Passive innovation system and local learning: *a case study of Embraer in Brazil*

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INTRODUCTION

The basic aim of this paper is to analyse the innovation pattern, the flows of interactive learning among firms and between them and research institutions, and the local dynamism of the science and technology (S&T) system in the aeronautical productive arrangement in Sao Jose dos Campos municipality, located in the region of Vale do Paraiba, Sao Paulo State. The focus is on the nuclear characteristics of the local productive arrangement, especially: (1) the production of goods and services of high technological complexity; (2) only one leader company centralising and organising the activities of aeronautical projects and assembly, with demand for products from a group of SME (small and medium companies) of highly heterogeneous technological levels and a set of locally generated services and products; (3) independent of cooperative interactions between local agents and research institutions such as CTA (Centre for Aerospace Technology), to certify and homologate the airplanes, to develop learning and innovation processes and to develop specific professional skills; and (4) considered a S&T intensive sector. For these reasons, it is important to analyse its capacity for generating aggregate value and spin-offs to other activities and economic services, such as software, automation and process control, management systems and quality guarantees, new materials, human skills and so on.

The field survey took place between June, 2000 and May, 2001. The main methodological observations are as follows. Based on government information on the nationalisation of Embraer's aeronautical productive network, on the analysis of AIAB (Brazilian Aerospace Industries Association) records, and on IFI (Industrial Foment Institute) records, we identified the companies that compose its supplier network and its flows of cooperation and demand for technological services in the local and national aeronautical productive arrangement. We visited CTA and its institutes, the Sao Jose dos Campos Municipal Development Agency. In the second phase we visited the local supplier companies and the new multinational companies that have settled down in the region. We identified a sample of 20 companies, defined by the records and selected by criteria of economic importance (income and employment) and diversity in supplying goods and services, of technological complexity of products and services. We then designed a map of the local supply network, its spatial, economic and technology articulations, the contractual regime pattern and a hierarchy of productive classification, such as: risk partners (responsible for delivering the complete technological systems or packages), suppliers and local subcontracted companies, segmented by technological complexity levels (high, intermediate and low).

1. THE IMPORTANCE OF EMBRAER AND THE AIRCRAFT INNOVATION SYSTEM IN THE BRAZILIAN ECONOMY

Since the early 1990s, structural reform - liberalisation, deregulation and privatisation - has affected significantly innovative behaviour at the microeconomic level in Brazil, with important consequences to the National Systems of Innovation. In another paper (Cassiolato and Lastres, 2000) we suggested that some of these consequences were:

- the substitution of imported capital goods for domestically-produced machinery and equipment;
- the discontinuation of local engineering activities by TNCs subsidiaries;
- structural changes, particularly privatisation, have changed significantly the balance between public and private R&D expenditures. In fact, with cuts in government expenditures for R&D, private agents are supposed to be playing a more important role in technological activities. However, empirical data seem to suggest that this is not the case;
- most of the few local innovative firms have been acquired by subsidiaries of TNCs that, as part of their strategies, are downgrading the technological activities carried out locally;
- independent and public R&D institutes are changing the mix of activities they conduct reducing the number of research projects they undertake and increasing the share of consultancy and technical assistance activities, which provide them with the resources they need.

Data about the pattern of Brazil suggest a specialisation in sectors and areas of relatively low dynamism. As it may be gathered from Table 1, in 1998, the share of exports of very dynamic goods (those for which international trade grew at least 10% in value from 1982-84 to 1996-98) in total exports, was 18% in Brazil and 16% in Argentina. This contrasts, for example, with 55% for Japan, 46% for Germany, 42% for the USA and 48% for Korea. In fact, given the specialisation pattern of Brazil's economy, its participation in trade flows in new technologies is negligible. Brazil's share of world exports of high-tech[1]. products decreased from 0.6% in 1985, to 0.26% in 1991 and 0.19% in 1995. This pattern is similar to other Mercosur's countries such as Argentina's that witnessed its share decreasing from 0.08% in 1985 to 0.04% in 1995. In both cases, the relative decline was accompanied by an absolute one, while total exports of these goods more than doubled during the period (see Table 1 and 2).

1 The definition of hi-tech here is the one given by the taxonomy proposed by OECD (1996) This definition ,, which was based on two criteria: R&D expenditures over value added or number of people performing R&D activities and coefficient of technology in production. By this classification hi-tech sectors would include aerospace, informatics, eletronics and telecommunications are considered high-technology sectors. See: OECD, (1996) "*Revision of the high-technology and product classification*", Paris. OECD.

TABLE 1. SHARE OF EXPORTS OF "VERY DYNAMIC" GOODS* IN TOTAL EXPORTS, SELECTED COUNTRIES, 1998

Country	%	Country	%
Japan	55	Malaysia	57
USA	42	Korea	48
Germany	46	India	19
France	41	Brazil	18
Spain	40	Argentina	16
Italy	38	Chile	9

* "VERY DYNAMIC" ARE GOODS FOR WHICH THE WORLD TRADE GREW AT LEAST 10% IN VALUE FROM 1982-84 TO 1996-98.
SOURCE: IEDI (2000), QUOTED IN FOLHA DE SÃO PAULO, 25/04/2000, P. 2.

TABLE 2. TOTAL EXPORTS OF HIGH-TECH PRODUCTS, SELECTED GROUPS OF COUNTRIES – 1985/1995 (US$ MILLION AND PERCENTAGE)

	1985		1991		1995	
	$ Million	%	$ Million	%	$ Million	%
European Union	139795	50.6	136761	43.1	193871	38.0
Nafta	61846	22.4	92054	28.9	121194	23.7
Latin America (less Mexico)	1959	0.7	1074	0.3	1314	0.3
- (Brazil)	1697	0.6	817	0.26	982	0.19
- (Argentina)	232	0.08	221	0.06	222	0.04
Asian Tigers*	64583	23.4	69777	21.9	149588	29.3
Australia	423	0.15	709	0.22	1392	0.27
New Zealand	140	0.05	88	0.03	213	0.04
South Africa	NA		322	0.10	516	0.10
Total	276237		317999		510710	

*NAFTA:NORTH AMERICAN FREE TRADE AREA, COMPRISING CANADA, MEXICO AND THE UNITED STATES.
** JAPAN, THE REPUBLIC OF KOREA, TAIWAN AND SINGAPORE
SOURCE: EUROPEAN UNION (1997)

The change in the volume and structure of FDI flows relates to the new technologies. In what refers to these trends, the integration of Brazil into the globalising knowledge-economy, is in fact, a one-way road. During the 1990s, Brazil has aggressively pursued policies geared to attract foreign direct investment (FDI) as a way to accelerate her integration to the world economy and to increase competitiveness. However, the new FDI of the 1990s was mostly directed to merger and acquisition of existing firms rather than greenfield investment. A recent study which attempted to uncover the strategies of TNC subsidiaries that are planning new investment found that they are basically import-intensive and aim at directing their production to the internal (Mercosur) market and are not geared to exports (Cassiolato, Bernardes and Lastres, 2002).

