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CHOICE OF NATIONAL STRATEGY AND INDUSTRIAL ORGANIZATION COMPARING AIRFRAME PRODUCTION BETWEEN BRAZIL AND JAPAN

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INTRODUCTION

This paper examines two reasons why the development of airframes as a national aircraft industry[1] have been met with more success in Brazil than in Japan: First, Brazil's aircraft industry was nurtured by a unified government administrative structure while in Japan the same industry instead became a victim of inter-ministerial battles. Second, the Brazilian government nurtured a single specialized national-champion firm, Embraer (*Empresa Brasileira de Aeronáutica S.A.*)[2], while the Japanese government relied on the traditional consortium approach that epitomizes most Japanese post-World War II industrial ventures. While usually successful, the consortium approach did not do as well to build a domestic aircraft industry in Japan. Making airplanes turned out to be an exception in Japanese business partly also because of the involvement of several government agencies at varying levels. In other Japanese industries, such as steel, semiconductors, and computers, a single ministry, the Ministry of International Trade and Industries (MITI) had managed these consortiums relatively successfully.

The remarkable economic growth observed in the development of high-technology industry in some Asian countries including Japan, South Korea, Taiwan and Singapore from the 1960s to the 1980s, had attracted many scholarly studies. Some studies focused on the characteristics of macro institutional supports such as national research institutes, financial incentives, and education systems—that is the "national innovation system" (Nelson, 1993). Others focused on the role of the government (Johnson, 1982) while yet others focused on industrial linkages or the relations between the private sector and the government (Hobday, 1995; Okimoto, 1989; Evans, 1995; Woo-Cumings, 1999). There have also been studies that showed experiences in different countries and significantly different characteristics of innovation among various industrial sectors (Mowery & Nelson, 1999).

This study attempts to look further by focusing on a specific industry, airplane design and production, by arguing that issues such as technological regimes and their natural trajectories can only be understood within specific institutional contexts that are not only industry specific but may also be unique from country to country. From our study that compares between the national aircraft industries of Brazil and Japan, the institutional set up matters more significantly than it used to be recognized, to the extent that it can override technological competency as a success factor. Japan is clearly more technological advanced than Brazil. Yet, within the narrow confines of the Brazilian aircraft industry, which is clearly high-tech, this study provides us a glimpse as to how the institutional factor can potentially enable Brazil to make a, perhaps unique, leap ahead of Japan.

NATIONAL INSTITUTIONS AND THE APPLICATION OF TECHNOLOGY

There are two fundamental reasons why Japan, despite its technological supremacy might have lost out to Brazil in their respective attempts to develop a national aircraft industry. First, Brazil had a unitary government commitment and support system that Japan did not and second, Brazil established a specialized, national-champion firm but Japan did not. Even though Brazil made a much later start in the aircraft industry compared to Japan and even though Brazil was technologically inferior to Japan, the Brazilian government was able to "fast-track" the industry's growth by establishing its own "crown-jewel" company. Then, an enabling institutional setting supplemented by strong public commitments led by Brazil's Ministry of Aeronautics helped foster the initial phase of heavy technological and financial investments needed for an aircraft industry to take off.

The creation in Brazil of a single, national champion, airframe-specialized firm—Embraer might be considered counter-intuitive by way of government policy, as any national champion firm would be typically perceived as overly protected, tainted with corruption and established mainly for political reasons rather than on the merits of economic rationale (Waterbury)[3]. But despite such likely pitfalls, Embraer, as a national champion firm became instead the epitome of the Brazilian government's commitment to produce a high tech industry within its borders as a do or die effort.

In contrast, government involvement in Japan's aircraft industry was marred by the rivalry of three related ministries in Japan: MITI[4], the Ministry of Transportation, and the Japan Defense Agency (JDA) resulting in much inter-ministerial bickering as to which agency would play which role in the aircraft industry's development effort.

