Canadian Aircraft Industry

Abstract

This study aims to bridge the literature regarding organizational learning and the system of innovation perspective. This paper explores the co-evolution of industrial technology policy learning and the innovation systems life cycle. Firstly, the main findings on organizational learning attributes are presented. Secondly, the process of public policy learning is discussed. Finally, a life cycle approach for analyzing technology policy learning is presented for the Canadian aerospace industry. By discerning the complimentary factors among differing theoretical perspectives, this paper provides a better understanding of the process and evolution of technological policy.

1) Introduction

Two primary observations drive the focus of this study regarding the links between technology policy learning and innovation system life cycle. On one hand, technology and innovation policies are the linchpin of innovation and developing national competence and, therefore, are the principal reason for variation in innovative between countries. On the other hand, the increasing complexity of the R&D activity combined with the very rapid pace of technological change amplifies the scale and scope of adjustments of all participants in technological innovation. Hence, the success of an innovation system relies on the learning capabilities of its constituents (Lundval and al, 2010).

Meanwhile, it is recognized that the most important elements of innovation systems are dependent on the learning capabilities of individuals, organizations, and regions; crucial details of their capacity and ability to learn are lacking (Lundval et al. 2002, p. 224). In the case of technological policies, the need for an in-depth understanding of learning content, processes, and mechanisms is even more compelling. Government has undertaken the multiple and complex task of generating, orienting, coordinating, diffusing, and regulating innovation activity. Furthermore, in a context of global interdependences, it has become imperative to design and pursue a more sophisticated and dynamic public support of innovation. Evidence of successful public policies corroborates the thesis that government's principal role «...is not the quest for avoid overarching institutional preconditions for growth or uniform, inflexible policy recipes. The evolutionary account rests on the sort of congruence conditions between ingredients and processes wherein feature prominently the matching or mismatching between capabilities accumulation and the institutions governing the distribution of information and the incentive structures of any one economy (Cimoli et al. 2009, p. 5) ». This in turn leads to the question: What are the attributes of technological policy learning and its evolution within a national innovation system context?

The following section provides defines the main characteristics of organizational learning. Then, the building blocks of technology policy learning are identified as well as the similarities and differences between learning in public versus private organizations. In the third section, the dynamic nature of technological policy learning is discussed and a framework proposed that considers the technology policy learning in the context of the innovation system life cycle . The empirical research is based in a diachronic analysis of the technological «catch-up» and «keep-up» of Canadian technology policies in the aerospace sector.

2) Organizational learning: definition and attributes

Even if learning is a recurrent theme in many theoretical perspectives, no general theory of organizational learning and no set of best practices have emerged yet. Economics, sociology, political, historical, and management studies offer valuable insights on the premises, contextual factors, sources, types, and levels of organizational learning. Most of these insights are complementary in understanding the various aspects of the organizational learning. But, often, the basic assumptions and the angles of examination adopted by each theoretical perspective vary greatly and sometimes may also be in contradiction with those adopted by the others. Therefore, it is necessary to combine the insights from the different theoretical perspectives on organizational learning. With this in mind, in the following session, we revisit the definition of organizational learning and draw attention to its main salient features.

2.1 Definition of the organizational learning

For the purpose of this research, organizational learning is defined as the process of exploring and exploiting internal and external new knowledge with the purpose of maintaining or improving the performance of the organization. This definition emphasizes organizational learning as a sustained phenomenon which generates gradual changes reflected by successful organizational transformation and improved actions through better knowledge and understanding (Fiol and Lyles, 1985, Auluck, 2002).

The competitive advantage of an organization is grounded on the process of generation, capturing, and applying critical new knowledge. This learning process relies on the organizational absorptive capacity, which is the organization's ability to recognize the value of new external knowledge, assimilate it, and apply it to commercial advantage (Cohen and Levinthal, 1989, Zahra et Georges, 2002; Lane et al, 2006). The concept of organizational learning assumes creation and acquisition of internal and external new knowledge, while the absorption capacity concept is centered on the ability of capturing and integrating external knowledge in the firm's routines. Organizational learning relates to processes, while organizational learning capacity relates to structures. Between organizational learning and organizational absorptive capacity, there is a co-evolutionary relationship (Van den Bosch et al. 2003). A high level of in-house R&D (on form of organizational learning) will increase a firm's ability (its absorptive capacity) to understand and access other innovators' R&D. Moreover, endowed with a superior absorptive capacity, an organization will produce more product or process innovations while enhancing its organizational learning (Cohen and Levinthal, 1989). Therefore, absorptive capacity may be considered as a major predictor and enabler of organizational learning.

2.2 Attributes of organizational learning

2.2.1 The Organizational learning process

Organizational learning is a *complex process* spanning over several stages. Based on the degree of absorption of new knowledge in an organization's routines, Crossan et al. (1999, p.525) quarter the organizational learning process in the following phases: 1) the intuiting phase or the preconscious recognition of potential valuable of new knowledge or idea; 2) the interpreting phase, or the explaining of the new idea to one's self and to others; 3) the integrating phase, or the developing of shared understanding among individuals and the taking of coordinated actions through mutual adjustments, and 4) the institutionalizing phase or the embedding of the new idea in the routinized actions of the organization. Other authors extend the organizational learning process by including the organizational memorizing, learning, and unlearning as some other important phases affecting present and future learning (Fiol, 1985, 2003).

2.2.2 Organizational learning sources

Organization learning *relies on an organization's direct experiences as well as on the experiences of others.* The study of Levitt and March (1988) focused on the dynamics of organizational learning from internal and external experiences and provided a detailed analysis of the positive feedback and pitfalls of learning generated from both sources. The authors associated the competence trap, or a maladaptive specialization, with an organizational lock-in of inferior practices. Imitation of others' successful experience risks a mismatch between the new knowledge and the organizational context, which may compromise the output of the learning process. Empirical research has identified various modes of organizational learning as the learning-by-doing (Arrow, 1962), learning by detection and correction of errors (Argyris, 1977), learning by using (Rosenberg, 1982), learning by interacting (Lundvall, 1992), learning by searching (Johnson, 1992), or the learning by performance feedback (Greve, 2003).

2.2.3 Organizational learning levels

The question about the unit of analysis has provoked many debates on the literature regarding organizational learning. Who learns in an organization? On one hand, there are authors who consider the organization as an inanimate object and therefore learning cannot be described by the same characteristics as human learning (March and Olsen, 1975). In their view, since only a small number of individuals have a decision-making role and are able to influence the organizational pathway, they may be representative of the organizational learning. On the other hand, another view of organizational learning is collective learning. According to Hedberg (1981), organizational learning is much more than a simple sum of learning by its own members. By comparing individual to collective learning, different studies have shown very different attributes of these two levels of learning and have also highlighted the multi-level character of organizational learning (Esterby-Smith et al, 2003). This multi-level perspective of organizational learning has oriented research towards investigation of the combined mechanisms of the diverse tiers of learning. Sanchez (2005) proposes an interpretative framework of the transformation of individual learning in organizational learning through the intermediary of group (teams) learning. Wenger (1998) introduces the notion of community of practice; while Powell et al. (1996) analyse organizational learning from the networking perspective.

2.2.4 Organizational learning modes

Organizations react to changes in their environment. Fiol et Lyles (1985) distinguishes between an organizational reaction representing only a defensive adjustment, and another involving the understanding of reasons beyond immediate current event. The authors associate high-level learning with the latter type of organizational behavior, and low-level learning with the former. The concepts of single-loop and double-loop make a similar distinction of the content of learning (Argyris, 2005). In the case of low or single-loop learning, adaptation to change occurs without changing the central features of an organization. Higher-level learning implies a change of the organization's overall rules and norms (Fiol et Lyles, 1985, Greve, 2003). According to the Torbert (1999) analysis on the links between organizational learning, organizational action, and organizational change, single-loop learning is concerned with the correctness of an action (Are we doing right?). In a double-loop learning process, the main question concerns the ways to improve organizational action (Can we do better?). Finally, in triple-loop learning, the questioning and reframing of the intent of an organization's vision may imply radical changes to the organization's actions (Are we going in the right direction?) Single-loop learning leads to incremental organizational changes while double and triple-loop learning may cause radical transformations to the organization.

3) Technology policy learning definition and its building blocks

Several authors note the high concentration of research on private organizational learning and point out the need for closer investigation on the learning within the governmental sector (Moynihan et Landuyt, 2007). Is learning in a public organization different from learning happening in the private sector? What are the building blocks of technology policy learning?

3.1 Public versus private organizational learning

Crossan (2004) recommends the study of organizational learning in public organizations as a key tool for improving both policy-making capacity and the delivery of public policies. Many scholars plead for careful investigation of the specifics of learning in the public sector (Busenberg, 2001; Getha-Taylor, 2008; Moynihan et Landuyt, 2009, Nutt, 2005). In their view, public organizations deal with greater complexity and ambiguity of the goals. Also differences in the organizational structure, the level of autonomy and accountability, the normative dimension, and work related attitudes and values are considered cause for important differences between organizational learning in public and private organizations. LaPalombara (2001) emphasizes the impact of power struggles that take place in public-sector organizations, which are described as risk-adverse and influenced by politics.