These two features of foreign direct investment in Brazil– relative concentration in acquisitions of local firms and market seeking, import intensive forms – have had a critical impact on local innovation systems in high-tech sectors. Several experiences in Brazil illustrate this. For example, in 1996 and

1997, a number of TNCs acquired several large domestic auto parts producers which were specialised in technology-intensive goods, such as Metal Leve, Freios Varga and Cofap. Subsequently, the R&D activities of the local firms were downgraded, and notably their more advanced research and development was relocated to the parent firms' R&D centres in their home countries.

Even in the case of many of the country's high-technology firms, R&D activities were scaled down when TNCs bought into them. This was the case, for example, when in 1992 Alcatel purchased Elebra – one of the most important producers of switching systems. In 1999, Zetax and Batik, two domestic firms producing and developing a technologically advanced switching systems called Trópico, became part of Lucent Technologies. Interviews indicated that Lucent was not interested in local R&D, preferring to rely on technologies developed in the parent company. A similar process has been observed in other telecommunications TNCs active in Brazil. Since they are increasingly exposed to international competition, they are scaling down local R&D as a cost-reducing strategy. In particular, R&D activities geared to the development of new products is discontinued, and effort shifted into the more simple adaptation of imported processes and products. In most cases, this has meant that highly-qualified engineers engaged in R&D are transferred to other, less-specialised functions, such as production, quality assurance, sales or marketing. A related process observed in the hi-technology telecommunications and information technology clusters in Campinas and São Carlos is that the newly established affiliates are not linking into locally-based supplier networks. Instead, they operate in total isolation from the domestic innovation system, relating to their parent companies and other affiliates rather than to local firms. This too has a negative impact on local R&D capacity. (Cassiolato, Bernardes and Lastres, 2002).

As a result, the country is losing the competitive edge it had developed in some product markets. This reinforces a process of increasing import intensity that began with trade liberalisation in the early 1990s. For example, the import penetration coefficient for parts and components in the car industry increased from eight per cent in 1993 to 20 - 25 per cent in 1996; import penetration in information technology and telecommunications products soared from 29 per cent in 1993 to around 70 per cent in 1996. If local production of high-technology intermediate inputs in production continues to decrease, the share of imports is bound to intensify further. The impact on technology would then be reinforced by a problematic impact on the trade balance.

Within the above-discussed pattern of world integration the Embraer case is an admirable exception. As shown in table 2 above, Brazil total exports of hi-tech products, in 1995 were less than a US$ 1billion **(**UU$ 1 = R$1**).** According to official statistics (see Table 3), Embraer was responsible in the same year for US$ 182 million 0,7 % of all manufactured goods exported by Brazil. In 1999, Embraer became the largest Brazilian exporter, with its international sales amounting US$ 1.8 billion This was more than twice of the remaining hi-tech exports of Brazil and 6.48% of all Brazilian exports of manufactured goods (Tables 3 and 4 below). In the same year, during the Aerospace Fair at Le Bourget, Paris, it signed contracts worth US$ 6.6 billion, braking a record of the world aeronautic industry. In a period of less than 5 years Embraer was able to reverse its imminent bankruptcy and becoming, in 1998, the world-wide leader in the commuter/regional jet market. It is now the 4th largest Western aeronautic firm, just behind Boeing, the Airbus Consortium, and the Bombardier Group, its direct competitor. Having designed, developed, produced and commercialised two successful medium-sized aircrafts, the ERJ-145 (50 places) and ERJ-135 (35 places), Embraer became the only world player of the Brazilian firms in the hi-tech area. It is also the only important locally-owned firm in this area that has, up to now, resisted attempts of acquisition by foreign multinationals. (Cassiolato, Bernardes and Lastres, 2002)

The remarkable recent success is certainly the result of deep productive and business restructuring processes following the privatisation that took place during the 1990s. However, most important, it is also a result of long-term government-sponsored institutional and technological developments that goes back to the 1950s. Next Chapter will discuss the origins and historical development of the Brazilian Aircraft Industry

TABLE 3 – BRAZIL – MAIN BRAZILIAN EXPORTERS 1999 AND 2000

	Exports	
Firms	US$ milhões	
	2000	1999
Embraer S/A	2.702,0	1.691,5
Cia Vale do Rio Doce	1.596,1	1.542,1
Petrobras S/A	1.456,5	739,8
Volkswagen do Brasil Ltda	1.128,9	527,4
Bunge Alimentos S/A	976,9	925,6
Cia Siderúrgica Tubarão	948,8	753,9
Fiat Automóveis S/A	622,6	813,4
Motorola Industrial Ltda	597,2	150,9
Aracruz Celulose S/A	587,0	488,3
General Motors do Brasil Ltda	572,6	456,2
Total (10 largest)	11.188,6	8.089,1
Outras empresas	43.897,0	39.922,3
Total	**55.085,6**	**48.011,4**

FONTE: SECEX

TABLE 4. BRAZIL – TOTAL EXPORTS, EXPORTS OF MANUFACTURED GOODS AND EXPORTS OF AIRPLANES. 1995-1999 (US$ MILLION)

	1995	1996	1997	1998	1999
A – Total exports	45506	47747	52994	51140	48011
B – Exports of manufactured goods	25565	26413	29194	29387	27329
C – Exports of airplanes	182	284	681	1159	1772
D – C/B0.71	1.08	2.33	3.94	6.48	

SOURCE: BRAZIL - SECEX

2. PROFILE OF THE EMBRAER ARRANGEMENT

2.1. Origin, Organisation and Development

The IAB (Brazilian Aeronautical Industry) is quite singular because it is represented by a leader company - Embraer. It was created by Federal government initiative on August 19th, 1969 and founded on January 2nd, 1970 as an open capital Mixed Economy Society , controlled by the Federal Government

and linked to MAER (Aeronautics Ministry). Their founders had the mission of implanting and disseminating the aeronautical industry all over the country, impelled by a strong military-inspired ideology. The process of capital vialiability to the sector – through fiscal incentives and government procurement– permits the company to finance R&D programs, transforming Embraer into a dynamic centre of this industry. Embraer conquered the international regional air transportation market with the EMB-110 Bandeirante line for 19 passengers (with 500 airplanes sold during its existence and an income of US$1.5 billion) and, later, the EMB-120 Brasilia for 30 passengers. Both guaranteed leadership in sales to the United States in the turboprop category. At the same time, the MAER was demanding new planes such as Xavante, Xingu, Tucano (a military training plane) and the AM-X subsonic fighter plane.

Brazilian aeronautical production is basically concentrated in the SJC region. This region has been called "Technology Valley" because it concentrates the country's high technology. The SJC region has a diversified technological and productive structure in the aerospace, automobile, telecommunications and petroleum sectors. The IAB is not exclusively restricted to Embraer. In the past, this sector registered around 100 supplier companies in Brazil; they are now around 40 SME in manufacturing, composite materials and milling and around 10 MPMEs in engineering of projects organized under the influence of only one leader company. In 2000 the sector registered an income of US$3.2 billion and its exports reached US$ 2.8 billion, generating around 13,800 jobs (10,800 at Embraer and around 3,000 in the SME).They are SME, most of them Brazilian and around 60% of them in the SJC region. The productive arrangement of Embraer's supplier network in the SJC region is basically formed by a little more than 30 companies of small and medium size – SME – (from 20 to 300 employees).

