IN SEARCH OF APPROPRIATE MEASUREMENT: THE CASE OF CASE STUDIES

In preparation of PhD dissertation work "*Where the Wings Come From? Emerging countries in the structure of the global aerospace industry*"

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1. PERSPECTIVES

1.1. A work in progress perspective

Scientific research in the overwhelming number of cases is appraised for its outcome. Its findings matter, its novelty matters, its added value for the scientific community or society matters, and it is perfectly understandable. PhD research is no exception to that. Is there then value in works that are 'under construction' to deliver the outcome but have not yielded results yet? For those who share the challenges of writing a thesis, there might be issues and research decisions to consider, case studies can be sources of ideas or signposts on what to avoid. This paper is written at an early stage of actual research into a topic – productivity and innovation in the aerospace industry in emerging countries – that requires a detailed understanding of historical and institutional background before quantitative methods can be applied. Thus what follows below is to be seen as "research in the making", or a view into the black box in the Latourian tradition. In other words: this paper represents work in progress, words of warning to the reader are that results are but partial; it contains historical overview, and somewhat extensive descriptive parts.

1.2. A development perspective on the aerospace industry

Box 1. The aerospace industry

<u>ISIC's definition of the aerospace industry</u> entails the manufacturing of aeroplanes, spacecrafts, their motors and engines, propulsion systems and launch vehicles, as well as their parts and components; also included are maintenance and repair.
There are <u>three considerations</u> to address here. Firstly, this study will focus on the aerospace manufacturing industry, which implies the exclusion of the services and air transport industry from direct analysis. While their importance are undisputed, especially as the spread of air services in the developing world precedes manufacturing, reasons such as different methodological requirements, our focus on high-tech sectors and practicalities such as data availability make it sensible to put the main emphasis on the manufacturing industry.
The second is that <u>air and space production</u> (and related research and development) are treated <u>together</u> here. Many developing countries are more active in aircraft components production than in space technology. However, as cases of Brazil, China, Korea, India, etc. show, governments have formulated space policies, that are institutionally often lumped together with aeronautics, especially in the military sphere. From an innovation point of view, application of space research most easily finds its way to aircraft related technologies and the trend shows that it can be true vice versa. Thus with such an elusive boundary at hand,

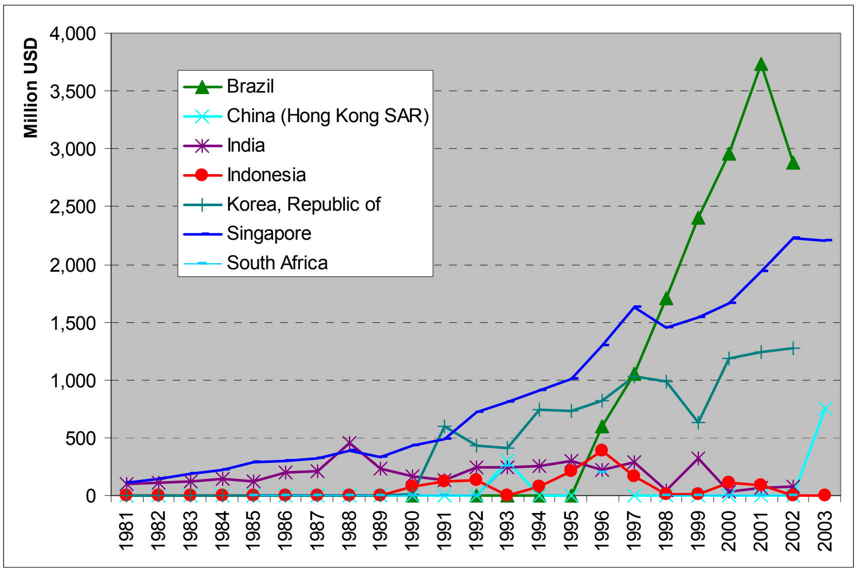
grouping together 'aero' and 'space' to 'aerospace' sector is justified. Data collection practices in line with the international statistical standards (ISIC Rev.3's 3530) also serve as a practical reason for treating them as one in the dissertation.
Thirdly, due to its strategic importance, the industry has always had a strong military dependence, in the forms of articulating and financing demand, by means of procurements and subsidies. Datamonitor's aerospace and defense industry profile gives an idea of the importance of the military side: in its market value estimates, 86.8 vs. 13.2% is attributed to the defense market (Datamonitor, 2007). This figure may be exaggerated since it includes all kinds of defense products. Since there are only unclear estimates[1] on the exact rate of military to civilian aerospace manufacturing, and given the fact that many products in civilian use today trace their origins in military R&D or applications (think of the Boeing 747 that was developed as a wide-body transport jet in the Vietnam War), any attempt to disintegrate civilian and military aerospace production would give biased results. Similarly to the 'aero/space', this boundary is just as elusive.

The aerospace industry has been an important contributor and promoter of globalization, but has also been – due to increased outsourcing practice – a subject of it. Globalization of both manufacturing and services have been underpinned by declining computing, communications and transport costs, the liberalization of product and factor markets, and a range of institutional and microeconomic reforms which have facilitated market entry. It is characterized by a diversified pattern of cross-border activities of firms, with high growth in international trade, investment and collaboration between firms for the purposes of product development, production and services. Technological change both adds to the competitiveness of firms and increases competition amongst them. As a result, more firms from more countries operate in a greater number of sectors and markets, and competition is increasing nationally and internationally.
Globalization brought an increasing international division of labor in the production processes of the aerospace industry. However, still only a limited number of countries possess sufficient level of capital and knowledge that happens to be complemented with entrepreneurial and political will, which is paired with efficient administrative and planning capacities. The achievements have significant external effects on countries and members of societies that did not engage directly in the industry, access to and possibilities to modify technologies, or the capability to move forward the technological frontier is limited to those few that did engage.
There are vast inequalities among countries in their level of technological capabilities and advancement, in income, productivity and ultimately wealth. It has been repeatedly shown that closing the technology gap in certain sectors means shift towards higher value added and ultimately wealth generation; where the inter-industry linkages play a significant role. The aerospace industry is number one among the high-tech industries in terms of direct R&D intensity (12.7% in average exceeding 11.3% of pharmaceuticals and 10.5% of office, accounting and computing machinery according to Keith Smith/OECD, 2005). The capital intensity of high technology research, development, design and production is undoubted; its yields in terms of value added and productivity have linked growth effects. In other sectors, such as electronics, newly industrializing countries have become innovators instead of merely imitators, able to move forward the technology frontier, as the case of South East Asia shows (see e.g. Hobday, 1995).