Meanwhile, other scholars dismiss the distinct traits of government organizations by considering them like public organizations from the private sector. They point out a tendency for priory considerations and oversimplifications that mark part of the accumulated knowledge about learning in public organizations (Rainey, 2009). According to Rainey et Bozeman (2000), the debate on this issue falls along two lines with some studies that consider differences between public and private organizations as a truism and others that treat these distinctions with contempt. By assessing a large number of studies spanning two decades, Rainey et Bozeman (2000) observed right and wrong points for both perspectives. Depending on the sector and type of organizational activity, private and public organization behavior may sometimes converge, while others diverge greatly. Therefore, the authors called for deep and meticulous empirical analysis of public organizational learning to avoid the superficiality trap.

3.2 Technology policy building blocks

3.2.1 What triggers the public policies changes?

Two different theoretical stances have sustained the debate on this issue, the first being based on an institutional approach, while the second emphases learning as a source of change (Bennett and Howlett, 1992; Lieberman, 2002). According to the institutional approach, public policies changes are propelled by the social pressures and conflicts or by the public bureaucracies. The other perspective considers governmental learning as the main driver of the policymaking process. Hall (1993) and Heclo (1974) describe public organizational learning as a deliberate, less conscious activity of government that revisits its own past experiences in order to adjust the goals of its policies, or to better respond to various environmental stimuli. Sabatier and Jenkin-Smith (1988) suggest that policy-oriented learning happen when, the results from the analysis of past and current policies are considered in the subsequent policymaking process. Finally, Rose (1991) has introduced the concept of lesson-drawing policy learning which is defined as the process of adoption from a country of programs and policies developed from other countries. As cross-national policy diffusion often relies on international networks and policy communities to provide forums for interaction, the patterns of policy adoption by governments can be explained by analyzing mechanisms of policy dissemination as processes of organizational learning (Crossan, 2004, p. 41).

3.2.2 Who learns in public organizations?

Stone et al. (2001) categorized the decision–makers in several groups based on the criteria of their access to new knowledge and information and their importance on the decision-making process. High-level politicians (the political executives and legislators) have the primary role on the decision-making, but they do not have the time to access and consider detailed information. In addition, high-level politicians are more likely to view the policy-making process as a political activity. According to Stone et al., another important faction is composed of Civil Servants and Appointed Officials, who are an elite group characterized by permanence, security, high standards, and promotion by merit and code of political neutrality. They are responsible for processing the information, synthesizing it, and briefing the high-level politicians. The street level bureaucrats and research editors and evaluators are supposed to gather the needed information, and to edit, prepare and synthesize the inputs that will be provided to the senior civil servants. Depending on each country's bureaucratic traditions, each of these decision-making levels will be more or less able to capture, explore, and exploit new knowledge in order to improve the decision-making process.

Benett and Howlett (1992) suggest a broader view of the participating groups in the policy-decision making process. These authors combine the state officials group, the policy networks group, and the policy communities group. The policy networks include various levels of government personnel in policy formulation and implementation, as well as researchers, policy analysts, journalists who play important roles in the generation, dissemination, and evaluation of public policies (Sabatier, 1988: 131). The policy community group relates to the community of practice concept and has been introduced in the public organizational learning literature from Rose (1991). He suggests that elected officials searching for lessons prefer to turn to those whose overall political values are consistent with their own. Therefore, national or transnational epistemic communities are created and they become sources of new ideas. A careful examination of the learning capability of each decision-making group provides important insights into the causes of public policies successes and failures.

3.2.3 The content of learning: what is learnt and what is the effect?

Is public policy learning a low or high-level type of learning? High-level organizational learning happens when the organizational members share the same understanding about the new knowledge and ideas and pursue the same goals in terms of transforming organizational values, culture, and operating processes. The multiplicity of participants in the decision-making process renders this sort of goal alignment difficult to attain in a democratic system context. In addition, double and third-loop learning should contribute to the achievement of organization's strategic objective. Or, in the case of public policy, the tendency to make decisions based on ideological standpoints prevails over theoretical and empirical evidence. Therefore, the policy environment is thought to not be propitious to double and third loop learning in public organizations (Common, 2004). This study challenges this perception by an in-depth examination of the policy environment and the modes of public organizational learning in the case of aerospace industry.

3.3 The evolutionary perspective of technology policy learning

There are two opposing approaches regarding the dynamics of technology policy learning. In an oversimplified neoclassical context, technological policy choices are made by homogenous and perfect rationality endowed actors, attempting to reach an optimal equilibrium in a deterministic environment. Therefore, from this perspective, organizational learning is considered a mechanistic rather a dynamic process. This consideration is invalid when looking into public organizational learning through the lenses of the bounded rationality model which implies that agents have a limited capacity to explore, to comprehend, and to exploit information (Simon, 1947).

Technology policy embodies the conceptual policy framework, the aspirations and goals, the strategies, and the tools of state intervention in science and technology. Technology policy decisions are highly complex and organizational learning is a key factor affecting policy results. The bounded rationality principle suggests that decisions about an issue will be made even if the decision makers do not know all the relevant information to that issue. Nevertheless, over time, the imperfectly informed agents will have other opportunities to learn by gathering and processing new information and use it to correct past errors (Busenberg, 2001). According to this evolutionary reasoning, chances for a technological policy to be perfect at once are minimal and therefore, several trial-and-error steps, constant re-evaluation, and fine-tuning are essential during any specific policy lifetime.

Technology policy is usually based on a policy paradigm whose choice is influenced and also influences a country’s economic, social, political, and institutional context (Freeman, 1987). Thus, dominant since the WWII appropriability (Mowery, 1983) or mission-oriented paradigm (Ergas, 1987) has been gradually superseded from information processing (Mowery, 1983) or the diffusion oriented paradigm (Ergas, 1987). When viewed with the appropriability paradigm approach, technology policy is usually concerned with the supply of research and development activity. Extensive empirical research on innovation policies provides enough evidence that ‘appropriability framework was strong on prescriptive generalities but it is very weak on precise guidelines for implementation (Mowery, 1983: p.36). A diffusion oriented approach, which is concerned with the utilization of the results of R&D, reduces the risk of policy misapplication. Policy paradigms and the context in which they are applied are proven to evolve rapidly. This suggests that only by adopting a constant learning attitude can government adjust its technology policy and avoid locking in an unfitted policy paradigm.

Risks of different nature are corollary of the intrinsic uncertainty characterizing technological change. While preparing and implementing technology policy, policy-makers deal with the economic, political, technological, and/or organizational risks. Even if they are poorly endowed with in-depth understanding of technology, policy makers decide about long term, massive, and expensive investments designed to support the technological change.

Furthermore, technology policy is a multi-dimensional effort that relies on the interrelatedness among the policy variables. This supermodularity generates cumulative and circular (virtual or vicious) causation. So, the change of one policy variable may have no effect, or even may generate an undesirable effect, if other policy variables are not changed at the same time (Mohnen and Röller, 2005). Empirical evidence indicates that the prevalence of complements depend on the phase of the innovation process (Zollo and Winter, 2002; Mairesse and Mohnen, 2009).

Time is a central dimension of technology policy learning. Several authors have considered technology policy in a life cycle context. According to Niosi and Belloni (1990) a policy life cycle helps to understand the context in which policies are conceived, developed and selected. Avnimelech and Teubal (2007) propose a generic catching up technology policy model which considers policy making as a multi-phase process. In authors view, life cycle is a helpful tool for underpinning the strategic priorities of the public intervention. Then, policy makers should prepare and apply a policy portfolio which is adequate to the specific objectives of each life cycle stage (creation of an innovation system, its development or its continuous improvement).

The following section explores the co-evolution of the Canadian aircraft industry system of innovation with Canadian technology policy.

4. The Canadian aircraft industry dynamics

Canada has a small domestic market and relatively modest defense and space programs. 78% of Canadian aircraft industry output is for civil use, as compared with 44% in the US. Nonetheless, the country ranks 5th in world aerospace sales and employment after US, UK, France, and Germany, and ranks 3rd in world civil aircraft production after US and France. Canada has attained world leadership in several industry sectors such as the regional and business aircraft sector (47 % of the world production); flight simulators (70 %), landing gears for large transport aircrafts (60 %), and environment control systems (60 %) (Boily, 2006). What are the roots of excellence of the Canadian aircraft industry? This section retraces the dynamics of the Canadian aircraft industry catching up and identifies how public policy has affected these dynamics.

4.1 Lagging behind: a self-organized system & a few sporadic public initiatives

The Canadian aircraft industry had a slow start. Two important waves characterized the emergence of the Canadian aircraft industry. They both represented private initiatives which gained importance during the Word Wars and faded immediately afterwards.