Japanese industries were typically developed through the consortium approach. Four major conglomerates (MHI, KHI, IHI, FHI[5]) and many small manufacturers divided the task of developing a series of aircraft models that had begun as far back as just after the end of World War II. This consortium method, one of the aims being to divide the risks associated with heavy investment, had been the pinnacle of Japan's successful post-war industrial developments in various sectors such as automobiles and semiconductors. The only problem is, the consortium approach did not seem to work as well in the case of the aircraft industry.

THE TECHNOLOGY REGIME OF THE AIRCRAFT INDUSTRY

The relation between the type of technology needed for developing a particular product and the kind of institutional support that needs to be present is of the utmost importance if we are to understand why some attempts in industrial development succeed while others fail (Nelson & Winter, 1997; Klevorick et al., 1995)[6]. A recent work by Mowery and Nelson emphasized the importance of sectoral differences in their comparative study of seven industries (1999), and helped explain why *exceptional* performances are possible, even when the level of technology, in relative terms, had been trailing behind others as this paper had observed between Brazil and Japan.

There are three technological requirements for a commercial airframe manufacturing to be successful[7]. First, there must be an *economies of scale*. Second, airframe manufacturing requires a *system technology* in which various parts must be integrated coherently and flawlessly, rather than by merely aggregating diverse component technologies that are available on hand. There is thus a stark difference between making airplanes and personal computers, the latter being modular and component based. Third, in the case of airplanes, development, modification and maintenance require extremely intimate *manufacturer-customer relations* or *user-active innovation*. In this sense, every passenger jet that takes-off, is in fact a customized product rather than a homogenous commodity[8].

Economies of scale[9] are so important to making airplanes that this industry can support only a few producers. There are currently only two companies in the world that produce large long-to-medium range aircrafts with more than 100 seats: Boeing in the United States (US) and Airbus Industries in Europe. There is no country in the world, with a possible exception of the US, that has a large-enough domestic market that can sustain the high Research and Development (R&D) and production costs in the aviation industry (Bernardes, 2000: 110).

Short-range commuter aircrafts are in the segment where Bombardier of Canada and Embraer of Brazil are currently competing intensely. Several other companies have already withdrawn from this market segment due to the inability to sustain profits. They include Fokker of the Netherlands, Saab of Sweden, British BAe, US Raytheon, and German Fairchild Dornier (Maema, 2002: 24). Thus here again, it is more than likely that this short-range commuter aircraft segment will eventually also limit itself to only two or three companies.

This dominance by only a few companies proves that the core of the technology trajectory in the airframe industry is scale economies. R&D costs are so immense that only a few models of aircraft in aviation history have actually recovered their costs and generated profits. Shear (1994) reported staggering figures: Of 22 aircraft companies launched in 1945, only 5 survived until 1994. That is a survival rate of only 1 in 4. Of 29 jet transporters that took to the skies since 1945, only 3, all Boeing jets, returned profits. "The $180 billion invested in aircraft in the 40 years following World War II produced a gaping $40 billion loss" (Shear 1994: xiv). Among the makers of long and medium range passenger aircraft, the pioneering British Comet was the first to withdraw, followed by the American Convair, Lockheed, and eventually McDonnell Douglass in 1996. The acquisition of McDonnell Douglass by Boeing created a combined behemoth company that dominated 65 to 70% of the civil aviation aircraft market (Bernardes, 2000: 127). Thus, fewer and fewer aircraft makers stay open in the market for the industry to remain financially viable.

In spite of these difficulties, however, strong incentives exist for tapping into this risky passenger aircraft industry. Despite the crisis within the aviation market that began in the early 1990s to be later aggravated by the September 11 attack on the World Trade Center in New York in 2001, Bernades (2000: 115) reported that the aviation market will grow three times larger in the next 20 years. As long as a company can manage gulping down the huge initial R&D and production costs, there is a very lucrative airplane market and profits waiting out there in the future (Fig. 1).