[1] The US Aerospace Industries Association (AIA, 2007) provides a fair indication in its 2006 sales revenue distribution (in USD): civilian aircraft 47.5b (31%); military aircrafts 52.8b (34%); missiles 14.9b (10%) and space 38.5b (25%).

The aerospace sector has been a source of many general purpose technologies. The space race between the United States and the Soviet Union, a remnant from Cold War times, has de-intensified with its ending, but it has left a legacy of human scientific and technological achievements of unprecedented scale. Space research, near-Earth orbit and first explorations into the solar system changed our perspective on the planet, and fostered a whole range of new innovations[2], resulting in new products and new markets, such as information-communications, with results that reached mostly all countries, way beyond those that financed the major part of research and development.
Over the last half a century, starting at different moments in history, companies from emerging countries (such as Brazil, China, India, the Republic of Korea, Taiwan, Indonesia, South Africa) have joined the aerospace production system, backed by government support for R&D and production. With cyclically returning high demand for aircrafts, shown by the backlog figures, create a growing market offering room to participate. Initially with components and systems or licensed manufacturing, but certain countries advanced to producing their own finished aircrafts, satellites or rockets. Figure 1 is a rough indication of this trend; it also projects data availability challenges; the lack of complete UNIDO data (no data on China, for instance).

Figure 1. Manufacturing value added in selected countries



UNIDO, 2006

Another side of a <u>global shift</u> have also become visible: Craypo and Wilkinson (2003) were warning that high-tech, high-skilled jobs in advanced manufacturing sectors are emigrating from the US, in (among others) the aerospace industry, where companies such as Boeing have become assemblers or integrators due to outsourcing of production to locations with lower costs. (Boeing provides an example of the exponential growth of outsourcing for commercial jets: the company is currently outsourcing half of its production while it was only around 15% in the 1980s and 30% in the 1990s.) Similar trends are to be seen in Europe as well, driven by the high exchange rate of the Euro.
When new countries engage in high-tech industrial activity – and as argued before, aerospace manufacturing is considered to be one –, it is always associated with technological learning, knowledge creation and skills development. In other words, activities considered to be

[2] Innovation is understood in a broad meaning, to include all five elements of the Schumpeterian typology (Schumpeter, 1934)

conducive to wealth creation in the long run. In such a strategic industry however, political motivations may go against (or enhance) expected economic mechanisms. Hence there is a need for a deeper insight.

1.3. A slice in the overall research agenda

Apart from posing questions on (1) what characterizes the global economic development of the aerospace industry; (2) what are patterns of technological change that characterizes the evolution of the industry – as reflected by research and development and innovations; the dissertation is also to look at (3) what conditions and technological capabilities are required on behalf of latecomer countries to enter the aerospace industry; and on (4) what are the actual and potential effects of aerospace R&D, production or components manufacturing of emerging countries for growth, technological change and catch-up.

A key issue is measurement. It is not only about the availability of datasets, but the identification of relevant variables that has to be sensible in the industry/country context. In order to do so, two case studies are presented below: Brazil and South Korea, to find the bases for innovative and manufacturing activities in the aerospace industry. One could question the selection of the two countries and is right to note that in terms of land mass, population, or per capita economic production the differences are immense. However, in terms of global competition in the sector, these countries are in a way competitors for resources; in terms of development of the national aerospace industry, any experience may have key characteristics that are most visibly pointed out when the countries are different. Looking at these countries shall be done with a reference to the following related sub-questions: (3a) What are the experiences of latecomer entrant firms in the industry? (3b) What are the determinants of successful catch-up for latecomer countries? (3c) What are policy implications for emerging country governments?

2. BRAZIL

The most broadly analyzed emerging country aerospace industrial development is the case of Brazil. With convincing detailed information most freely available on the history of a large number of stakeholders of the industry, ranging from the government ministries and attached agencies, to the private sector manufacturers (of full products or components), it has been discussed from various aspects. Goldstein took a predominantly political economical approach (2002a), with hindsight also on strategic trade (2004); a system of innovations approach, limited to the civilian aircraft manufacturing, was employed by Marques (2004); another probe was through a case study of privatization (Goldstein, 2002b). The above-mentioned works relied heavily on data collected by Frischtak (1992), whose interest was to investigate Embraer, the leading company's role in the commuter aircraft industry in an industrializing country, its technology strategy, rivalry and cooperation and broader lessons on a specialization and national champion nurturing. The topic has been further open to less direct industry analysts, to mention but one interesting aspect, Botelho and Schwartzman (1966) discussed the US impact on Brazilian science, writing about the "Americanized science and technology" in the case of aeronautical research centers' development. Most of the literature focuses on the success of the aircraft manufacturing company Embraer, while the space segment of the sector is less widely discussed.

In the following, I will present the main turning points and results around the development of the Brazilian aerospace industry, relying heavily on the afore-cited works and descriptive trade statistics on the industry as a whole (UN Comtrade) and specially on the military flows

(SIPRI, Jane's), complemented with company and agency reports. The use of such sources is directly linked to some practical advantages: these are not only the most easily accessible data, but – especially the exports and military licencing activities – reveal parts of the technological capabilities of the countries examined.