Almost all the companies were founded by ex-employees who lived in the SJC region in 90s, during the crisis in the sector, on the initiative of Embraer and CTA and its Institutes. These SME are dependent on the technology centres and local research institutes, enjoying the advantages of proximity and of participating in the aeronautical network through a subcontracting regime with Embraer. However, there is a set of companies which integrate productive networks localised in other regions such as GE/Celma (Petropolis – RJ), Rolls Royce (Sao Bernardo do Campo – SP), Dynamic Solution (Campinas – SP) and Neiva (Embraer's subsidiary company located in Botucatu – SP). Is important to mention the Aeromot Group, localised in Rio Grande do Sul State (producer of the monoplane Ximango) and Digicon (electronic appliances). There are few companies in the aeronautic defense segment that have survived the 80s and 90s crises, marked by the reduction of expenses and military programs. Among them are Mectron, in SJC region, and Aeroeletronica, in Porto Alegre in southern Brazil. Finally, we emphasize the growing importance of the helicopter market, distinguishing CKD, a Helibras helicopter assembling factory, under French license, situated in Itajuba – Minas Gerais State.

The experience of the aeronautic arrangement is a result of industrial decentralizing policies implemented in Sao Paulo State, induced through deliberate action by military and governmental policies of regional attraction and sector development during the 70s and 80s, stimulating the geographical and sectoral agglomeration of companies (clustering). Placed in the Rio–Sao Paulo axis– which gives the municipality a very privileged situation – SJC region obtained investments that enlarged an important state nucleus of technologic development with institutions such as CTA and industrial enterprises of strategic character such as Embraer, Avibras and Engesa, which consolidated their position as reference centres in scientific, technological and industrial development of the national defense and aerospace complex. Diniz and Razavi (1999:11) separate the SJC region industrial development process in three phases. The first important investment cycle took place between the 50s and 60s, along with the establishment of an automobile and consumer goods industry, when

companies such as GM, Eaton and J&J have started and Rhodia had its productive basis expanded. The second phase spans the 70s and 80s, due to government investments in military and aerospace activities. The third and last phase is characterised by the attraction of investments by multinational electronic and other industries (Ericsson, Panasonic, National, Philips, Hitachi, Kodak and Kone Elevators), providing the growth of the mechanical sector in the region.

The remarkable fact that transformed the municipality of SJC into a *technology pole* was the establishment of CTA and Embraer, attracting high-technology aerospace, defense and electronic companies. A great number of them are spin-offs of this centre. After the founding of CTA, the State – through MAER – demonstrated its intention to support the creation of a group of scientists and engineers working in development and/or absorption of aeronautical technology. The main idea of this plan is based on the long-run view that CTA would surely occupy a central position in the aeronautical activities developed in Brazil. Some educational institutes have also been created to provide regular and graduate programs, training human resources for research and aerospace activities. Military leaderships concluded that learning from unsuccessful experiences in previous production would depend on a qualified work force and on research centres that could organise and stimulate development and dissemination of aerospace and aeronautical knowledge.

The SJC region experienced a very prosperous period in the 70s and 80s due to the development of the defense and aerospace complex. In the first half of the 90s, structural reforms and changes in the economic development model deeply affected the aeronautical productive arrangement and the defense sector in the SJC region. The local industrial and economic environment suffered a disruptive process – worsened by the crisis in the defense and aerospace complexes – causing high unemployment rates and the dismantling of industrial plants and service companies. The fiscal unstability of industrial firms, the political crisis and the disruption of the macroeconomic profile have created the conditions for a gradual cut in R&D resources, weakening the national, sectoral and regional innovation and infrastructure systems related to technology and scientific research development established in the 70s. In the SJC case, this movement has deeply affected the resources consigned to government procurement in the aeronautical, space and defense sectors. At the end of the 90s, the aeronautical productive arrangement started a new era marked by the deregulation, the institutional restructuring and privatisation processes, launching the ERJ-145 program, a regional transportation plane. The economic prosperity resulting from this process has worked as a population growth-inducing factor, transforming the municipality into a regional attraction centre.

3. INTERACTION AMONG THE AGENTS FOR INNOVATION AND LEARNING

3.1 Relationship between Companies and Innovation and Learning Mechanisms

The architecture of a hierarchic structure of suppliers coordinated by Embraer follows a tendency of the world aeronautical industry, specially the airplane producers such as Boeing, Airbus and Bombardier consortium, characterised by disseminated lean production techniques, globalised productive and assembly phases, reduction and selection of suppliers, specialisation and centralisation of design activities and, finally, product development and strategic management of the supply network. These tendencies result from the process of competition that imposes new criteria of price formation, demands customisation – following new flexibility patterns – and integration and speed in the production and delivery of an airplane.

The network is made up of the main producers and assemblers of cells or fuselage, who constitute the productive chain links of the aeronautical sector. They are responsible for the study, conception and development of the airplane project, integration of the final product, commercialisation and technical services, assuring the integration of the motors and of all the equipment needed its operation. The logic of the innovation pattern in the aeronautical network may be seen as an architectural configuration of centralised webs of "complex products and systems" articulated to the global value networks. The aeronautical network articulation is determined by a global logic commanded by great producers and assemblers of airplanes. Global productive networks organised by producers are those in which the big corporations and oligopolies –mostly multinational companies – have a central role in the coordination and hierarchy among the productive links and the production networks, suppliers, commercialisation and global technical assistance services. In this dimension, some of the critical points for competitiveness are: (a) the capacity to manage the global supplying network; (b) the factors regarding logistics; (c) the reduction of transactional costs through profit gains resulting from price fixing during the productive phases; (d) the pioneering and emulative innovative processes and technology. The family concept[2], which offers the advantage of commonality among the airplanes and a regime of "co-design" to develop a new airplane project is another world tendency, stimulated by the technological characteristics of the product, by the market structure, by the development and high risk cost, which requires that risk partners have a solid financial capacity to invest.

Embraer detains the command power over the risk partners and over its local and global productive network, strengthening its competitive position. The essential competence of the company is expressed in the excellence of R&D, in the design, in product development, in the integration of systems of high technological complexity and in the assembly and technical assistance. In 2000, the expenses in R&D were 5% of its revenue, with 1,500 engineers and technical workers to operate the routines, representing 14% of the total occupied people in the company.[3] The technological philosophy of Embraer is less engineering-driven and more centred on competence management strategy that aggregates value and competitive advantages to the company. The technological and corporate policy of the company foresees the external purchase of all the commercial systems and of the technological packages, since they are not considered as an advantage or a competitive differential for the company. Thus, the nature of the innovation strategy is conditioned to a valorization logic of the financial activities and economic returns directed more to technological adaptation than to the development of creative innovations (nonexistent in the market), trying to direct the resources to the goal-activity that constitutes their main business vocation, eliminating the support activities or the production process phase, transferring them to a net of small and medium suppliers that are organised for this objective. Through this focusing strategy they search for an operational equalisation, avoiding idleness due to productive non verticalization, reducing administrative costs, product and process development costs and obtaining the same final production with less company investment. The operation of a new supply policy is characterised by three movements: (i) an effort towards nationalisation of

2 The concept of planes' "family" regards to less maintenance infrastructure costs, less pilots and technical personnel training costs and possibility of crew up-grading. Besides the time-to-market reduction, the marketing decisions are made agilely.