Canadian Aerodrome, founded in 1909, was the first Canadian firm dedicated to the production of flying machines. It was a derivative of Aerial Experiment Association (AEA) whose founder was Alexander Graham Bell. The famous inventor motivated two of his colleagues to continue their efforts in finding practical utility of the flying machines. They successfully built two flying machines which both crashed during the flying tests which in turn sealed the fate of the company. In 1915, on the verge of WWII, the American company Curtiss-Wright established a subsidiary in Toronto. Its aim was to benefit from the military orders of both Canadian and British governments, but the Canadian government created in 1916 its own experimental center, the Canadian Aeroplanes. During the two following years, without surprise, Canadian Aeroplanes received most of the aircraft orders related to public procurement and produced 1243 planes. The company was dissolved after the Armistice. Curtiss Aeroplanes & Motors of Canada also ceased activity in 1919, after having produced only 30 planes. As shown in Table 1, some twenty Canadian companies tried to design and built planes between 1909 and 1920. Some 38 prototypes were built but could not reach technological and commercial success. The majority of these firms did not survive the first year of existence. Apart for the planes produced during 1917 and 1918 by Canadian Airplanes, only 63 planes were produced in Canada between 1909 and 1920. During the same period, 17674 planes were built in the United States.

Table 1 about here

Contrary to what happened to the United States, where the pioneers of the aircraft industry worked simultaneously to build their aircrafts and created a market for them, in Canada the success of air transportation preceded the domestic aircraft production activity. Canada’s rapid adoption of aircraft as a means of transportation was accelerated by the large geographical distances separating dispersed populations, the lack of infrastructure connecting several corners of the country, as well as the concentration of most natural resources (forestry, copper and gold mines) in the country's Northern regions. By the end of WWI, most of southern Canada had been linked by railways, but the North remained as inaccessible as ever by land. Its innumerable lakes and rivers did, however, provide a landing place for water-based aircraft in summer and ski-equipped aircraft in winter. Laurentides Air Service was the first transporter, which formally started its activity in 1920. This Quebec company carried out air-mail, passenger, and freight services in Quebec and Ontario. Then, air transportation spread gradually in Ontario and in the Canadian western provinces. However, all the aircrafts circulating in the Canadian sky were bought or rented in the United States.

Meanwhile, the Canadian military demand for aircraft was nonexistent. ***Compared to the other developed countries, the Canadian government showed the least level of interest in the aircraft industry***. This disinterest persisted even during the First World War. Finally in 1918, when a few German submarines approached the Nova Scotia's coasts, did the Canadian government create the Royal Canadian Naval Air Force, equipped with British planes. In 1922, a government commission concluded that from the point of view of planes manufacturing, the country lagged far behind other countries. However, no concrete initiatives were undertaken to change this situation.

A second wave of solely private initiatives was accountable for the resurgence of the Canadian aircraft industry in the late 1920s. Some twenty firms carried on aircraft manufacturing activities. Some were subsidiaries of American and British companies'. For instance, Fairchild Aircraft (1929), Boeing Aircraft of Canada (1929), Fleet Aircraft of Canada (1929) were subsidiaries of American companies. In 1927, because of its non-Canadian nationality, Fairchild was ruled out of the contracts for the Canadian air-mail. To avoid this in the future, the company decided to create a subsidiary in Canada. Boeing acquired a shipbuilding manufacturer from Vancouver and used it as a subcontractor whenever the demand for hydroplanes exceeded Boeing's own Seattle-based production capacity. In this context, the production of Boeing's Canadian site was intermittent. From 1932 to 1937 it didn't produce any aircraft. Fleet Aircraft also used its Canadian subsidiary to handle excessive demand. In 1934, the mother-company handed over to the Canadian subsidiary the production of 34 planes which were ordered by China.

Canadian companies such as Ottawa Car & Aircraft (1927), MacDonald Bros Aircraft (1928), National Steel Car & Victory Aircraft (1935), and Canadian Car & Foundry (1936) also came into being during this second wave of aircraft firms' founding. Ottawa Car & Aircraft (OCA) was initially engaged in distribution and service operations on behalf of Armstrong Siddeley (GB) and Consolidated (US) and then upgraded its technological capabilities and became a subcontractor for Armstrong Siddeley, Consolidated, and other aircraft companies. Furthermore, Reid & Curtiss-Reid Aircraft and Noorduyn Aircraft were two notable spin-offs firms. Thomas Reid left Canadian Vickers and launched his own firm in 1928. In 1934, after working several years for Fokker and Bellanca (both American companies), Robert Noorduyn decided to start his own company in Montreal, Quebec. The City's primary attributes were availability of capital and favorable geographical location. Noorduyn became one of the most eminent airframe manufacturers of the Canadian aircraft industry, while Thomas Reid's firm went bankrupt in 1932 due to the Great Depression

Government's role during this period remained modest and was mostly focused on attracting foreign investments in this sector. In 1928, by opening the door of potential access to public procurement, the Canadian government convinced the British company De Havilland to invest in a Canadian subsidiary. Also, a few years before then, determined to stimulate Canadian naval construction, the government had solicited several British shipbuilding manufacturers to invest in Canada. One of them, Vickers Co., responded positively by establishing a division in Canada in order to benefit from aircraft orders from the Royal Canadian Navy. In 1923, Canadian Vickers entered into the aircraft manufacturing business and won a contract to supply Vickers Viking flying boats to the recently formed Canadian Air Force. Table 2 summarizes the factors that determined the location of aircraft firms during this emergent period.

Table 2 about here

The choice of location of the young Canadian firms indicates a strong dependence on established industrial paths. It was the presence of formative industries, such as automobile industry in Toronto, or shipbuilding and railroad construction in Montreal, that conferred an important advantage to these cities. Most of these new Canadian aircraft manufacturers were previously involved in one of these formative activities and converted thereafter, partly or entirely, to aircraft manufacturing. Such was the case of Canadian Vickers, the National Steel Car & Victori Aircraft, and the Canadian Car & Foundry. The choice of Boeing for its Canadian subsidiary, the Hoffer-Beeching Shipyards, combined Boeing exigencies for pre-existing know-how and the proximity with its own facilities in Seattle. This proximity was also taken into account by Fleet aircraft and Curtiss-Wright. After comparing Toronto and

Montreal, Fairchild chose to establish its manufacturing facility to the later due to more suitable conditions of landing of its seaplanes. Noorduyn almost settled in New Brunswick in order to merge with the local firm Saint John Drydock and Shipbuilding. However, an industrialist from Montreal, W.R.G. Holt, became its principal shareholder and attracted the company to Montreal. During this time of emerging companies, government influenced a limited number of cases. One example of government efforts to stimulate the development of the aircraft industry throughout Canada was the government's contract services with MacDonald Bros Sheet Metal and Roofing located in Winnipeg. The firm became MacDonald Bros Aircraft thereafter.

From 1940 to 1944, Canadian aircraft manufacturers contributed greatly to the WWII efforts by producing some 15649 aircraft. In 1944, the five largest Canadian aircraft manufacturers had 43557 employees, shared respectively as following: Nooduyn Aviation (12000 employees); Canadian Car and Foundry (10000 employees); Fairchild (9620 employees); Canadian Vickers (9000 employees), and Fleet (2937 employees). Canadian firms produced and assembled mainly training aircraft and several types of multi-uses plains like Norseman of Nooduyn Aviation which was one of the few models designed in Montreal.

The scale and scope of the war efforts endowed Canadian aircraft firms with state-of-the-art aircraft technologies. As shown in Table 3, the Canadian planes were produced under license from British and American models. Only one out of twelve aircraft models built in Canada was based on an indigenous design. As Todd and Simpson (1986) stated, Canadian industry was then appendix of the American and British aircraft industries. The prewar inability to create indigenous aircraft models indicates the low level of technical and organizational capabilities of Canadian aircraft manufactures. The Canadian government followed a path that was much less ambitious than the other developed countries (US, United Kingdom, France, Germany) which showed more interest and offered more support to the newly formed aircraft industry. However, during WWII, Canada's aircraft manufacturers experienced an accelerated learning curve and expanded their activity far beyond the levels that would have been possible by following the pre-war rhythm of growth.

Table 3 about here

4.2 Forging ahead: the aircraft industry under the government wing

Despite its modest beginnings and without a strong military aircraft sector, the Canadian aerospace industry became one of the world's best. What are the modalities and features of this successful 'catching up'? ***Government technology policy became the main determinant factor of this process.*** Following the path of other developed countries, Canada moved from a traditional conception of the industrial policy according to which government's main role is to provide the basic economic infrastructures, toward technology policy where government plays an active role in promoting industrial development (Shin, 1996, Niosi, 2005 and 2010). Starting in the mid-1950s, still a new and fledgling industry, ***Canadian aerospace will henceforth be considered a highly strategic industry from the point of view of both national security and the promotion of the technological progress of the country***. Thus, from a sporadic contributor, the Canadian government became the principal determinant of the post war growth of the Canadian aircraft industry.