2.1. The origins of manufacturing; military and domestic

Considering the fact that the interest in constructing and using aircrafts for commercial, postal or defense purposes is just as old as the industry, in this sense, Brazil is not a latecomer. Countryman of the heroic age, Alberto Santos-Dumont, once a prize-winning balloonist and aviation pioneer[3] wrote his name in aviation history next to the most famous European and North American when he made his maiden flight 1906. Marques describes the period 1910-1930 as one where investments were made, the lack of engineering and technological capabilities, coupled with lack of government support resulted in no significant development in the industry. (Marques, 2004: 86)

Military needs of the allies in the Second World War initiated aircraft manufacturing in Brazil for a decade of 1935-1945. Training of local engineers and pilots by US experts resulted in the production of one fighter plane a day at its peak. Apart from military aircrafts, smaller agricultural and training machines were produced. To compensate the lack of local components and expertise, the government made the decision to finance the high-level training of aeronautical engineers and the Technological Institute of Aeronautics (ITA) was set up under the auspices of the Ministry of Defense. Technical support was provided by the US, through NASA and MIT.

The developments after the war show signs of a coordinated army-industry joint effort to establish a Brazilian aerospace industry; in which the drive was less private, much more with a public defense interest but also fitting the prevailing view on industrialization. Starting as a chain of reactive measures to sustain the already available expertise and find ways to (re)produce it at a time when military production serving US war needs halted and to (though not fully flawlessly) ensure that aeronautical engineers.

The Aerospace Technical Center (CTA) was established by the military with the aim of employing ITA graduates in a research center focusing on the development of what they called a 'Brazilian aircraft'. Backed by strong government support (manifested in direct financial and policy support by the Ministry of Defense and the Ministry of Aeronautics, but also with the backing of protectionist policies, the aerospace production idea gained momentum.

Licensed assembly initiated aircraft production in the fifties, this time from the Dutch Fokker company. Between 1956-59 a hundred Fokker S-11 Instructor single engine, light trainer aircrafts were manufactured in Brazil (SIPRI, 2007). The first product of the effort involving ITA experts and an entire relocated German research group to create a general purpose, light transport aircraft serving civilian as well as military needs was a 19-seater, twin-engine model. It took a decade after the flight of the first prototype until the first aircraft, the Bandeirante was announced ready in 1969. The most important achievement was the FAA certification of the plane. It was in that respect that the apparently odd "19-seater" characteristic of the plane brought a major advantage on the US market: it could save the cost of a necessary flight attendant required from 20 or more passengers, as was highlighted by

[3] Originally successful with lighter-than-air vehicle, Santos Dumont turned to the heavier-than-air problem. After some unsuccessful attempts his 14-BIS aircraft's wheels left the ground on October 23rd 1906, and his airplane flew 50 meters. His flight a month later brought him the "Archdecon Prize" for solving the problem of making a heavier-than-air machine take off by its own means.

Teitel (2006). For the launch of the Bandeirante, the Brazilian Aerospace Enterprise Co., (Embraer) a state-owned aircraft manufacturer, was founded by CTA experts. Five years after the military coup in the country (starting military rule of 21 years), it was not surprising that the army had a large share in the enterprise. Goldstein (2002: 525) nevertheless notes that although the company was in public hands, it was governed by private law and lead by Ozires Silva, whom he called a competent and independent manager.

The 'aerospace industry' at the time looked heavily unbalanced in favor of government, with a high dependency on the Ministry of Defense playing the key role in procurement and supporting by tax-incentives and subsidies, backed by a protectionist trade policy. The development bank BNDES also provided special financing schemes. It was also the government that ensured generous technology and research support. Private investors of Embraer contributing to the payment of R&D received tax incentives. To counter this unbalanced structure, the national supply chain was encouraged, but it was again the Ministry of Defense that made investments in assembly and supply. Marques refers to Dagnino and Proenca's (Ibid, p.87) estimate that 68% of parts, components, sub-systems were imported, mostly from the US. Strong import-deterring measures in support of the local market included a 50% tariff of 1977 on commuter-type aircraft imports to Brazil, and the "law of similars" precluded the public sector from the acquisition of foreign planes when a local substitute was available. Table 1 reveals the intensification of military aerospace imports from the 1970s, it should also be noted that the majority of imports can be accounted to military orders for an increased volume of transport and fighter aircrafts, helicopters, radars and missiles. Goldstein (Ibid) remarks that Embraer's contribution was low on added technology, rather concentrated on fuselage design and production as well as final assembly having the crucial technologies imported.

Certain local suppliers have become, however, over time, also producers of small aircrafts – such is the case of Aerotec and Neiva. These two deserve a few thoughts since the Brazilian aircraft industry is often referred to as only the developments of Embraer. Aerotec S.A. was also a spin-off of CTA and started operations even earlier, in 1962, also in Sao Jose dos Campos. The fruits of its operations were the development and manufacturing of a two-seater trainer for the air force, the A-122 Uirapuru and a slightly advanced version, the Uirapuru II or A-132 Tangara, which, apart from a small Bolivian export, did not reach government attention. Aerotec's main profile became component manufacturing for Embraer – which in 1987 bought out the company. Neiva was launched in 1954 and started to produce light aircrafts (models such as Corisco, Tupi, Carioca, Sêneca, Sertanejo and Carajá); became a supplier to Embraer in 1975 and their relations tightened until it was acquired by the latter in 1980. It is still an active component supplier to Embraer's latest models.

The production concentrated at the by far the largest company, at Embraer, which could make benefit of economies of scale. To support technology diffusion, the Institute for Development and Coordination of the Aerospace Industry (IFI) has been set up and it played a major role providing consultancy services and encouraging networking.