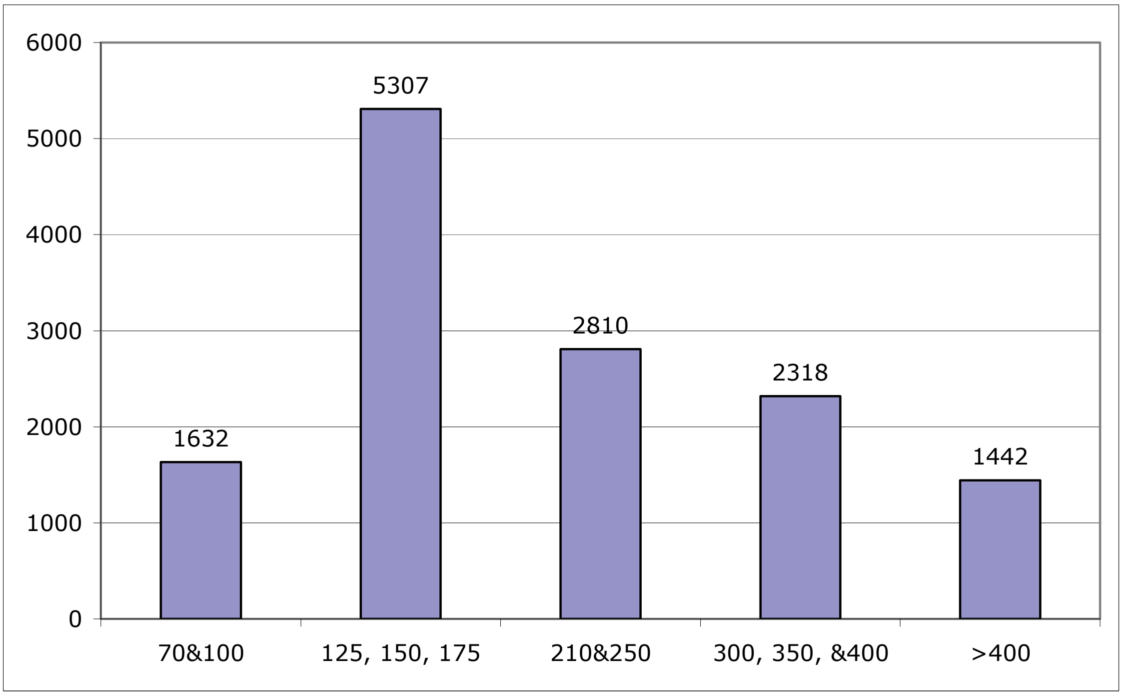

Figure 1. Estimate of airplane demands by category between 1996–2016

Source: Global Market Forecast: 1997–2016 by Airbus Industries cited in Bernardes (2000: 116)

Because huge R&D costs are involved, government involvement in aircraft development appears to be essential. Sixty percent of total R&D spending goes to the aviation industry in countries like the US, Britain and France (Bernardes, 2000: 96). Although the proportion is lower in Japan, the government's R&D expenditure for the aerospace industry there is at par with those for the computer industry (Shear, 1994: 6).

In many countries, the synergy between the development of military and civilian aircraft help to absorb the huge R&D cost. Many technologies were first developed for military use but later found applications in civil aviation thus allowing continuing revenue stream without additional R&D investments. JDA has been purchasing about 75% of total sales of the Japanese aircraft industry (Bernardes, 2000: 105) [10]. Examples include military transportation, reconnaissance, and air tankers[11] (Bernardes, 2000: 98).

Table 1 suggests the significance of government R&D involvement in this industry. If one combines civil aerospace development and defense,[12] about half of the government R&D, are used for aircraft related industry in the US, France, United Kingdom (UK) and Italy.