The catching up of the Canadian aircraft industry was a long and gradual process. Aiming to constitute a solid Canadian presence in the growing and promising civil aviation sector, at the end of the WWII and after the complete collapse of military demand, the Canadian government protected and subsidized the aircraft industry. In this context, the first crucial intervention by the government was to ***secure strategic investments to the industry but by targeting in the same time only a few winners.*** In terms of selection, government choices reflected a recently learned lesson. During the war, due to the shortage of airplanes, the United States and United Kingdom denied Canada's requests for military aircraft, even during the time that the Japanese army was seriously threatening the Canadian West Coast. After being denied the purchase of Hawker Hurricanes that were being produced in Fort William, Ontario, the Canadian government realized the importance of ***developing an independent aircraft industry*** (Molson and Taylor, 1982).

In 1944, Canadian Vickers decided to reorient its activity by focusing solely on shipbuilding and withdrew from the aircraft sector. The government acquired the Canadian Vickers aircraft division and founded Canadair whose first mandate was the conversion of a few thousand military aircraft to civilian use. At the same time, Ottawa bought from Douglas Co. the license of the C-54/DC-4. With these successful acquisitions, Canadair produced its first commercial success, the North Star, and monopolized the orders from Royal Canadian Air Force, Trans-Canada Airlines, and Canadian Pacific Airlines. In 1947, now well on track, Canadair was acquired by the Electric Boat Company, which in 1952 became General Dynamics. The privatization of government-owned companies was forced primarily by

Clarence Decatur Howe, then the Canadian Minister of Transports, whose objective was to maintain a viable Canadian aircraft industry. Minister Howe was a central figure in shaping the future of the Canadian aircraft industry. His personal involvement went as far as bringing a former vice-president of Boeing, H. Oliver West, to be the head of Canadair,. West's most remarkable contribution was the transformation of Canadair ton a Tier 1, system assembling company. De Havilland was the other aircraft manufacturer that received strong public support. Also, in 1945, after three years of negotiations, the Canadian government attracted to Toronto a subsidiary of the British airframe manufacturer A.V. Roe.

After being excluded by this 'select club' of firms receiving public support, several airframe manufacturers closed their doors. Examples included Noorduyn Aviation (ended the activity in 1945), Boeing Aircraft of Canada (ended the activity in 1945), Ottawa Car & Aircraft (1947), and Fairchild Aircraft (1948). Canadian Car & Foundry (CCF), which was the second largest airframe manufacturer in Canada at the end of the WWII, tried to survive by drastically reducing its activities. In the years following War, the company's facilities downsized from 1,700,000 to only 157,930 square feet. In 1955, CCF was acquired by Avro. Fleet adjusted by downgrading its activity and becoming a supplier for Canadair, Avro, and Republic. MacDonald Bros tried to find a niche in the armament sector.

The after War winners - targeting public procurement and subsidies shaped the future of the Canadian aircraft industry. In the next decade, Canadair, Avro, and De Havilland controlled 84 % of overall Canadian aircraft production. As shown in Figure 1, this level of consolidation was common to all the aerospace countries. However, the limited aircraft market and the companies' lack of resources accelerated the rationalization and concentration of the Canadian industry. Figure 2 shows the effects of the 'winners' selection' policy.

(Figure 1 and 2 about here)

Parallel to the efforts of supporting national champions, the Canadian ***government invested for the development of diversified and multidisciplinary R&D infrastructure.*** Created in 1916, the National Research Council (NRC) became after the WWII a multidisciplinary network of public institutions that helped the aircraft industry transform into a leader in aerospace innovation Also during this time, the government strongly supported the ambitious innovation projects of private companies. For instance, in the case of the Jetliner project of Avro, public financial participation increased to 75 % of overall R&D expenditures.

The third major aspect of public intervention in developing the Canadian aircraft industry ***was the successful integration of the industry within the US market***. In 1957, Canada and the United States signed the North American Air Defense Agreement (NORAD) which stipulated the creation of a bi-national defense command. One of the positive consequences of this agreement was full access of Canadian companies to the US market, including the US defense-related public procurement. This was of great importance because the ‘Buy American Act’, made the US market impenetrable to foreign firms. Since the long years of the Vietnam conflict, Canadian aircraft companies have directed almost all of their exports towards the US military market (Todd and Simpson, 1986).

However, the aircraft industry is known for cyclic growth, and if the Canadian aircraft industry benefited during the rapid expansion of the American demand, it also paid a high price during the period of stagnation or contraction. This was the case in the mid 1970s. Following the drastic reduction in American demand of the Canadian aircraft industry, employment decreased from 48.000 to 25.000 in 1976 (Todd and Simpson, 1986).

This downsizing period in the aircraft industry coincided with the introduction of the Canadian government’s national strategy for diversifying the productive structure in order to reduce dependence on natural resources. Theircraft industry remained in the group of industries considered as essential vectors for Canadian technological development. This ensured long term and solid public support of the Aircraft industry. The government’s determination to drive the aircraft industry toward the best international standards was made clear in 1974. When the British group Hawker Siddeley decided to shut down the DHC Dash 7 program at its Canadian subsidiary De Havilland, the Canadian government nationalized the company and financed the rest of the project. This avoided the potential risk of downgrading the airframe manufacturer to an outsourcing company.

At the same time, Canadair was also going through a very difficult period. The company’s efforts to diversify were not successful. The industry’s downturn in the mid 1970s caused Canadair to reduce its workforce from 9250 to 2000 (Pickler and Milberry, 1995). In 1976, in order to prevent the company’s loss, the federal government acquired Canadair for the second time in twenty years.

The analysis of this period emphasizes a successful combination of private and public efforts which helped the Canadian aircraft industry to overcome the world recession. While De Havilland kept working on the Dash 7 program, Canadair launched the Challenger project.

The infallible public support helped the two manufacturers to face innumerable technical, financial or organizational uncertainties and risks inherent to their ambitious innovation projects.

In the mean time***, the government wisely used its trade and foreign investment policy to obtain from the American partners considerable offsets*** which involved strategic outsourcing such as technology transfer or components that went far beyond what would normally have been assumed to be commercially necessary (Mowery, 1999). Canada was the foreign country that received the largest offsets from American public or private sector companies. Furthermore, by offering different types of incentives, the Canadian government was the main force behind the decision of world's aircraft industry leaders to invest in Canada. Public incentives are the main explanation of the De Havilland (1928), Pratt and Whitney (1928), Avro (1945), and Bell Helicopter Textron (1984) decisions to establish their respective Canadian subsidiaries.

4.3 The challenges of maturity phase: from 'catching up' to 'keeping up' technological policies

After the privatization in the 1980s of the aircraft industry, government remained a key actor. However, its role and modalities of supporting the industry have changed radically. Without becoming a passive protector of the aircraft industry, ***government distanced itself from the industry strategic decisions which were thereafter the prerogative of the system integrators.*** For instance, the decisions of Bombardier to acquire the Irish Short Brothers (in 1989), the American Learjet (in 1990) or De Havilland (in 1992) was a result of the company's strategic vision of becoming the world leader in the business and regional aircraft niche. Yet, attaining this objective would have not been possible without the persistent support of both federal and provincial governments.

Furthermore, significant industry reorganization occurred by the end of the 1970s. The increasing product complexity, the explosion of the R & D expenditures, and the persistent pressure of the budgetary constraints forced the main aircraft manufacturers to focus their activity toward the core competences or the sources of their competitive advantage. The aircraft is an assembly of interdependent subsystems that are designed to perform a particular function. This highly modular architecture of aircraft was very favorable to the industry's reorganization. A three-level hierarchical industrial structure emerged with the top (Tier 1) being the system integrators or the prime contractors which are in charge of the design, development, and final assembling of aircraft. In the second level (Tier 2), there are Original Equipment Manufacturers (OEM) or the subsystems suppliers which are responsible for the assembling of the main aircraft subsystems (for instance, avionics, airframe systems or power plants). At the bottom (Tier 3), there are the subcontractors who offer specific components or services.

The reconfiguration of the inter-firms' relationships had a double effect on the regional and national airspace innovation systems. On one hand, the new hierarchical organization of the aircraft industry was followed by an increasing geographical densification of the firms. The presence in a region of one or a few prime, tier I aircraft contractors exerted a powerful attraction of Tier 2 and Tier 3 firms. This was the case of the Montreal aerospace cluster, where the presence of Bombardier, Bell Helicopter, and Pratt and Whitney attracted a considerable number of other aerospace related firms. In 1970, there were 50 firms in Montreal, there were 100 firms in 1985, while presently, the Montreal aerospace cluster counts some 250 Tier 1 and Tier 2 firms.

On the other hand, the new hierarchical industry configuration transformed the relationships among the firms. In the traditional context, the interactions were sporadic, of short duration, and driven mostly by the market, the price being the principal criterion of choice of the subcontractor (Lefebvre and Al, 1993; Bourgault, 1997). In this new context, relationships were longer term and indicated proactive exchanges among the partners. The prime contractors drove the system toward higher quality standards and the sub-system assemblers and, to a lesser degree, the subcontractors participated in the prime contractors' innovation efforts (Lefebvre and al, 1993).