Table 1. Distribution Trend of Military aerospace products import to Brazil 1950-2006

	1950-54	1955-59	1960-64	1965-69	1970-74	1975-79	1980-84	1985-89	1990-94	1995-99	2000-06
Austria	0	0	0	0	0	0	0	0	0	0	12
Australia	0	0	0	0	0	24	6	0	0	0	0
Belgium	0	0	0	0	0	0	0	0	0	77	19
Canada	0	0	12	159	159	6	34	62	23	0	69
France	0	0	40	12	182	109	156	457	187	163	536
Germany (FRG)	0	0	0	0	51	109	12	150	156	340	140
Israel	0	0	0	0	0	0	8	0	0	22	37
Italy	0	0	0	0	140	243	165	50	36	13	131

Japan	0	152	0	0	0	0	0	0	0	0	0
Kuwait	0	0	0	0	0	0	0	0	0	99	0
Netherlands	0	220	6	0	4	7	1	0	0	1	0
Norway	0	0	0	0	0	0	0	0	24	0	0
Russia	0	0	0	0	0	0	0	0	10	0	0
Saudi Arabia	0	0	0	0	0	0	0	0	0	0	36
Singapore	0	0	0	0	0	0	0	0	30	20	10
Spain	0	0	0	0	0	0	0	0	0	0	56
Sweden	0	0	0	0	0	19	4	38	0	8	80
Switzerland	0	0	2	0	0	0	0	0	0	0	0
UK	345	2	169	10	159	1435	257	62	210	933	4
USA	282	357	354	575	898	695	17	507	94	188	350
Unknown country	0	0	0	0	0	0	12	0	0	0	0
Total:	627	731	583	756	1593	2647	672	1326	770	1864	1480

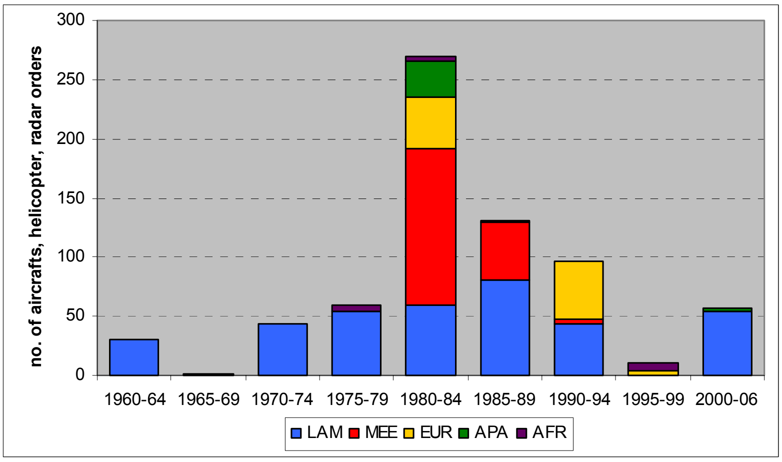
Source: SIPRI (2007)
Note by data compiler: The figures given in the table are calculations to indicate trends in volume

2.2. Beyond Brazil

The end of the seventies saw the largest growth in internationalization of the Brazilian aircraft industry, both in the civilian and military segments. With the deregulation of the American market in 1978 the 30-seater advanced twin-prop plane became the main commercial product that gained dominant market share in the US. (Frischtak, 1992: 13). Targeting the corporate market, the EMB-121, an 8-seater, all-Brazilian, pressurized twin turboprop plane was developed in 1979. A new product line, or 'family' was born, that, based on earlier experience and the concept of becoming self-reliant, became referred to as local from the development phase to the production as all-local, all carried out by Embraer (including financing).
In order to do so, the company strategically focused on the development of its technological capabilities through four channels, notes Teitel (ibid): licensing, international partnerships, subcontracting and local R&D. To highlight some of these, licensing agreements were signed with Piper Aircraft for the production of light aircrafts (that had an important result of producing an increased number of components (exceeding two-third) locally), with the Italian Aermacchi, but also with the French Fennec light military helicopter (SIPRI); partnerships with Aeritalia and Aermacchi brought complex parts such as wings and electrical system production to Brazil; Embraer signed subcontracting agreements for assemblies of parts of Boeing B-747s, Northrop F-5Es, McDonnell Douglas MD-11s.
The most successful child of the military product line was the EMB-312 Tucano, a trainer aircraft that boosted exports all over the world, but especially in the Middle East. (Embraer evidently benefited from the Iraq-Iran war through selling 80 Tucanos to Iraq and 25 in the end to Iran; an important receiver and link was Egypt (54), where 30 of the type were assembled in the mid-eighties under license, mostly for the Iraqi army.) Its sales record is evidently the largest non-developed country achievement in the field of military-use aircrafts[4], especially one that had considerable demand in the developed world – 130 aircrafts were manufactured in the UK under a license agreement. Apart from the Tucano, the Bandeirante was responsible for the surges in number of orders for Embraer aircrafts in the 70's and 80's (Figure 2). While the US orders of the latter were all for business purposes, the dual civil-military use capability made it an important export product to South-America, but also reached the African continent with deliveries to Angola and Gabon.

[4] According to SIPRI's information (ibid), buyers of the Tucano include the following countries (with number of orders): Angola (6), Argentina (30), Egypt (54), France (50), Honduras (12), Iran (25), Iraq (80), Paraguay (6), Peru (30), Venezuela (31)

Figure 2. Geographical Distribution of Brazilian Military Aerospace Exports (1960-2006)



Source: SIPRI (2007)
Note: LAM=Latin America; MEE=Middle East; EUR=Europe; APA=Asia/Pacific; AFR=African Countries (excluding Egypt)

Global competition came hand in hand with the need to make adjustments to international market standards. A bigger challenge was the technology race; the Embraer turboprop planes were reliable and cheaper than its competitors (e.g. Saab-Fairchild SF340), they were less reliant on cutting-edge technology. With the end of the military rule in Brazil and the retreat of the generous government (defense) expenditures, the demand for higher-technology subsystems and components could not be fulfilled, they were not available locally. Improvements in digital technology, new materials and software hardly found their way to Embraer, lack of government support for technology upgrading, decreasing subsidies and orders, the end of the export support regime FINEX (at a time of lower global demand), coupled with cuts in funding of key agencies such as IFI marked serious difficulties at the end of the eighties and early nineties. It should not be forgotten that it was also the time of the debt crisis. The worst year for Embraer was 1994 with immense losses.