Notice, however, that the absolute amount does not necessarily translate into the success and failure of a passenger aircraft industry. While Japan spent US$2,443 million on civil aviation, space and defense in 1994, the Brazilian government spent only US$201 million in 1996. Furthermore, there are many countries that do not own their own passenger aircraft industry such as Italy that spent much more than Japan in this industry[13]. The absolute size of government R&D does not, therefore determine the success or failure in the development of national aircraft industries. The figures on Table 1 merely suggest that governments are quite involved. Beyond financing, how countries locate their respective national aviation industries within the overall industrial organization is also a key determining factor between success and failure.

TABLE 1
GOVERNMENT R&D EXPENDITURE OF SELECTED COUNTRIES

Object	Brazil	Canada	US	Japan	Germany	France	UK	Italy
Year	1996	1992	1994	1994	1993	1993	1994	1993
Civil aerospace development	69	324	7448	1357	870	1385	269	3016
Share in total government R&D (%)	2.2	9.6	10.9	7.5	5.8	10.1	3.1	37.5
Defense	132	209	37787	1086	1274	4595	3858	523
Share in total government R&D (%)	4.2	6.2	55.3	6.0	8.5	33.5	44.5	6.5
Civil space & defense total	201	533	45235	2443	2144	5980	4127	3539
Share in total government R&D (%)	6.4	15.8	66.2	13.5	14.3	43.5	47.6	44.0
Total government R&D	3137	3370	68331	18099	14991	13716	8669	8042

Source: Bernardes (2000)

The aircraft industry also requires *system technology.* Overall planning and design of a new aircraft is not merely an aggregation of diverse technologies and parts (Bernardes, 2000: 107). Here lies an important difference between the making of Japanese and Brazilian aircraft.

In spite of possessing advanced composite materials and other component technologies, Japanese corporations have so far failed to design a commercial aircraft fuselage after the YS-11 project. Embraer, on the other hand, was able to design an airframe even though Brazil had to depend on imported materials and parts. In the ERJ-145/140/135 program, for instance, out of 43 first level suppliers, only 1 company is Brazilian. The other companies are mostly American (73%) (Cassiolato et al., 2002: 39).

Another indication of the significance of system technology is seen in the fact that Boeing, which increasingly relies on international consortium to develop a new aircraft, has been extremely careful not to let this system technology leak to its rivals in its major projects such as 767 and 777 programs (Mowery, 1987). Although calling it a "consortium," Boeing is in reality using its partners instead as subsidiaries. The key to the overall aircraft design down to the avionics in the cockpit never left the hands of Boeing in these projects[14].

Making airplanes also require *user-active innovations* (Mowery, 1987). The manufacturers and users, mostly airlines and governments, need to form a very close knit network from the time of conceptualizing and planning a new aircraft through to final production because of the constant need for design improvements and adjustments. According to Boeing's ex-chairman, Philip M. Condit, the core competency of the company resides in the know-how in the large-scale system integration, efficient project and production, and *especially, the minuscule knowledge of the necessities of clients and the constant search for the satisfactions of clients* (Bernardes 2000: 133). There are two reasons for this; the long life span of an aircraft and the high as well as risky R&D costs involved.

Even at the developmental stage, the interaction between the users (airlines) and manufacturers remained critically important. Fitting the airplane into the correct market segment will determine between success and failure. If there is a competitor developing another aircraft in the same segment but ahead in terms of development time frame, this time advantage can entirely destroy the viability of any other aircraft development programs. Airlines have a strong incentive to use the same made of aircraft[15] to save on parts and training leaving little room for new comers to penetrate the market. Thus finding the right market (airline clients) and developing the right aircraft is essential to succeed[16].

COMPARING BRAZIL TO JAPAN

Two important differences between Brazil and Japan have become determining factors for the relative success in developing their respective national aircraft industries.[17] In Brazil, the government was able to establish a single unified administrative structure under the Ministry of Aeronautics. In Japan, on the other hand, government participation was instead fragmented into separate government institutions. In Brazil, a specialized national champion firm, Embraer, was established. In Japan, a consortium approach was adopted instead. These two factors: the form of government participation and the corporate structure adopted produce critically important effects as summarized in Table 2.