Universities and public R & D laboratories have also multiplied the links with the industry. Attentive to the industry needs, the Canadian government has continuously upgraded the public R & D infrastructure with specialized laboratories or national agencies (for example the Canadian space agency). By combining horizontal and vertical policy programs, government has evolved from a few intensive partnerships with the major aircraft industry firms toward a more SME inclusive programs.

Universities role also has progressively grown by transforming their role from centers for preparing a highly skilled labor supply toward active industry partnerships in innovation projects. Conversely from other knowledge intensives sectors, where research universities are a major source of knowledge spillovers and many spin-off firms are created, in the case of the aircraft industry, it is the private sector that has taken the lead of R & D and launched many initiatives involving universities in research projects.

Since its beginnings, the aerospace industry has been global in terms of market. Furthermore, since the 1980s, its supply chain has also become increasingly international. In search of foreign governments subsidies and access to markets, risk-sharing collaborations, and lower production costs, system integrators have established a close international network. Presently, system integrators have engaged in an active supply chain transforming process intended to reduce the number of suppliers by going from one-to-many to one-to-few relationships. The high degree of activity concentration that characterized the Tier 1 and Tier 2 levels of the industry reduces the choice of OEM (subsystem integrators) and increasingly orients the prime contractors toward the international supply chain. Figure 3 represents the globalization of Bombardier's supply chain. Only 18% of Bombardier's suppliers are Canadian firms.

Several authors have noticed that the acceleration of the globalization process of the aerospace industry is increasingly disrupting the traditional interaction of local actors and is redefining the role of national governments (Talbot, 1998; Bélis-Bergouignan and al, 2001; Iaurif, 2005; Frigant and al., 2006). The same phenomenon is observed in the case of Canadian aircraft innovation systems which calls for policies able to reinvent the relationships between the local actors. The ability to stimulate the upgrading process of the Tier II firms in subsystem integrators has become a great challenge for policy-makers. Figure 5 represents the complexity of the R&D life cycle and its financing network.

Figure 4 about here

In this context, the growth and maturity stage of the aircraft industry is characterized by far more complex dynamics compared to the emergence period. The number and type of actors, and as a result, the decision-making centers are more diversified and dispersed, which directly affects the efficacy of the top-down type of public policy. Table 4 shows some Canadian technological policy instruments dedicated to the aerospace industry.

Table 4 about here

5. Conclusion

The Canadian aerospace industry 'catching up' was a long and complex process. Benchmarking, learning by doing, and trial and error policies are at the base of the level of excellence obtained by the Canadian aircraft industry. Substantial and continuous long term government support to the industry was a key success factor. Government was the driving force during the growth phase of the industry. Public support was central to all aircraft development initiatives. Many of them failed to deliver a successful model. However, each of them contributed actively to the national knowledge base and competence accumulation which were transformed into commercial successes in later programs. This is the case, for instance of Challenger 600, which was a commercial failure with only 83 aircraft sold. Yet, this program was the basis of a successful business aircraft venture launched by Bombardier a few years later. Also Bombardier's CRJ aircraft program, still the most important commercial success in terms of civil aviation (1500 aircraft sold), was based on the Canadair CL601RJ program that was developed when Canadair was a public organization. Many other examples indicate that Canada has been able to benefit by knowledge externalities (Oswald, 2004). The analysis of the 'catching up' of the Canadian aircraft industry shows that proactive learning followed by continuous policy adjustments were the keys to avoid a lock-in situation and improvement in national and regional innovation systems performance.

However, the issue of how radically new knowledge is produced, and redefines 'best practice' as radical innovations are created, is left largely unexplored and merits further investigation (Odgaard and Hudson, 1998). Only a few countries have successfully learned and have been able to make the change from one development trajectory to another. But many others continue to be unable to break their path dependences. The organizational learning perspective provides insightful elements towards an answer. Successful learning is bound by a conception of learning as a process rather than as an output (which is mostly the case). Also, learning and its output may be desynchronized in time and in space, so organizations should adopt a constant learning attitude.

References

Archibugi, D. and J. Michie (1997) «Technological globalization or National systems of innovation». *Futures*. 29 (2):121-137.

Amsden, A.H. (2001) *The Rise of "The Rest", 1850-2000: Late Industrialization Outside the North Atlantic Economies*. Oxford: Oxford University Press.

Argyris, C. (2005) «Double-Loop Learning in Organizations: A Theory of Acton Perspective» in Smith, K. G. and M.A. Hitt (Eds) *Great minds in Management: the process of theory development.* Oxford; Toronto: Oxford University Press, 261-279.

Arthur, W.B. (1994) *Increasing Returns and Path-Dependence in the Economy*, Ann Arbor: University of Michigan Press.

Auluck, R. (2002) «Benchmarking: A tool for facilitating organizational learning?» *Public Administration and Development*. 22: 109-122.

Bélis-Bergouignan, M.-C., Frigant,V. et D. Talbot. 2001. "L'articulation global/local des modèles industriels pharmaceutique, automobile et aéronautique." Notes de recherche no.2001-6. Equipe Industries Innovation Institutions, Université Bordeaux IV.

Bierly III, P.E., Damanpour, F. and M.D. Santoro (2009) « The Application of External Knowledge: Organizational Conditions for Exploration and Exploitation» *The Journal of Management Studies*. Oxford. 46 (3): 481-502.

Busenberg, G.J. (2001) «Learning in Organizations and Public Policy» *Journal of Public Policy*, 21(2): 173-189.

Cantner, U. and A. Pykas (2001) «Classifying technology policy from an evolutionary perspective» *Research Policy*, 30 (5):759-775.

Castaldi, C., Cimoli, M., Nelson C. and G. Dosi (2004) «Technological Learning, Policy Regimes and Growth in a 'Globalized' Economy: General Patterns and the Latin American Experience.» *LEM Working Paper*.

Cimoli, M., Dosi, G. and J.E. Stiglitz (2008) «The Political Economy of Capabilities Accumulation: the Past and Future of Policies for Industrial Development», LEM Working Paper Series, Sant'Anna School of Advanced Studies, Pisa, Italy.

Cohen W.M. and D.A. Levinthal (1989) «Innovation and Learning : The two faces of R&D». *The Economic Journal*. 99 (397): 569-596.

Common, R. (2004). «Organisational Learning in a Political Environment: Improving policy-making in UK government.» *Policy Studies*, Vol. 25, No. 1, pp. 35-49.

Crossan, M.M., Lane, H. W. et R.E. White (1999). «An organizational learning framework: from intuition to institution» *Academy of Management Review*, 24 (3): 522-537.

Easterby-Smith, M., M. Crossan and D. Nicolini (2000) «Organizational learning: Debates Past, Present and Future». Journal of Management Studies. 37(6):783-796.

Easterby-Smith, M. and M.A. Lyles (Eds) (2003) *The handbook of organizational learning and knowledge management*. MA, USA; Oxford, UK : Blackwell Publishing.

Edquist, C. 2005) «Systems of innovation: perspectives and challenges» in Fagerberger, Mowery, Nelson Oxford handbook of innovation, Oxford University Press, 181-208.

Ergas, H. (1987) «The importance of technology policy. » In: Dasgupta, P., Stoneman, P. (Eds.), *Economic Policy and Technological Performance*. Cambridge Univ. Press, Cambridge.Hall.

Iaurif, T. P. 2005. La filière industrielle aérospatiale en Ile de France: état des lieux et enjeux. Paris: Institut d'aménagement et d'urbanisme de la région d'Ile de France.

Hedberg, B. (1981) *How organizations learn and unlearn. Handbook of organizational design*. London: Oxford University Press.

Heclo, H. (1974) Modern Social Politics in Britain and in Sweden. New Haven, CT: Yale University Press.

Getha-Taylor, H (2008). «Learning indicators and collaborative capacity: applying action learning principles to the U.S. Department of Homeland Security» Public Administration Quarterly. 32(2): 125-147.

Greve, H.R. (2003) Organizational Learning from Performance Feedback. A Behaviooral Perspective on Innovation and Change. Cambridge: Cambridge University Press.

Fiol, M.C. and M. A. Lyles (1985) Organisational learning. *Academy of Management Review.* 10 (4) : 803-813.

Frigant, V., et D. Talbot. 2003. "Convergence et diversité au passage à la production modulaire dans l'aéronautique et l'automobile en Europe." Présenté à la 135ème journée de travail du GERPISA, MSH-EHESS, Paris, février.

Fuchs, G and P. Shapira (Eds.) (2005) *Rethinking regional innovation and change: path dependency or regional breakthrough*. New York : Springer.

Lall,S. and M. Teubal (1998) «Market-Stimulating technology policies in developing countries : a platforme with examples from East Asia» *World Development*. 26 (8) : 1369-1385.

Lane, P. J., Koka, B. R. and S. Pathak (2006) «The reification of absorptive capacity: a critical review and rejuvenation of the construct» *Academy of Management Review*. 31: 833–63.

LaPalombara, J. (2001) «Power and politics in organizations: public and private sector comparison» in Dierkes, M. et al. (eds.) *Handbook of Organizational Learning and Knowledge*, , Oxford University Press, 557-581.