3 In the state management period the expenses were maintained in upper levels (around 9% of the revenue), decreasing after the privatization period. The explaining axes are two: 1. an exponential trajectory of gross receipt and maintenance of P & D expenses; 2. the co-design regime implied in a net reduction of P&D routines at Embraer, so that great part of them were demanded from its risk partners.

equipment and subsystems supplies, by attraction of the ERJ-170/190 partner companies to localities near the SJC plant; (ii) selection and reduction of external and local suppliers, establishing new forms and parameters to compose and integrate its supply network. The ERJ-145 program had around 400 suppliers; the new ERJ-170/190 family will have around 20; (iii) reduction of the integration tax of systems, structures and plant parts, resulting in a new supply structure and new management flows among the suppliers of technological systems, parts, components, structures and services.

This structure tends toward a new "technological package" pattern. In practical terms, the risk partners acted as first line suppliers and will be responsible for the aggregation of a set of subsystems and components that are going to compose a project airplane's "technological package", which will be part of the final phase of Embraer's assembly line. With the reduction and concentration of the local and external suppliers, the company created new forms and parameters to compose and to integrate its supply network, resulting in a new global and local supply structure. The main requests imposed as a condition for the local subcontracted firms to participate in the new programs are: (a) ISO 9000 (2000 version) certificate, before the end of 2001; (b) responsibility in purchasing inputs, treatment, milling and technological services application in order to supply Embraer (in the past, the company itself purchased the inputs and offered them to its local suppliers); (c) the local suppliers must develop new market competencies in order to be exclusively dependent of Embraer's production scale.

We identified a set of patterns in the learning and innovation mechanisms with distinct technological intensity levels, regulated by distinct contract regimes. Learning and innovation interactions between producer and client are global, synchronised and prospective in terms of future demand of the world air transportation operators. The adopted focus is characterised by a sophisticated analysis of performance indexes (system performance feedback), profitability, clients' satisfaction and management of future changes in the market. It demands a set of formalised and institutionalised mechanisms to generate, to register, to analyse and to interpret information. These mechanisms are vital in a context of high competition, fast obsolescence of the technological frontier and market uncertainty. In the past, the company's competitive strategy was calculated through prospective studies about airplanes demand commissioned from external consultant companies. From 1998 on, the company created an area called "Market Intelligence", by which prospective studies methodology in market knowledge was incorporated into Embraer's competitive and innovation strategy, that is, the company started to do its own market analysis.

A new dimension in the innovation and learning dynamics concerns a **strategic alliance** between Embraer and the French consortium led by Aerospatiale Matra, Dassault Aviation, Thomson-CSF and Snecma. This alliance will allow access to new critical technologies in civil and military areas (supersonic technology, weapon integration software, up-to-date aeronautic equipment, among others). It will also allow the development of new products and new financing sources for R&D, acquisition of business and corporate knowledge (opening new financing market windows). This alliance is fundamental for the application of US$700 million in the FAB (Brazilian Air Force) FX-BR supersonic pursuit plane program. The new contract includes know-how transference and local production clause through the application of an offset policy.[4]

4 The proposal of the Mirage 2000-5 MK 2 program to compete with the FX-BR program, submitted to FAB by Dassault-Embraer consortium – that foresees the pursuit plane's assembly in Brazil in the new Gaviao Peixoto plant – has been criticized due to the high cost of acquisition per unity (US$35 millions), due to an old-fashioned technological platform (in operation since 1978) and due to an inferior operational performance compared to the competitors', with risks of deep technological dependence on French companies.

The interaction between the agents of the SJC region productive arrangement may be organised in three dimensions. The **risk partners** are in the first learning level. The partners develop and produce significant components of the plane, including turbines, hydraulic components, aeronautic equipment, wings, tail, inside parts and fuselage. As soon as the agents have selected the risk partners and have started the development program and the planes' production, it becomes very hard to substitute them. This relationship makes the company susceptible to the performance, quality and financing conditions of the risk partners. Indeed, the contracts between Embraer and risk partners are long-term ones, as are those with the large multinational companies that participate of the co-design regime and aggregate technological value. The knowledge networks come from this level, where two important things occur: (a) a creative and integrated combination of R&D know-how and know-why; (b) the creation of competencies to innovate the product and the learning-by-interacting process. This phase was characterised by the project's separation into its component parts and by the distribution of tasks among the companies, followed by the definition of the airplane's parameters between Embraer and the partners. The innovation of the ERJ-179/190 program resulted from a philosophy called "Collaborative Engineering Connected to Global Sites", that is, an R&D network formed by labs and plants of the several international partners, centralised and coordinated by Embraer, in Brazil. The institutional construction of this new R&D pattern resulted from the creation of decentralized multidisciplinary teams – a matrix model organised by innovation teams that operate in all the company's departments – supported by new tools that allow the development of parts of the plane with the partners' help, permitting a reduction of the development cycle from five to three years. The collective efficiency concept occurs in the search for cooperative action through a global logic (where the local factors are important but not determinant to develop integrated design). The local factors are strategic logistic variables to supply technological packages in the ERJ-170/190 planes' assembly. We also identified the company's strategic focus on learning corporate management, on training policy, on human resources qualification (learning by training) and on management of a transnational culture among the companies, motivated by strategic partnerships and alliances.

Box I. The ERJ-170/190 Program

The first major difference of new program as compared to the ERJ 145 is that it is being developed within a concept of strategic partnerships that have a greater degree of integration and sophistication. The project of the aircraft, for instance, has been co-designed with the partner companies. Embraer has a 45% share in the design and will be the responsible for the integration of all systems, aircraft structure and final assembly technique. The group of risk partners integrating the program of the new family of regional jets for 70, 98 and 108 passengers, designated the ERJ-170, ERJ-190-100 and ERJ 190-200, were selected based on the analysis of 85 potential partners; of which 58 were pre-qualified and 16 were chosen. The risk partnership idea got more complex with the new program.

General Electric (GE) is the largest participant, and is responsible for the supply of the turbines. The engines represent about 20% of the sales price of the aircraft, estimated to be around US$ 22 million in the case of ERJ-170 and US$ 27 million for the ERJ-190. GE also holds 99.6% of the capital of Celma, an Embraer supplier of motors, accessories and

parts, located in Petrópolis in the state of Rio de Janeiro. According to the specifications, the new aircraft should be faster than the ERJ-145, cruising at Mach 0.80, and meeting the challenge of low operating costs in relation to competitors. Other important partnership is with the North American Honeywell Company, recently taken over by GE for US$ 48 billion, who will supply most avionics. Gamesa, which integrated the previous program, will develop and will supply the *empennages* and the rear fuselage. Hamilton Sundstrand will be responsible for the fuselage rear cone, among others. Figure 2 **(in file apart)** provides a visualisation of the risk partnerships for the ERJ-170 family.