Type of Government Support

One of the most significant achievements of the Brazilian government was that it concentrated all authorities related to the aircraft industry into one administrative organ: the Ministry of Aeronautics. In 1941, the Ministry of Aeronautics was created for both civil aeronautics and air force. Thus, the unified government institution that would control both air-traffic and aircraft production was born[18]. By doing so, the Brazilian government was able to commit itself to the development of aircraft industry without bureaucratic bickering with other ministries. The Ministry of Aeronautics is positioned above all other ministries including the Brazilian Air Force. It is in charge of producing aircrafts for both civilian and military usages, and regulating the airline business as well.

In contrast, the government's overseeing of Japan's aviation industry was marred by the crash of interests among at least three ministries; the Ministry of International Trade and Industry (MITI), in charge of producing of aircraft[19], the Ministry of Transportation that given charge of air traffic operations, and the JDA, in charge of military aircraft development, procurement and operation[20].

TABLE 2
TECHNOLOGY REGIMES COMPARING BRAZIL TO JAPAN

Technology Regimes		Country	(I) Type of Government Support	(II) Type of Industrial Organization
Institutional Settings	A	Brazil	Unitary Administration • Ministry of Aeronautics	Specialized National Champion Firm • Embraer SA
	B	Japan	Fragmented Administration • Three different administrative bodies (MITI, Ministry of Transportation and JDA).	Consortium by Conglomerates • MHI, FHI, KHI, and two minor corporations. • (YS-11 Project)
Economies of Scale • To establish economies of scale, credible commitment is essential	C	Brazil	• A clear signal of commitment from one source facilitates credible commitment among players.	• Because survival or death for Embraer is at stake, it will commit itself to achieve the economies of scale.
	D	Japan	• Mixed signals of commitment from multiple ministries/agencies create confusion and doubts.	• There is no strong leadership & commitment as each member is only partially responsible of the project. • Battle among the divisions within a conglomerate weakens the aircraft division.
System Technology • To master system technology, the industry must have a strong incentive to complete system	E	Brazil	• National Security and Industry are together. • Can nurture nationalistic development.	• A single firm can commit itself to system technology without worrying about collective action problems.
	F	Japan	• National Security and Industry is separated. • JDA and MITI's interests are different. • Weak nationalistic development.	• Because of the divisions of labor and rivalry among consortium members, it is very difficult to provide incentive to master system technology.
User-active Innovation • To master user active innovation, good communications between manufacturers and airlines must be established.	G	Brazil	• Better communication as airlines and the manufacturer know who in the government is coordinating.	• Embraer is a sole channel for airlines (customers) to communicate and improve the products.
	H	Japan	• MITI does not communicate with airlines well because it is not responsible of operation side. • Ministry of Transportation uncooperative with MITI.	• Airlines were confused which company to make claims and requests to.

When Japan was occupied by the US after the end of World War II, both MITI and Ministry of Transportation tried to expand their respective administrative powers in 1951. In 1952, the "political" solution was to divide the powers into two; the operation side was given to the Ministry of

Transportation while the production side was put under MITI (Maema, 2002, pp. 180–87). The rivalry between these two ministries had since been bitter and resulted, among other things, in the cancellation of some of the YS-11 purchases. Airline operations come under the regulation of the Ministry of Transportation but airline production come under the supervision of MITI. For example, based solely on operational reasons, All Nippon Airways (ANA) elected to import the F-27 Fokker Friendship turbo-prop transport from the Netherlands instead of buying the domestically produced YS-11, thus sidelining MITI's priorities. Another major Japanese airline Japan Airlines (JAL), refused to buy YS-11. Even when one ministry said no, another ministry would say yes allowing company objectives as opposed to national objectives to take precedence over critical decisions made. In Brazil where the government supervision role over aircraft production and operations is unitarily centered in one ministry, the kinds of inter-ministerial bickering that Japan faced did not arise.