Levitt, B. And J.G.March (1988) «Organizational learning» *Annual Review of Sociology*. 14: 319-340.

Lieberman, R.C. (2002) «Ideas, Institutions, and Political Order: Explaining Political Change» *The American Political Science Review*. 96 (4): 697-712.

Lundvall, B-A., Johnson, B., Andersen, E.S. and B. Dalum (2002) «National systems of production, innovation and competence building» Research Policy 31: 213–231.

March, J. G. and J.P. Olsen (1975) «Organizational learning under ambiguity» European Journal of Policy Review, 3 (2): 147-71.

Moynihan, D. P. and N. Landuyt (2009) «How do Public Organizations Learn? Bridging Structural and Cultural Divides» *Public Administration Review,* 69 (6): 1097-1105.

Mowery, D.C. (1983) «Economic Theory and Government Technology Policy» *Policy Sciences*, 16 (27-43).

Nelson, R.R. (2008) «Bounded rationality, cognitive maps, and trial and error learning». Journal of Economic Behaviour & Organization» 67: 78-89.

Nelson, R.R. (1959) « The Simple Economics of Basic Scientific Research." *Journal of Political Economy*. 67: 297-306.

Nelson, R.R. and P. M. Romer (1996) «Science, Economic Growth and Public Policy» Challenge, 39: 9-21.

Niosi, J. (2010) *Building National and Regional Innovation Systems. Institutions for Economic Development*. Cheltenham, Edward Elgard Publishing.

Niosi, J. (2005) *Canada's Regional Innovation System: The Science-based Industries. Montreal*, McGill-Queen's University Press.

Niosi J. and B. Bellon (1990) «Une interprétation évolutionniste des politiques industrielles» *Revue d'économie industrielle*. 71 : 213- 226.

Nonaka, I. (1994) « A dynamic theory of organizational knowledge creation» Organization Science, 5 (1): 14-37.

Nutt, P.C. (2005) «Comparing Public and Private Sector Decision-Making Practices» *Journal of Public Administration Research and Theory*. 16:289-318.

Rainey, G.H. and B. Bozeman (2000) «Comparing public and private organizations: empirical research and the power of the a priori» *Journal of Public Administration Research and Theory.* 10 (2): 447-470.

Rainey, H.G. (2009) *Understanding and managing public organizations,* San Francisco, California: Jossey-Bass.

Rose, R. (1991) «What Is Lesson-Drawing? » *Journal of Public Policy*, 11(1): 3-30.

Rothwell R. and W. Zegveld (1981) *Industrial innovation and public policy: preparing for the 1980s and the 1990s*. London: F. Pinter.

Pierson, Paul (2000) «Increasing Returns, Path Dependence, and the Study of Politics» *The American Political Science Review*. 94(2): 251-267.

Prange, C. (1999) «Organizational Learning. Desperately Seeking Theory?» in Easterby-Smith, L. Araujo and J. Burgoyne (Eds) *Organizational Learning and the Learning Organization: Developments in Theory and Practice*, London: Sage Publications, 23-43.

Powell, W. W. , K. W. Koput, and L. Smith-Doerr. 1996. "Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology." Administrative Science Quarterly 41:116-145.

Teubal. M. (1996) «R&D and technology policy in NIC as learning processes.» *World Development*, 24(3): 449-460.

Turc, E. and P. Baumard (2007) « Can Organizations Really Unlearn? » in McInerney, C. R. and R. E. Day *Rethinking Knowledge Management: From Knowledge Objects to Knowledge Processes.* Springer Berlin Heidelberg.

Sabatier, P. and H. Jenkins-Smith (Eds) (1988) «Special Issue: Policy Change and Policy-Oriented Learning: Exploring an Advocacy Coalition Framework» *Policy Sciences.* 21:123-278.

Sanchez, R. (2005) «Personal Knowledge versus Organizational Knowledge Approaches to Knowledge Management Practice» in Rooney, D., Hearn, G. and A. Ninan (Eds) *The Knowledge Economy Handbook*, Oxford: Routledge.

Shapira P. and S. Kuhlmann (Eds.) (2003). *Learning from science and technology policy evaluation : experiences from the United States and Europe.* Cheltenham, UK ; Northampton, MA : Edward Elgar Pub.

Smith, K. G. and M.A. Hitt (eds) (2005) *Great minds in Management: the process of theory development.* Oxford ; Toronto : Oxford University Press.

Van den Bosch, F., Van Wijk, R. and H. W. Volberda (2003) «Absorptive capacity: Antecedents, Models and Outcomes» in Easterby-Smith and Lyles (Eds) (2003) *The handbook of organizational learning and knowledge management*. MA, USA; Oxford, UK : Blackwell Publishing, 278-302.

Wenger, E. (1998) «Communities of practice: learning, meaning, and identity» Cambridge: Cambridge University Press.

Zahra, S. A. and G. George (2002) «Absorptive capacity: a review, reconceptualization, and extension» Academy of Management Review, 27: 185–203.

Tables and Figures

Table 1: Canadian aircraft constructors, 1909-1944

Canadian aircraft constructors, 1909-1944	Localisation		Start of production	End of production	Number of aircraft produced
	City	Province			
Bell Laboratory	**Beinn Bhreagh**	**New Scotland**	**1909**	**1912**	
Canadian Aerodrome	**Halifax**	**New Scotland**	**1909**	**1910**	**3**
Guaranty Iron Works Aircraft	**Winnipeg**	**Manitoba**	**1910**	**1914**	**3**
W.W.Gibson	**Victoria**	**British Columbia**	**1910**	**1911**	**2**
P.H.Reid	**Montreal**	**Quebec**	**1911**	**1914**	**4**
W.P.A.Straith	**Winnipeg**	**Manitoba**	**1911**	**1912**	**2**
G.& 'Ace' Pepper	**Davidson**	**Saskatchewan**	**1911**	**1911**	**1**
W.&W Templeton & McMullen	**Vancouver**	**British Columbia**	**1911**	**1911**	**1**
H.E. Clarke	**Vancouver**	**British Columbia**	**1912**	**1923**	**2**
G.Pollien	**Montreal**	**Quebec**	**1912**	**1912**	**1**
Canadian Aircraft Works	**Montreal**	**Quebec**	**1914**	**1914**	**2**
Pollay Bros	**Belleville**	**Ontario**	**1914**	**1914**	**1**
Curtiss	**Toronto**	**Quebec**	**1915**	**1919**	**30**
J.& H. Hoffar	**Vancouver**	**British Columbia**	**1915**	**1919**	**3**
E.D. Bonisteel	**Toronto**	**Ontario**	**1915**	**1915**	**1**
F.Kent	**Vancouver**	**British Columbia**	**1915**	**1915**	**1**
R.McDowall	**Owen Sound**	**Ontario**	**1915**	**1915**	**1**
Hamilton Aero	**Vancouver**	**British Columbia**	**1916**	**1916**	**1**
Polson Iron Works	**Toronto**	**Ontario**	**1916**	**1916**	**1**
Canadian Aeroplanes	**Toronto**	**Ontario**	**1917**	**1918**	**1243**
Ericson Aircraft	**Toronto**	**Ontario**	**1920**	**1926**	**37**
Canadian Vickers	**Montreal**	**Quebec**	**1923**	**1944**	**532**
J.V.Elliot	**Toronto**	**Ontario**	**1925**	**1927**	**7**
Reid-Curtiss	**Montreal**	**Quebec**	**1928**	**1932**	**44**
Canadian Aircraft	**Winnipeg**	**Manitoba**	**1928**	**1928**	**1**
Fleet Aircraft	**Fort Erie**	**Ontario**	**1930**	**1947**	**2720**
Fairchild Aircraft	**Montreal**	**Quebec**	**1930**	**1945**	**989**
Boeing of Canada	**Vancouver**	**British Columbia**	**1930**	**1945**	**389**
O&W McVean	**Chatham, Dresden**	**Ontario**	**1930**	**1931**	**2**
G.W Saynor & R.N.Bell	**Montreal**	**Quebec**	**1930**	**1930**	**1**
Noorduyn Aviation	**Montreal**	**Quebec**	**1935**	**1945**	**3703**
Opas	**Toronto**	**Ontario**	**1935**	**1937**	**4**
Canadian Car& Foundry	**Montreal; Hamilton**	**Ontario; Quebec**	**1938**	**1945**	**3612**
De Havilland of Canada	**Toronto**	**Ontario**	**1938**	**1947**	**2600**
National Steel & Car	**Toronto; Montreal**	**Ontario; Quebec**	**1939**	**1943**	**961**
Canadian Associated	**Montreal; Toronto Winnipeg**	**Quebec; Ontario Manitoba**	**1940**	**1942**	**160**
Noury Aircraft	**Hamilton**	**Ontario**	**1940**	**1940**	**3**
McDonald Bros Aircraft	**Winnipeg**	**Manitoba**	**1941**	**1945**	**1067**
Ottawa Car & Aircraft	**Ottawa**	**Ontario**	**1941**	**1942**	**60**
Federal Aircraft	**Montreal**	**Quebec**	**1941**	**1943**	**2**
Victory Aircraft	**Toronto**	**Ontario**	**1943**	**1945**	**432**