2.3. Embraer after privatization

The government has already been considering privatizing the company since the beginning of the 1990s, and at the end of the year it successfully sold a controlling stake to a consortium lead by US investors and Brazilian financial institutes. The privatization also meant the reorganization of the company, a new management structure and finally a serious cut in the workforce, by almost 2/3 in comparison with the 1990 level. (It did not lack signs of outsourcing: a number of firms, such as Compsis, entered the supplier market employing ex-Embraer technicians.) A new target market was set: the civilian regional jet niche[5].
Since the privatized company could not rely on the earlier established government (military) backing, a new system was necessary to bear the risks of developing and launching a new product line. 'Tier two and three' component suppliers from Europe and America partnered in to share risk.

Table 2. Embraer's post-privatization results (1996-2007)

[5] Frischtak's (1992: 2-3) note highlights the risky nature of striving for niche market: "The fundamental reason [for earlier successful firms facing substantial difficulties is that…] the market became more crowded in the 1980s, making it increasingly difficult to pursue niche-oriented strategy…"

	commercial aircraft deliveries	Number of employees[1]	Net sales (m USD)	Net income (m USD)
1996	4	n/a	n/a	n/a
1997	32	n/a	n/a	n/a
1998	60	6,737	1,354	145
1999	96	8,302	1,837	235
2000	160	10,334	2,762	321
2001	161	11,048	2,927	328
2002	131	12,227	2,526	223
2003	101	12,941	2,144	136
2004	148	14,658	3,441	380
2005	141	16,953	3,830	446
2006	130	19,265	3,807	390
2007Q1[2]	25	21,005	843	26

[1] incl. Embraer Join Ventures in Sao Jose dos Campos
[2] As of March 2007
Source: Embraer (2007)

The regional jet series started to deliver success from the end of the 1990's (see Table 2.) The jetliner product line could be divided into two main designs, the ERJ 135, 140 and 145 focusing on the less than 50-seater market, and the ERJ 170, 175, 190 and 195 types aiming at 100-200-seater market. The line was started with the ERJ 145 that, after being put on hold in 1991, under the new management, finally rolled out in 1995; until present day this twinjet gained the largest share among the company's jet products, both in terms of orders (47%) and deliveries (62%) (Embraer, 2007). The ERJ 170 was launched in November 2001, followed by the 190, which continues to attract much attention from airlines around the world: total orders reached 327 (21%) by the first quarter of 2007.
The consolidation of the global regional jet market at the turn of the millennium saw virtually two major players competing on the field: Brazil's Embraer and Canada's Bombardier. Goldstein and McGuire (2004) give a detailed analysis on the harshest fight in the history of WTO between two countries, Canada and Brazil, after the two competitor companies' quarrel escalated to country level and addressed the wider export policy measures. What is still clear that Brazilian aerospace products and components export has sharply grown in the second half of the 1990s (Fig. 3.a), close to 7 times between 1996 and 2000 (UN Comtrade, 2007).

2.4. The space segment

The CTA's scope has been aero*space* research and development since its founding, but the space research only intensified in 1965 when Space Activities Center, the IAE was set up (one year after the beginning military rule, with direct involvement of the air force) to boost rockets develop. The year 1971 marked the start of the full-scale space program with the establishment of the Brazilian Commission for Space Activities, the Cobae. Under direct influence of the military, headed by the Armed Forces General Staff and reporting to the National Security Council, the Cobae was responsible for the Complete Brazilian Space Mission (MECB). The coordination of the three main fields of activities (launch vehicles, launch sites and satellites) was dominantly overseen by the military, with relatively the highest level of civilian involvement in the satellite manufacturing. This was carried out by the INPE, an organ of the Ministry of Science and Technology, with a mission to develop meteorological and space research satellites and take part in engine development.
The United States had a major role in the development of Brazilian space activities, starting from the 1966 direct help with rockets, to agreements on data sharing, training and technical assistance with INPE. The relations cooled towards the beginning of the 1990s, when the US started to criticize the lack of civilian control over Brazilian space programs, but especially the recent focus on the development of ballistic missiles, taking in mind the advanced nuclear

program. Brazil developed stronger ties with Russia and China, but the in 1994, President Franco agreed to a restructuring of the Brazilian space sector toward a higher level of civilian involvement.
The Cobae ceased to exist and was replaced by the Brazilian Space Agency, the AEB, with a civilian leadership, reporting to the President. The AEB was overseeing the MECB; the Ministry of Aeronautics got in charge of the launch vehicles and launch facilities and the INPE continued to be responsible for satellite development.
The balance of the Brazilian space activities is rather mixed: heavy involvement of the military until 1994 and slow commercialization starting only recently; Brazil fired around 2000 rockets since 1965, launched 6 satellites under the INPE (3 data collecting, 1 data collecting and low-orbit earth communications experimental and 2 remote sensing satellites); two space launch facilities (Alcantara and Barreira do Inferno) established a tracking and control center (CRC) and has developed close ties with other space agencies. Striving to become independent in launching capabilities[6], still it has a history of three failed launches of vehicles. The most recent, successful cooperation has been with China; the two countries launched in 1999 the CBERS-1, followed by the CBERS-2, the China Brazil Earth Resources Satellites. Their multiple applications include agriculture, forest, use of land, environment, and water resources and has been praised for high quality remote sensing. The fact however that public information has not been made available alarmed some observers about possible military use. Talks have also been going on with Russia on cooperating in further improved resolution remote sensing.