There has been also an important progress related to the reduction of the number of suppliers, with increase of the number of parts and components for each one. The aerospace division of Kawasaki Heavy Industries, from Japan, is also among one of the ten companies chosen as risk partner. Kawasaki will invest US$ 100 million in the development of the central part of the wing, control surfaces and pylons (motor support structures). And, finally, EDE, the Equipment Division of Embraer, established a joint venture with Liebherr (Germany) for the supply of the landing gear. Several elements are crucial to the understanding of this program. The first is that the technical requirements for the selection of the new strategic partners were established before the project of the aircraft was begun. This allowed a rigorous and strategic selection of the new partners, emphasising capacities to develop new technologies and investment. The second point to be emphasised is the decision by Embraer, after 20 years (since the Brasilia program), to internalise the production of the aircraft wing. This task, in the ERJ-145 program, was the responsibility of the Spanish company Gamesa and clearly Embraer considered it to be too critical to the company to be left to other partners. Finally, there was a change in the system of innovation and development of the project engineering, towards a system of more integrated routines and co-ordination among the partners. From the operational point of view, the ERJ-170/190 program was organised in three phases. Phase 1 is named "Initial Definitions". At this phase, the concept and detailing of the design of the aircraft which was performed. This was done before the choice of risk partners. A business plan was prepared focusing on market requirements and product detailing; cost planning, analysis of the life cycle; investment, analysis of the risk and return on the investment were part of this phase. In addition there was a specific market identification study with a methodology prepared by Embraer. The second phase is called "Joint Definitions", because it is performed jointly by all risk partners. This phase was characterised by the division of the aircraft in several sections and the division of the work among the companies; it was followed by the joint definition of the aircraft parameters among the partners and Embraer. The innovation made during this phase was the internationalization of R&D routines that were developed through the use of a philosophy that the company calls *co-operative engineering*. It simply means the setting up of a network of R&D between plants and laboratories of the several international partners centralised and co-ordinated by Embraer in Brazil. The institutional arrangement of this new pattern of R&D was obtained with the establishment of decentralised multi-disciplinary teams, a type of matrix structure. It was organized by innovation teams across the entire company, for the joint development of airplane components with the partners. These procedures allowed the integrated development of the product, since all decisions taken were made by

specialists from company partners and who therefore, had the decision-making authority. About 600 full-time engineers were assigned to the program, with 300 specialists from Embraer and 300 specialists of the other international partners, from Japan, Spain and the U.S., among others, who worked intensely and "in-house" at the Embraer headquarters in Brazil. The engineering work and project was performed in the Embraer advanced data-processing centre that provided a fully integrated project atmosphere. The co-design strategy permitted savings 18 months in the development of the aircraft, (36 instead of 54 months), with substantial gains in quality. With the implementation of web systems and EDI - Electronic Data Interchange, it was possible to call on-line the network of partner firms in the electronic mock-up and the ERJ170/190 database that were centralised in the Embraer IT structure. The general design modifications made by the partners and suppliers were sent electronically to Embraer, where they were checked and validated for later updating of the mock-up and database.

The final phase is called "Detailed Design and Certification". The program is presently entering this phase, where the work is finalized and final definition of the aircraft is made. The engineers and technicians of the partner companies return to their home countries to finish the detailing phase and require the certification of the aircraft in different market.

Suppliers of services and components are on the second level. The architecture has the characteristics of commercial and technological information networks. The companies offer their equipment, avionics systems, components, etc, attending Embraer's required specifications, with significant learning processes among users and suppliers but with less intensive innovation if compared with the first level. In this aspect, Embraer must be considered as an active and highly technologically qualified user, with significant processes of learning-by-using and learning-by-adapting. The decision of selecting partners and international suppliers results from the fact that Embraer gets indirect investment benefits from leader companies such as Boeing and Airbus when it purchases components and parts in other countries. These companies finance R&D projects and their suppliers.

On the third level are **national subcontracts** with companies and individuals that receive raw material and design from Embraer and sell services in man hours or lots, resulting in two subcontract models: one *in house* (which happens inside the company with goods and services supplied) and another that happens outside the company's production space. The cooperation among companies, established by Embraer and its local suppliers is highly centralized characterised by training processes to attend technical, productivity/quality and equipment-offer requests. The structural characteristic of the Embraer arrangement concerning the development of technological qualification is the dependence on the transference mechanism and technology learning generated by the leader company. The national suppliers' situation, compared to that of the risk partnerships and of international suppliers, is highly unstable and insecure, since they do not have permanent formal contracts. The supply is activated by a purchase order issued by Embraer, who can suspend the purchase if some irregularity occurs in deadlines, quality criteria, price or market oscillation.

The dynamics of technological and productive learning between companies and local institutions is vertically induced by formal and informal mechanisms between the agents, which favour the

regional learning routines related to the productive and operational qualification trajectory more than to the innovative qualification processes. The architecture of a propitious innovation and learning environment is stimulated by an assembly of research institutions and by a pool of specialists and qualified educational institutions, generating an offer of qualified workers for the companies and creating specialised suppliers of technological services and inputs, due to technological knowledge transmission between companies. The relationship between companies and the technological qualification pattern present two dimensions relating to industrial segmentation: (i) the project, system and tool engineering services, where the advanced and intermediary innovative qualification processes take place; and (ii) milling and chemical treatment services, revetment, composite materials and general production services, where intermediary and basic qualification processes are identified.

Project, systems and tools engineering services are characterized by higher knowledge-intensity activities offered by technology-based companies, outlining the innovative technological qualification trajectories. We distinguish two medium-sized national companies: (1) Akaer (responsible for the project engineering and central-II-fuselage details of the ERJ-170/190 program); (2) Dynamics Solutions (responsible for the project engineering and production of tools). Two more companies must be mentiooned: (1) Fibraforte, a small INPE spin-off which developed the EBC (Knowledge-Based-Engineering) software in a consortium with Embraer; and (2) Serco (Engineering Services Cooperative), constituted by ex-employees of Embraer, Avibras and Engesa. Many risk partners, such as Gamesa, Latecoere, Kawasaki and Enaer, didn't have a history or competence in aeronautical projects. They acquired the competence during the program's operation through training processes and man-to-man technology transfer/qualification processes, since some of Embraer's and Akaer's engineers were transferred to these companies' headquarters.

The milling and chemical treatment, composite materials, revetment and production services are characterised by a relationship between companies of low complementarity and low technological complexity. The kind of learning occurring in these companies is associated to the operational capacity of intermediary and basic production. One interesting example of this learning interaction in productive networks is Alltec, which also participates in the supply network of helicopters hull parts assembled by Helibras and exported to France. Embraer is responsible for employees' training and technical monitoring and for the subcontracted companies' technology learning processes through the engineers, who disseminate the necessary knowledge. The company is prioritizing its relationship with the suppliers, in order to improve the indicators, promoting systematic meetings about technological information monitoring, dissemination and harmonisation. The main obstacles to promoting local suppliers are due not only to the lack of technological qualification in several areas: aeronautical engineering, electronics, fine mechanics, composite materials, milling services and stamping with CNC-4-and-5-axes equipment and high-speed equipment, but also to the absence of technical and economical scales, to the great dependence of suppliers on Embraer, to the lack of knowledge in international markets, to the non-capitalized economic structures and to the low capacity for investment.