Table 2: Canadian industry location factors

Location factors	City	Company name
Path dependence	**Montreal; Toronto; Vancouver; Winnipeg**	**Canadian Car &Foundry/ National Steel Car & Victory Aircraft/ Boeing Aircraft of Canada/McDonald Bros Aircraft**
Geographic proximity	**Fort Erie/Vancouver/Toronto**	**Fleet Aircraft of Canada/Boeing Aircraft of Canada/Curtiss Aeroplanes**
Proximity to investors	**Montreal**	**Noorduyn Aircraft/Reid& Curtiss-Reid Aircraft**
Favorable site conditions	**Montreal/Toronto**	**Fairchild Aircraft/De Havilland of Canada**
Government decision	**Winnipeg**	**McDonald Bros Aircraft**
Spin-off	**Montreal**	**Reid& Curtiss-Reid Aircraft**
Historical accident	**Montreal**	**Canadian Vickers**

Table 3: The origin of Canadian aircraft designs

Aircraft manufacturer	Aircraft Model	Number of aircraft produced	Aicraft designer company	Country of origine of aircraft designs
Nooduyn Aircraft/Aviation	Harvard IIB	2800	North America	United States
Fleet Aircraft	PT-26 Cornell	1642	Fleet	United States
DHC	DHC 2 Beaver I	1631	De Havilland	United Kingdom
Canadian Car & Foundry	Hawker Hurricane	1451	Hawker Aircraft	United Kingdom
Candian Aeroplanes	JN-4 (Canadian)	1210	Curtiss	United States
Canadian Car & Foundry	SBW Helldriver	835	Curtiss	United States
Nooduyn Aircraft/Aviation	Norseman VI	756	Nooduyn Aircraft/Aviation	Canada
MacDonald Bros Aircraft	652A Anson V	748	Avro	United Kingdom
National Steel Car	652A Anson II	736	Avro	United Kingdom
Fleet Aircraft	16	435	Fleet	United States
Victory Aircraft	683 Lancaster X	422	Avro	United Kingdom
Fairchild Aircraft	Bolingbroke IVT	407	Bristol	United Kingdom
DHC	D.H.98 Mosquito B.25	400	De Havilland	United Kingdom
DHC	DHC-6 Twin Otter 300	380	De Havilland	United Kingdom

Source: Prepared from data shown in K.M.Molson et H.A.Taylor (1982). Canadian Aircraft since 1909. Great Britain: Canada's Wings Inc.

Table 4: Canadian Technology policy supporting tools to the aerospace industry

Aerospace public support mechanisms	Public Policy objectives	Tools
Financing R&D programs in public laboratories and Universities	Increasing the global competitiveness of Canadian industry by engaging all of national competencies in the development and application of leading aerospace technologies.	
1. NRC Aerospace	- Ensuring industry's access to technical expertise and information - Ensuring industry's access to national test facilities and data bases - Encouraging cost-shared programs with Canadian and foreign aerospace firms	- Annual budget of $64M - 5 laboratories - Major facilities: 8 wind tunnels; 8 research aircraft; Full-scale structural test rigs; Engine and combustion test cells; Materials characterization and testing equipment; Aero-acoustic reverberant chambers; Lubrication/ tribology test rigs; Flight Recorder Playback Centre; Manufacturing research facilities
2. National Research Council Industrial Research Assistance Program (NRC-IRAP)	NRC-IRAP provides a range of both technical and business oriented advisory services along with potential financial support to growth- oriented Canadian small and medium-sized enterprises.	- Nation-wide network of more than 260 Industrial Technology advisors in 100 communities across the country - Offers two kinds of financial assistance: - R&TD - provides mentoring support and invests on a cost-shared basis for research and pre-competitive development technical projects - Youth Employment Strategy Programs - provide firms with support to hire post-

3. Natural Science and Engineering Research Council of Canada (NSERC)	NSERC promotes and assists research in the natural sciences and engineering	secondary graduate - Fund more than 10,000 university professors every year and encourage more than 800 Canadian companies to invest in university research. - Several programs, including University and Industrial Research chairs - Over the last ten years, NSERC has invested $6 billion in basic research, university-industry projects, and the training of Canada's next generation of scientists and engineers.
<u>Fiscal incentives</u> The Scientific Research and Experimental Development tax credit. Canada offers one of the most favorable tax treatments for R&D among the G-7 members	Stimulate strong and permanent competitive R&D infrastructure investment	- Canada provides a system of tax credits and accelerated tax deductions for a wide-variety of R&D expenditures. - Eligible costs include: salaries, overhead, capital equipment, and materials
<u>Direct and indirect subsidies</u> 1. Funding technology development through Technology Partnerships Canada (TPC). 2. The Strategic Aerospace and Defense Initiative (SADI)	Funding pre-competitive aerospace and defense technology development. - Encourage strategic R&D that will result in innovation and excellence in new products and services - Enhance the competitiveness of Canadian aerospace and defense companies - Foster collaboration between research	Nearly $1.7 billion in technology development support to the aerospace and defense industry SADI was launched April 2, 2007 and is expected to invest nearly $900 million over the next 5 years

	institutes, universities, colleges, and the private sector	
3. Industrial and Regional Benefits Program (IRB)	The framework for using federal government procurement to lever long-term industrial and regional development.	A contractual commitment by prime contractor to place work in Canada as a result of successfully bidding a Canadian defense program. IRBs are mandatory for projects over $100 million (usually Major Crown Projects). Currently $10 billion under contract.
Collaboration enhancing initiatives 1) Office of Collaborative Technology Development, a public/private sector partnership 2) Technology Roadmaps	Defining and launching collaborative technology development Enable sector stakeholders to work on a collaborative basis to assist with the pre-competitive development of new technologies;	Established in 1999 to assist collaborative projects