In a short, overall evaluation of the developments of the Brazilian aerospace industry, one can first and foremost see the major shift from military oriented export to commercial one in the aircraft segment. Embraer, a successful global player in the commuter market with its Bandeirante, Tucano and Brasilia types, also gained a reputation and a large market share in the regional jet market and is attacking the mid-range segment as well with the ERJs; it has shares traded on the Brazilian and New York Stock Exchange. The key to Embraer's success could be simplified to two points: (1) Government support: strong political and material support for the development of the industry (including attraction of technology from other countries), including R&D and export protection/promotion; (2) strong linkages: joint government-private ownership moving to private ownership, but national research, training and industry (CTA and ITA) have always had strong ties. The clustering of the suppliers, research and other actors of the field (Paraiba Valley, Sao José dos Campos) were a source of knowledge spillovers.

3. SOUTH KOREA

The aerospace industry of the Republic of Korea[7] remains one of the less-discussed cases, which is not surprising considering the dominance of military production and use in a country that has officially not ended a war with a neighbor of over half a century. It is nevertheless an interesting case since the Korean economy has provided astonishing evidence of learning and technological upgrading, innovative potential and dynamic growth. My analysis at this current stage relies most heavily on Korean ministries' (e.g. Ministry of Science and Technology) and agencies' (e.g. National Science & Technology Council, Satellite Technology Resource Center) published data and overviews given by Tae Hwan Cho (2000) and Doo Hwan Kim (2006), complemented by available defense trade reports and international trade statistics.

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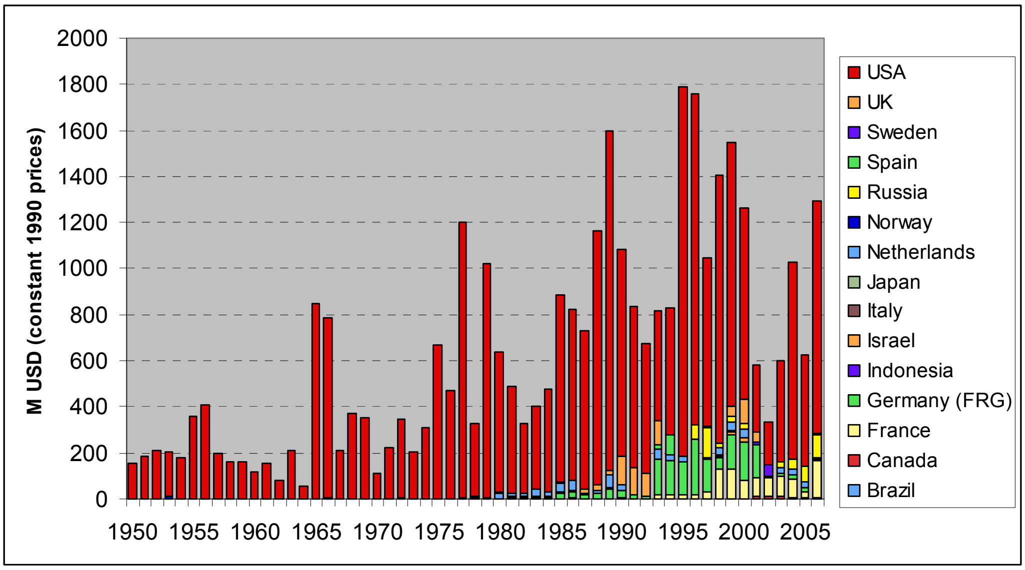
[6] Also by local production of ammonium-perchlorate, an oxidizer for solid fuels; production started in the 1980s to decrease reliance on the US.
[7] South Korea or Korea are used here interchangeably for the Republic of Korea

The historical development of the Korean aerospace industry shows two distinguishable lines of development, one of the military aircraft manufacturing and the satellites and systems manufacturing.

3.1. Into military aircrafts and components

During the years of the Korean War and after the ceasefire, South Korea received and increased amount of military equipments from the US (see Fig. 2.) of which aircrafts consisted a considerable part. While Korea was introduced to the technology, local capabilities sufficed in depot-level maintenance in the end of the 1950s, with incremental improvements during the 1960s. This was supported from the government level after the establishment of the Agency for Defense Development (ADD), which aimed at doing defense related research, inter alia for the air force and also turned to be the military procuring agency. The agency was borne at a time when the US support was decreasing (Fig. 2.), and as Texier (2000, p.136) refers to his interviewee, it was a concern that was to be overcome even if new equipment production cost more than purchasing from other countries; acquiring competences was considered crucial for the independence of South Korea.

Figure 3. Distribution Trend of Military aerospace product transfers to the Republic of Korea (1950-2006)



SIPRI (2007)

The advancement to a phase of local production was brought[8] by the assembly of MD-500MD (1977-85) helicopters and F-5E/F tigers (1982-86). The aerospace sectoral developments lost steam at the end of the 1980s, as Cho (2000) criticizes, government policy promoting the aircraft industry virtually stopped, a 1978 promotion law and a 1987 R&D support law failed to create local capabilities; the Korean Fighter Programme (KFP) of the late 80s was in effect strengthening the acquisition of fighter aircrafts for the military instead of really boosting domestic industry. Nevertheless the KFP also received immense material support. (Cho estimates 1 billion dollars worth a program or five times the size of the domestic aircraft industry; SIPRI (2007) estimates show a 2.5 billion dollar deal to assemble 120 F-16s over 1994-2001, of which up to 51% of value was produced in Korea.)

[8] There have also been earlier experiences with local assembly, a total of 4 PL-2 trainer aircrafts in 1971 and 74.

Two main paths of development are observable from the late nineties: a continued production of foreign licensed military aircrafts and the efforts to develop indigenous types. The Korean Fighter Programme was followed by KFP-2, signed in 2000, to produce 20 F-16C block 50/52s and F-16Ds over 2003-2004, a deal with the US 663 million dollars, with an increase to 78% of value produced in Korea; another 20 are in discussions under KFP-3 negotiations for delivery in 2009-10. Texier (ibid) describes the by then increased competition between three major chaebols, Daewoo Heavy Industries, Korean Airlines and Samsung Aerospace to bid for the KFP, contrasting it to the interest in the F-16 offset program in the 1980s, when it was only Daewoo to pursue its bid. The KFP was won by Samsung which has been earlier active in engines production.