The national market is the main source of income for the local companies, which operate to offer and supply services to Embraer and to the new multinational companies that have been established in the SJC region. For the national firms, the status of participating in Embraer's goods and services supplier network enables them to offer services to the international suppliers and partner companies. Indeed, the aeronautical world market must be considered as a real income alternative and a real source of survival, as far as it offers technological opportunities in determined niches. The commercial and technological learning that has resulted from this experience allows the national suppliers to

have a "beneficial economic and productive triangulation", by gradually accessing the foreign market and by permitting upgrading trajectories through interaction with Embraer's international suppliers.

4. ARTICULATION WITH THE SCIENCE AND TECHNOLOGY (S&T) SYSTEM

The main technological centre is CTA (Aeronautic Technologic Centre), whose headquarters is in the SJC region. Its basic structure is composed by GIA (Support and Infrastructure Group) and by four institutes: ITA(Institute for Aeronautical Technology), IAE (Space and Aeronautical Institute), dedicated to research, technology development and advanced studies, IFI (Institute for Industrial Coordination and Promotion), which operates in three different areas: (a) promotion and support of the aerospace industry's activities; (b) execution of metrology, normalization and industrial quality certification services; and (c) qualification and homologation of aerospace products and companies, and IEAv (Advanced Studies Institute), which carries out aerospace research and development.

The competitive pressure, Embraer's strategy of competition and innovation and the institutional obsolescence and degradation of CTA constitute a problematic cooperation pattern. The cooperation and research relationship between Embraer and CTA was more organic in the past, degenerating in the 80s and 90s, during the state crisis, when the institutional disconnection of the technological cooperation pattern with the aeronautical industry took place. This context has been unfavourable for technicians and the institutes have suffered with the departure of several qualified professors, scientists and technicians, many of them with PhD degrees from other countries. The majority of the specialists who left IFI and IAE (which lost more than 500 employees) were taken on by Embraer under not-to-be-rejected salary proposals, revealing a contradictory leader-company strategy. Besides, the technological and scientific park is quite old-fashioned and research funds have been reduced under government S&T expense cuts. This fact threatened the airplanes' homologation and certification services. In the last ten years CTA has extinguished around 1,400 jobs. The ICAO (International Civil Aviation Organization) report, after an audit in Brazil in 2000, induced the FAA (Federal Aviation Administration) to send technical staff to evaluate whether IFI is in accordance with the required international patterns to certify airplanes. Otherwise, it would be reduced to level 2, resulting in its services' shutdown.[5] The gap between the Embraer's airplane sales estimate and the IFI adverse context suggests a critical scenario, unless emergency decisions concerning the reestablishment of the certification capacity of the Institute take place.

Motivated by the favourable performance of the company, we may see a movement of isolated actions by the federal actors (Ministry for Development and Ministry for Science and Technology[6]) and the state actors. Thus, the initiatives of state government (resulting in fiscal and budget incentives to Embraer's and Universities' researchers) became a powerful instrument of technology policy. PICTA

5 Embraer doesn't keep contact with IFI. The resources paid by Brazilian companies in the homologation processes are almost symbolic and don't reach 0.1% of the complete process cost, due to the emolument values established by law as a government policy.

6 MCT, through the 227th resolution, gave the 8661/93 Law fiscal benefits to Embraer for five years. This Law deals with the PDTI (Industrial Technology Development Program). According to this Law, the company deduces 4% of Income Tax, reducing 50% of IPI (Industrialized Product Tax) in the acquisition of machines and equipment, and fastening the depreciation of P & D goods. According to the initial previsions, the company may save, until April, 2004, around R$140 millions, as soon as it invests R$762 millions in new technologies development. The PDTI assured incentives must be applied in the engineering, tools and methods & processes areas. Embraer program is the biggest one approved in 1999, in the PDTI ambit.

(Partnership for Innovation in Aerospace Science and Technology Program), destined around R$18 million, in the first year, to support university and research institutions' projects together with companies of the aerospace sector. It intends to reach the amount of R$ 120 million in a six-year period, extended for four more years.

4.1 Commercial Flows, Composition of the Supply Network and Nationalisation Indicator

Around 95% of the physical volume of inputs, raw material and components, turbines, aeronautic equipment, aeronautical aluminum and cabling used in Embraer's production process come from the international market. The main locally produced system is the landing gear, produced by ELEB (ex-EDE, a former division of Embraer). It is important to emphasize that to produce the landing gear, it is necessary to purchase 95% of the mechanical and electric/electronic components and 100% of aluminum and steel in the international market. For the local SME suppliers, almost 100% of low-technology inputs, such as steel, carbon and metal links, are locally purchased. The more sophisticated inputs, however, such as aeronautical aluminum for milling and software and project engineering systems of are 100% purchased in other countries. The ERJ-145 program supplier companies are around 450. In this program, around 95% of the suppliers are located in other countries. From the universe of external suppliers, 73% are distributed in the United States, 25% are in Europe and the remaining 2% are located in other countries. Some changes have taken place in the ERJ-170/190 program. The number of suppliers will be reduced to 20 companies. The majority of the suppliers are in other countries (85%). Concerning the entrance of new countries in the international suppliers network, the current distribution is: 53% in United States, 27% in Europe, 8% in Japan and 4% in other countries. The relative composition of the supply categories, according to economic importance the airplanes' production, is: 60% equipment, 34% metal structures, 4% electrical and mechanical hardware, 2% inputs.

From the total of Embraer's supply system, considering the relative economic participation, the risk partners are responsible for 36%, the second level suppliers are responsible for 57% and the national subcontracts for 7% The nationalisation indicator[7] of the aeronautical industry, considering the final plane cost, is estimated around 40%, decomposed according to its economic participation as follows: 60% of the final price is related to imports , 2% is related to services of engineering and treatment, milling, producing of composite material offered by national companies and the remaining 38% concern the added value, based on the labour costs, product development, plant depreciation, etc, in the leader company.

5. RECENT TRAJECTORY OF THE LOCAL PRODUCTIVE ARRANGEMENT

The first half of the 90s was marked by structural reforms and market-oriented by macro-economic stabilization plans - due to the industrial, technological and export financing policies – which have provoked a recessive and destructive cycle for the arrangement, deepening the retraction in government

7 The financing information were extracted from the document of Countable Demonstration and had the report of the Arthur Andersen Independent Auditors (December, 31th, 2000 and 1999).

demand and in production and employment, resulting in losses of competitive positions in the international and national markets. There was a significant regression in the enterprise's technological trajectories and losses of technological knowledge due to the sensitivity of the productive arrangement to government policies and public defense expenses.

On the external front, the recession in the world market for airplanes resulted in a reduction of sales of EMB-120 'Brasilia'. Embraer's difficulties in the pre-privatisation period contributed to increase financial costs, with direct impacts on airplane price formation. At the same time, this airplane entered the final phase of its life-span, as the aeronautical market demonstrated clear signs of preference for jets. The difficulty in financing - due to the lack of competitive credit lines for exports (the 1991/ 1992 Finex program had ended and its substitute, Proex,suffered delays) - was a negative factor that contributed to reduce the airplane's sales. Besides, the process of democratisation moved the decision centre away from the military, who had constituted a powerful pressure group in defense of the aeronautical sector.