Figure 1: Concentration and shakeout in Aircraft industry

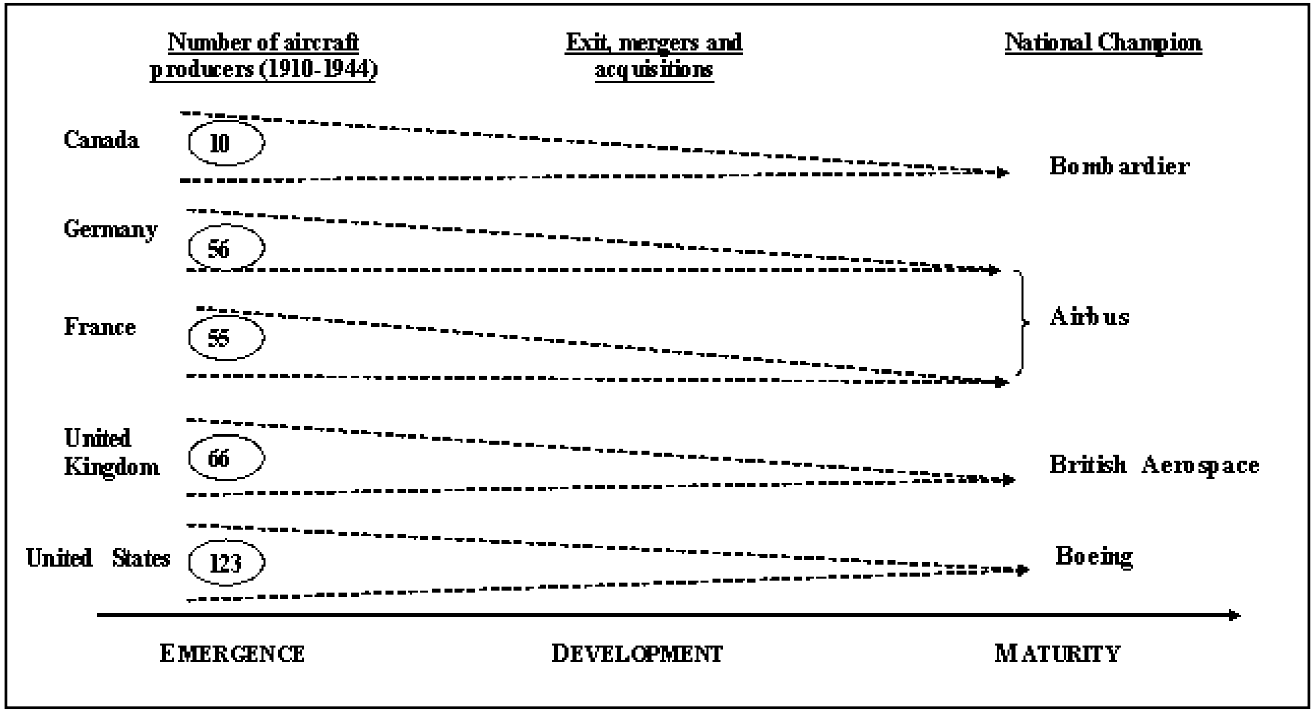


Figure 2: Concentration and shake out in the Canadian aircraft industry

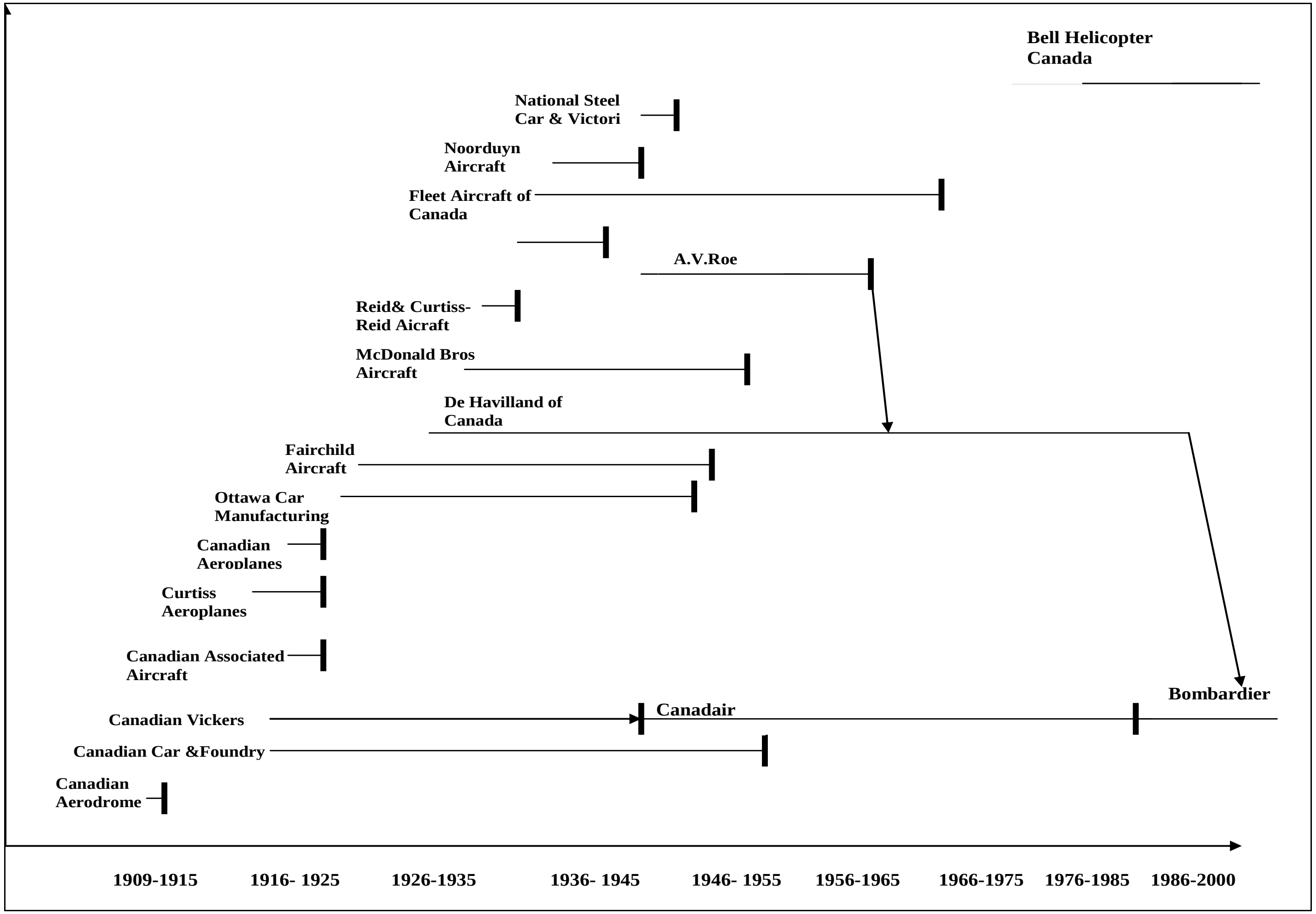
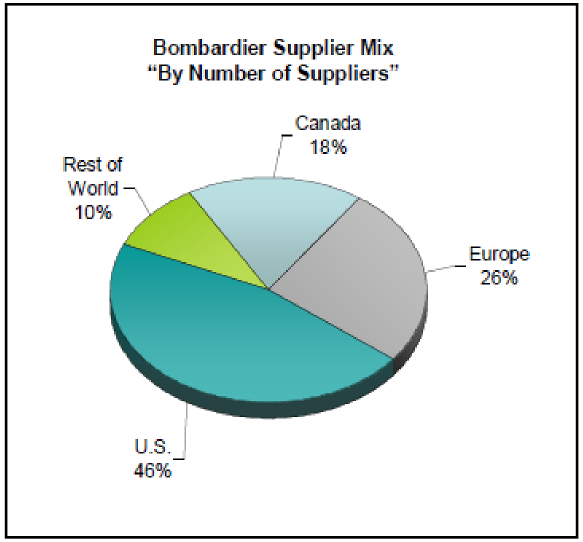
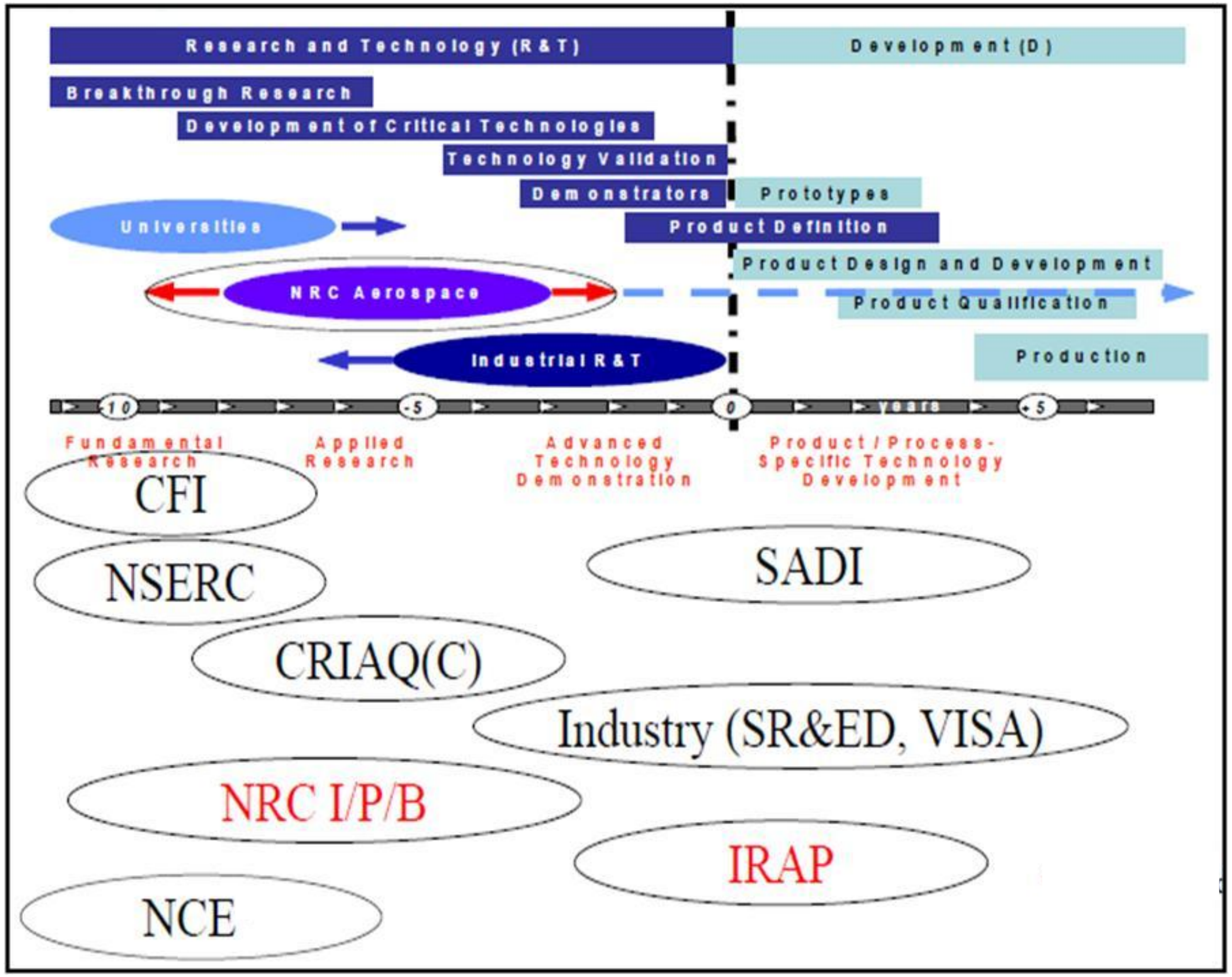


Figure 3: The internationalization of Bombardier supply chain



Source: Industry Canada

Figure 4: Public support to Canadian aircraft industry R&D



Source : Industry Canada