Apart from the KFPs focusing in fact on F-16s, further licensing and production offset agreements were signed: Dutch and Swedish fire control and air surveillance radars were produced over 1998-2006; with another 12 German Bo-105C light helicopters (1999-2000); and a deal of 4.2 billion USD to produce 40 F-15E fighter/bomber jets, as well as Apache helicopter fuselages. Clearly, the most intensive ties remain with the US, shown by volume as well as the multilevel links with the government and the two major manufacturers, Lockheed Martin and Boeing. The product of intense Lockheed – Samsung (KAI) cooperation is a jointly developed supersonic trainer and fighter jet, the T/A-50.

Korean component development activities for the civilian market have also been visible, even if not that boldly: Bell helicopter fuselages are continued to be produced in Korea, and Boeing has also been outsourcing components' production not only for the AH-64D helicopter fuselage, but also sections of the B767 and a wing rib of the B747. Links with European producer Airbus are also noteworthy, through aircraft structure manufacturing for A318-321 and A330/340 families; and risk-sharing partnership for the A350.

3.2. Push for local capabilities

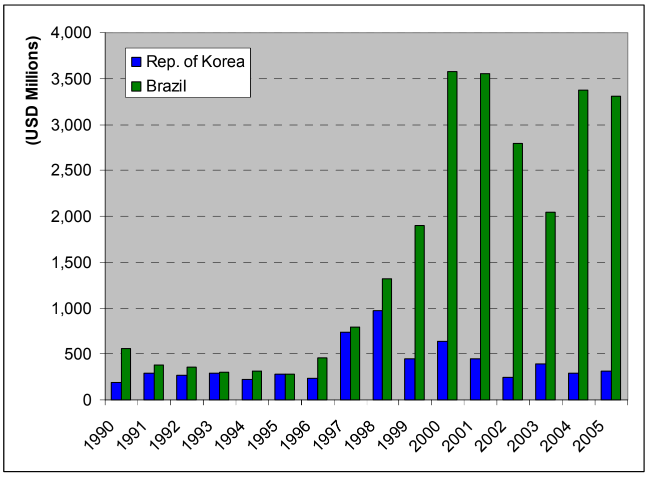
The other track, gaining increased political support is the local development aircrafts, drawing from the experience of helicopter and fighter plane assembly and component manufacturing to US giants. A trainer aircraft, the Cheng Kong 91 and the KT(X)-1 are the results of such developments (although in export figures they don't show up yet [Fig. 3a.]). What lead to the KTX development owed much, according to Texier (ibid, pp.151-153) to Daewoo's loss of the KFP bid and the not acute, but still present need from the air force for turboprop trainers. The KT(X)-1 was developed by Daewoo cooperating with the Swiss Pilatus, as well as the French GECI companies; in the year of the first test flight, 1991, however, Pilatus left the program due to tensions between the organizations. The success of the KT-1 (taking the name Woong Bee, or great flight) is mixed; apart from the Korean air force, Indonesia has been a buyer, in an evidently promotional trade agreement as a form of indigenous aircraft exchange[9].

Most recently, interest has turned to an indigenous stealth fighter, the KFX. Following the two-year project definition study by the Defense Acquisition Program Administration, a feasibility study is in preparation, to be completed by 2008 February; the decision whether to go ahead with the program estimated currently at 13 billion dollar may come in the following year (*Aviation Week & Space Technology*, Apr 23, 2007). Korean aerospace industries, apart from developing the KT-1, are also active in unmanned aeronautical vehicles' (UAV) development, still under a high level of secrecy.

[9] In a 2001 agreement, Indonesia bought 7 KT-1B Woong-Bees and agreed in 2005 for another 5 and option for 8 more; the deal (with additional military equipment delivery) was to offset South Korean order for 8 Indonesian CN-235 transport aircrafts. (SIPRI, 2007)

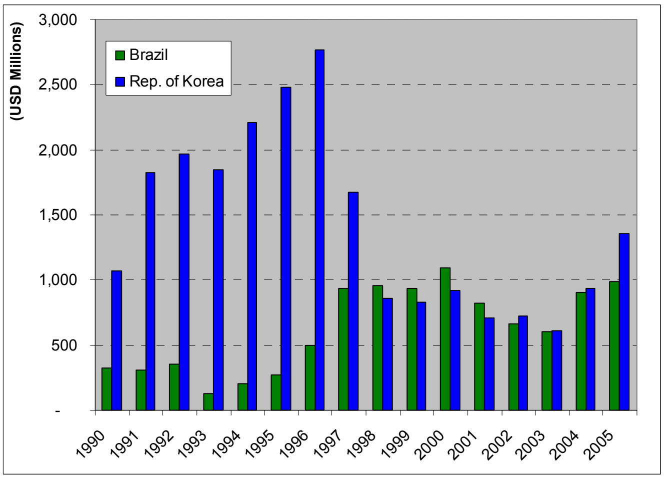
Fig. 4a/b Trade performance of Korea and Brazil (1990-2005)

4a. Exports of Aerospace Products and components



Source: UN Comtrade (2007)

4b. Import of Aerospace Products and components



Source: UN Comtrade (2007)