On September 7th, 1994, after a period of financial and economic crisis, Embraer was transferred to the private initiative. At that time, Embraer had already produced 4,500 planes, detaining 31% of the regional planes world market and 42% of the military training planes market. In the same year, the ERJ-145 project was practically concluded and the most delicate phase of personnel dismissal had already been accomplished with resources offered by federal government. A consortium of companies and funds offered by Bozano Simonsen Group purchased the company. The new administrative staff centred its strategy on a new management plan based on six vectors: (a) a reengineering strategy and financing capitalisation, organisational and productive restructuring; (b) reconstruction of the relationship with clients, suppliers and technical support; (c) a plan identifying the company's mission and the new market strategy towards a new methodology of competitive intelligence; (d) priority to the ERJ-145 program; (e) a new entrepreneurial philosophy focused on strengthening strategic management of business, of product development processes; (f) use of a policy of alliances and multilateral and strategic partnerships.

This fact enabled Embraer to change the scenario - marked by a precarious financing and economic situation - to a favorable context with successful sales of ERJ-145 (50 passengers) and ERJ-135 (35 passengers), conquering, in 1998, the 4th world position among the biggest aeronautical producers of regional jets. On July 23rd, 1999, the company sold 20% of the ordinary stock of Embraer (around US$209 million) to the French consortium led by Aerospatiale Matra (5.67%), Dassault Aviation (5.67%), Thompson-CSF (5.67%) and Snecma (2.99%), stock control remaining with the Bozano Simonsen Group (20%), Previ pension funds (20%) and Sistel (20%), Brazilian Government (3.2%) and other companies (16.7%). This new strategic alliance aims to duplicate the client base and open new windows to the international financial market, enabling the establishment of a long-term operational platform in China, which is considered the fastest growing market in the world. The idea of a strategic alliance has been presented in the long-term strategy plans since the beginning of the new post-privatisation management, intending to grow in a market where giants such as Boeing, Airbus and Bombardier operate. The search for a strategic partner presents some obstacles. The main one was the Aeronautical Ministry's lack of interest. Several technical viability studies were made to opt in favor of the French consortium, considering the possibilities of British Aerospace and the Swedish SAAB. The decision was conditioned by considerations of the risk factor for the defense sector development in market conflicts with Embraer. However, the sale of voting stock without previous consult to the aeronautical command set off an institutional crisis among the military, the controller Bozano Simonsen and the Brazilian government. The military alleged that the stock sale implied the transference of part of the

control in Embraer to state companies and to French companies, opening up the road to a denationalisation of the sector. The contract did not guarantee the transference of strategic technologies to Brazilian national industry, and the funds from stock sales were collected for Bozano Simonsen, not reinvested in Embraer. After a long analysis made by the Brazilian General Attorney and a harsh public debate in the Brazilian Senate, the stock sales were deemed legitimate and the transaction got the government's approval. After this episode, institutional relations between Embraer and FAB (Brazilian Air Force) became more conflict-ridden and undefined.

The company launched, in 1999, a new regional jet, a variant of the ERJ-145 family, called ERJ-140 for 44 passengers. Identifying new market opportunities, the company also launched a new regional jet family: ERJ-170, ERJ-190-100 and ERJ-190-200, for respectively 70, 98 and 108 passengers, which demanded US$850 million for its development. The new jet family has already sold 325 units, considering real orders and options. The first ERJ-170 delivery is expected for the end of 2002. Embraer foresees that in ten years the company will earn around US$12 billion, for an estimated market of 2,500 planes. Exports, which represent 90% of the revenue increased from US$180 million, in 1995, to around US$3 billion, in 1999.

The dispute for market leadership has aroused disputes between Embraer and Canadian Bombardier in the WTO (World Trade Organization) forum, because of export subsidies in the Proex/BNDES program. Pressed by successive protests by Bombardier[8], a change in productive strategy took place, through initiatives of BNDES and a new competitive strategy, motivating Embraer to implement a policy of concentration on the national productive network by attracting its partners to SJC region. This program was named PEIAB (Program for Brazilian Aerospace Industry Expansion) and its purpose is to increase the national content of airplane parts, that is, to increase the inputs which receive some kind of local industrial transformation or treatment. PEIAB is not a program of technological skill destined to establish national suppliers. On the contrary, the program has structured its actions toward the attraction of multinational companies to the local supply of technological packages. The reasons for this lie in factors such as financial structure, investment capacity, technological capacity and logistics of the international supply network. (See Annex 2)

Based on the new supply policy and, the new scenario and on the strengthen of the competition (provoked by the entrance of multinational companies that begin to operate in the SJC region), the local suppliers organised themselves, in 1999, to build an export consortium. The consortium HTA (High Technology Aeronautics). Identified 16 small companies that integrate the local aeronautical network. The consortium HTA, employing 1,000 workers, presents a competitive differential that dominates the entire technological cycle (design services, project engineering, manufacturing). This experience presents a potential margin for external supply, beyond certain internal market niches. Estimates foresee a potential for exports between R$14 and R$ 20 million per year.

8 Canadian government stated that the Brazilian exportation program (Proex), used to sell regional planes, was not connected to the development countries necessities, as far as Brazil had stopped the application of determined national contents criteria norms about the use of Proex by the other sectors. According to Canada, at least 60% is the minimum of national contents required to allow Proex to realize an equalization of 100% of the interest tax to finance an airplane. Based on a study ordered by Ernest & Young, Canada informed that the ERJ-145 national contents was around 26% and that ERJ-135 was 14.8%. So, the interest equalization practiced by Proex should be proportional to Embraer's nationalization index.

6. CONCLUDING REMARKS: THE POLICY PERSPECTIVE

After the changes occurred with the privatisation process, Embraer is nowadays one of the few Brazilian companies with wide ample capabilities in innovation in the complete technological learning process. It attributed great importance to the process of solidification of technical knowledge, its transformation and information and, above all, its fast dissemination through the company's communication channels. In addition, Embraer is highly qualified through the mechanisms of learning by doing. This is especially so in the manufacturing process, in the assembly of fuselages and in systems' integration. It is also so in the dynamics of learning by using complex products, new materials, software or avionics resulting both in operating practices and more effective maintenance and adaptation that in turn result in improvements in the product. And finally in the learning by interacting dynamics, that derives from the interaction and institutional administration between the partners and the suppliers linked by information, goods and services.

The cycle of technological innovation is now perceived as a business dynamic not exclusively restricted to the routines of R&D. This is because the technological learning processes have demonstrated that they require interdependency and intercommunication. In other words, an interdependence between technical, production, human resources, financial-economical and marketing spheres in order to be carried out by the organization while at the same time also satisfying market demands, implying the merger of many functional activities at Embraer.