While the aircraft industry was originally low value added, slowly transforming to higher technology, but still far from the frontier, and was an exclusively military oriented project, the other trajectory in the Korean aerospace sector, that of **the space industry** has been more a latecomer, but aiming at the higher-end. The Korean achievements in electronics found their ways closer to the satellite and its systems production. Kim (2006) described the efforts of this late entrant as an attempt "to achieve fast-track development in the space race". While the relevance of the teachings of the over five hundred years old rocketry traditions is considered to be the accuracy of production, the post world war South Korea only started to be engaged in the space segment in the 1980s. The earlier mentioned 1987 legislation had more successful results in this latter segment: with the institutional backing by the creation of the Satellite Technology Research Center (SaTReC) under the Korean Advanced Institute of Science and Technology (KAIST) the first experimental satellite program was conceived, and in 1992 the first experimental satellite was launched, followed by the second science satellite a year later. By 2000, Korea has sent 3 scientific satellites (*Uri Byul 1-3*), fired 2 scientific sounding rockets, to which adds the 3 (foreign manufactured) *Mugoonghwa* telecommunication satellites by the Korean Telecommunications Co. The focus has been on the infrastructure development for micro science satellites, such as the 3 Uri Byuls and the KOMPSAT-1, the Korean Multipurpose Satellite (or *Arirang-1*), short-term plans include the further launch of KOMPSATs (to a total of 5), for communications, ocean monitoring, meteorological as well as land observation goals. Plans with a budget of 2.6 billion dollars for space research for the period 2005-10 include moving further up the technology ladder to have not only a space launch vehicle (KSLV) with a capacity of 100 kg, but to be able to send 1.5 t satellites to low-Earth orbit. As Kim (ibid) writes, it could bring Korea among the top 10 space powers of the world, and fully catch-up with the current 60-70% competitiveness rate. (This still does not give it regional technology edge: China, as a comparison, is currently capable of launching a payload of 12 t to low-Earth orbit and, according to the white paper of 2006 October, is now working on the 25 t class).

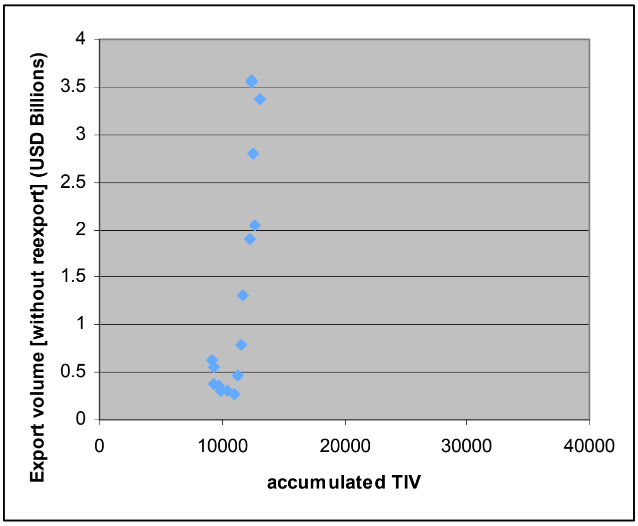
The selection of company locations, has heavily been influenced by the state's security concerns as Markusen (1993) argues, it is worth noticing that insulated sites, such as Changwon may not have the development effects, technologies developed for the military may not easily find their way to commercial use.

4. CONCLUSIONS

The two cases show two rather divergent trajectories. While industry in general has historically played an important role in both countries, Korea's national conglomerates and Brazil's import substitution policy have been widely discussed, however, in the case of the aerospace industry, they may be less effective in describing the developments. In both countries the start was heavily military oriented – it remained so in South Korea, whereas Brazil has moved to a more commercial path in the aircraft segment. The path the two countries took after the 1990s is rather divergent, Korea maintains the military orientation of domestic design, with subsequent component manufacturing for US and European producers; Brazil has seen the fruits of orienting towards the commercial sector (See figure 4a/b). The structure of companies remains also an interesting source of differences: Embraer in Brazil 'swallowed' other companies with strong capabilities while large chaebols that diversified towards the aerospace sector are competing with each other within the country. This more competitive structure and Korea's experience in electronics may show different results in the space capabilities development, more specifically the development Korean satellites and their commercialization have the potential to be more successful than the Brazilian counterpart. The availability of reliable data on military imports by SIPRI allows a projection of some basic correlations: such as the one shown in Fig. 5. Using the TIV volume index (cumulated since 1950), in a two-year lag to see how it influences export, the two graphs confirm that while the case studies showed that military involvement could boost the industry at an early stage, it does not ensure later success.

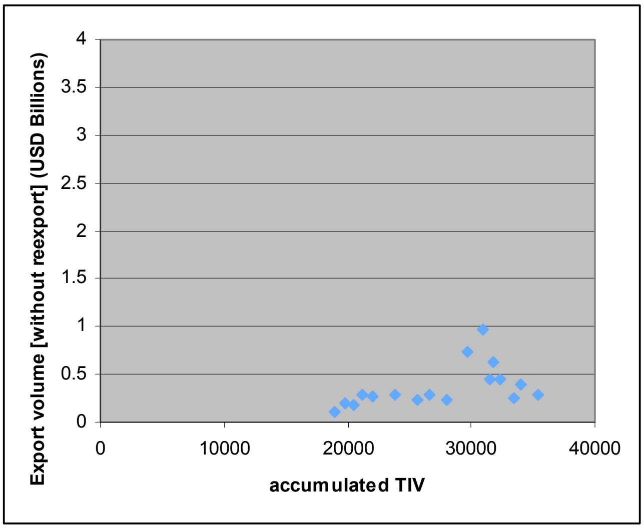
Fig. 5a/b The effect of military imports on overall aerospace exports (1989-2006)

5a. Brazil



SIPRI / UN Comtrade (2007)

5b. South Korea



SIPRI / UN Comtrade (2007)

]Regarding the issues of finding variables for measurement, the case studies suggest three groups on technological capabilities development:

(a) cross-country learning and spillovers (such as trade data in terms of export, export productivity, ; military trade data in terms of volume; acquisition, licensing agreements, subcontracting and cooperation agreements)
(b) local knowledge and skills development (such as achievement in tertiary education towards the field; R&D expenditures and people involved)

(c) local technological achievement (technical properties of technological capabilities, as seen in product catalogs; space launches, number of products produced)

This gives the next step: there should be a systematic collection of such variables, depending on their availability...

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