This would require a further strategic change for Embraer, which would be based implementing a management model emphasising learning, innovation and knowledge. In this aspect, the studies for the implementation of a project of corporate education/university already have been initiated, under the responsibility of the human resources department. The focus adopted by the new administration is characterised by sophisticated analysis using indicators of performance, profitability, client satisfaction, and the monitoring of change and future market transformations. This requires the establishment of a set of formalized and institutionalized mechanisms to generate, register, analyse and interpret information that is considered strategic and vital in a context of high competition, swift obsolescence of the technological frontiers and market uncertainty. In the past, the competitive strategy of the company was articulated through studies regarding aircraft demand, conducted by outside consulting companies, and the methodology was an attribute of those consultants. Since 1998, a "Market Intelligence" area was created where the methodology of these studies on the knowledge of the market started to be internalized within the culture and competitive strategy of Embraer itself. In other words, the company began to carry out its own market studies. Basically, they include market trends through the quantification of the global demand of aircraft using "Top Down" technical analysis, which consists of evaluating elements such as fleet size, number of airplanes in operation and fleet condition, sales development, backlog, sold and undelivered units, and sales forecast. The other method for quantification is called "Bottom Up" and consists of a direct approach to the customers, sounding them out for quantification and their real interest in a new product.

Embraer is responsible for the employees' training, technical monitoring and for the technological learning processes of the sub-contractors, by sending Embraer engineers who disseminate the necessary know-how. The Embraer successful strategy of competition and innovation in the 90s has been matched by a period of rupture in government support for CTA and other local technological institutions. The Brazilian government decreased its resources for government-sponsored science and technology institutions. In this sense, what happened to CTA and other local institutions has not been exceptional but certainly had some impact in the local innovation system. As a matter of fact a

quite problematic co-operation pattern has emerged between Embraer and the local R&D institutions. The Embraer co-operation and research relationships with CTA used to be more organic in the old days of total government control, but currently are limited to aircraft certification and approval. Even with other universities, such as the São Carlos School of Engineering and the Polytechnic School, contacts are only informal, contrasting with European and North American experiences, where a more structural relationship of firms and R&D centres are found.

Throughout the 90s Embraer was able to create an important participation in the world market for aircafts and become a member of a very selected club of competitive firms in this sector in a period when the Brazilian federal government's policy towards the industrial sector was almost non-existent. Without entering into a wider discussion about general industrial policy, it is just important to remind that there is no doubt that in this sector – aircraft industry – all successful experiences point towards large government support through several different ways. Boieng and McDouglas, of the USA, the Airbus European consortium and the Canadian firm Bombardier all are highly subsidised by their local governments. As a matter of fact, the Brazilian government has required a panel at the WTO under the idea that 5 Canadian policy programmes directed to Bombardier do not conform with WTO's rules: loans and guarantees under TPC (Technology Partnerships Canadá) consdidered to be direct subsidies for the production of 70-seat CRJ; the so-called Canada Account (a secrest financing fund); the support for export financing given by the Canadian Treasury (EDC – Export Development Corporation); the acquisition of De Havilland Inc byBombardier, with direct government subsidies; e, and regional development policies given by the State of Quebec, to Bombardier, which has headquarters in Montreal.

The possibility for the type of investment becoming real is certainly dependent on some important changes in government industrial policy. The federal government has been allowing "location tournament" from State governments, without any significant interference from central authorities. These locational tournaments have been related almost only to fiscal incentives (tax breaks or significant reductions of state level taxes) in order to attract foreign firms to different parts of Brazil and have a limited role in attracting the type of new investment associated to Embraer's case.

In order to analyze policy alternatives it is necessary to discuss briefly what role did the Government play in supporting Embraer's efforts to establish itself. The federal government did in fact stimulated significantly Embraer's sales through a program of financing its exports. Coming from a developing country Embraer has had difficulties in finding international banks and financial institutions willing to provide the financial engineering needed to sell airplanes. In fact in this type of market the sale of a good is coupled with a financing package. The importance of the program of financing exports (PROEX) of the Brazilian National Economic and Social Development Bank (BNDES) was that it not only provided the financial package but most important has had a framework under which local interest rates are equated to international interest rates. As mentioned above, this kind of incentive was heavily contested at the World Trade Organization by Embraer's immediate competitor Bombardier and by the Canadian government .

The other significant policy initiative of the federal government which partly benefited Embraer was a fiscal incentive to stimulate firms to increase R&D expenditures. Embraer is able to deduce up to 4% of its income tax for R&D expenditures, it can reduce 50% of the Value Added Tax for equipment acquired for R&D activities and accelerate the depreciation of goods acquired for R&D

There are also some credit lines by Finep, the technology bank of the Ministry of Science and Technology, but this is not an excellent option given the high interest rates that characterize the Brazilian financial system. As already mentioned, there have also been several attempts both from

the State of São Paulo and from the city of São José dos Campos in providing help. The problem with this type of policies is that there is no co-ordinating effort which would render them more efficiency. One of the more important policy mechanisms that could help the development of the local innovation system would be a series of mechanisms targeting supporting the setting up and growth of small high technology firms around Embraer. In fact, all major competitors of Embraer benefit from this type of support which, by the way, is approved by the World Trade Organization.

In fact, contrary to traditional wisdom, subsidies receive relatively permissive treatment under WTO law. They fall into three categories. Some are prohibited (for exports and for domestic, rather than imported, inputs);others are "actionable" (they can be punished subject to proof of injury); and three are permissible (all heavily utilized in the North Atlantic). There are, however, subsidies that are totally permitted under WTO rules. They include those to promote (i) R&D, (ii) regional development and (iii) environmentalism. Any high-tech industry, therefore, can receive unbounded subsidies for the purpose of strengthening S&T. (Amsdem, 2000).

It may be concluded that federal policies and state actions allowed for the success of the modern phase of the Brazilian aircraft industry. The federal government offered solid and continuous governmental support to Embraer during its stage as a government-controlled enterprise through the allocation in its budget of sufficient financial resources to the S&T infrastructure and procurement. It was through procurement that technological learning was made viable and feasible to a great extent. This government policy, particularly from the Ministry of Aeronautics, imposed the

In these days of Embraer as a private company, it has been able to implement a supporting program, namely, the Program for Expansion of the Brazilian Aerospace Industry for increasing local content. requirement of local production in associations of Embraer with outside partners for supplying the local market in order to acquire technology transfer. Even after privatization, the federal government stimulates significantly Embraer's sales through a program of financing its exports that equates local interest rates to international interest rates. Additionally, the federal government stimulates firms' R&D expenditures through fiscal incentives. States also offer to firms different kind of tax incentives.

In terms of international trade rules, since the civil aircraft segment will be subject to specific multilateral rules, the provision of relevant WTO Agreement, namely the Agreement on Subsidies and Countervailing Duties, do not apply to this industry. Otherwise some benefits received in the form of fiscal incentives could be claimed as actionable subsidies. However, the Canadian government claimed the financing program PROEX as entailing an export subsidy, which is defined as prohibited subsidy by the Agreement. Finally, Embraer's experience in cooperative agreements involving transfer of technology, in particular through local production requirements, could serve as an inspiration for other developing countries seeking to make transfer of technology feasible in consistency with the TRIPS Agreement.

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