Type of Industrial Organization

Many studies on the Japanese economic "miracle" praised the consortium approach that typifies Japanese business for the effects that consortiums have on rectifying collective actions (Johnson, 1982; Okimoto, 1989). They argue that consortiums avoid redundant R&D and thus are able to share results from research conducted to the benefit of all consortium members while at the same time reducing the risk from investments. Furthermore, by restricting excessive competition, the Japanese corporations in many industrial segments succeeded in upgrading their technologies in remarkably short time.

On the other hand, a national champion firm, which tended to be state owned entreprises (SOE)[21], is usually prone to inefficiency (Waterbury). The Brazilian computer company COBRA, France's Bull, and many other nationally owned monopolies were considered typical examples of inefficient SOEs. Indeed, no SOEs in the computer industry were successful. This study, however, challenges this traditional notion and argues instead that under certain situations, a single national champion firm not only works but also is the only form of industrial organization that can work in the case of the aircraft industry[22].

This author maintains that an aircraft (and aerospace in general) unlike many industries, requires a national champion firm—a single firm supported by the government and representing the nation. No company, even a US company that has the access to the world's largest domestic aviation market, can survive without exporting planes. Because of this need to sell in the exports market for airplanes, the types of inefficiencies that are typically attributed to a national champion firm are not as evident since the firm has to compete in international markets.

As Mowery (1987) suggested, there has been increasing numbers of international consortiums that share in the development costs. But, such consortiums must not be confused with the typical Japanese style consortium. In an international consortium, a single company has to play the leadership role relegating other member companies to assume subsidiary roles. Mowery also maintained that strong leaders such as Boeing in its 767 project led successful joint ventures. Airbus Industries which was created in 1970 has a similar international consortium set up involving four companies: French Aerospatiale, British Aerospace, German Daimler Benz and Spanish Construcciones Aeronáuticas S.A. (CASA) (Bernardes, 2000: 104)[23]. Yet, Airbus Industries is a specialized aircraft company with one strong and clear leadership provided by the French partner. As long as a clear leadership is established and other participants accept subordinate roles, such a type of consortium, which is substantially similar to subcontracting, can produce positive results.

Similarly, a manufacturer must be a specialized firm to make airplanes. This is due to the fact that it takes many years for an aircraft company to be profitable and needs to expect huge initial losses. If a member company is a conglomerate like in the case of Japan, the aircraft division becomes the target to blame by the other profitable divisions from the same conglomerate. Therefore, unless the president of the conglomerate is able to convince the other divisions as was seen in the case of Canada's Bombardier, huge losses faced before the plane being developed can make its first flight by the aircraft division of the company cannot be sustained[24]. Conglomerates tend to limit their financial commitments to the aircraft division keeping losses small.

In the case of Brazil, upon the successful development of the IPD-6504, later known as the EMB-110 Bandeirante, the Brazilian government decided to establish the company called Embraer as the national champion firm for Brazil's aircraft industry under Presidential Decree in August 1969 (Ramamurti, 1987: 184–185, 191). Since then, the company has also succeeded in developing a series of regional turbo-props and jets which includes the *Brasilia* as well as best-seller ERJ-140 series and moving on to the ERJ-170 and 190 series. Embraer focused only on designing and developing airframes to be flown with North American made engines like the Pratt and Whitney turbo-prop. Although as a consequence to the financial crisis faced by Brazil during the late 1980s, Embraer was privatized in 1994. Regardless, the nature of a specialized champion firm did not change.

In the case of Japan, the YS-11 project started in 1959 when Nippon Aircraft Manufacturing Corporation (NAMC) was established. The NAMC was a consortium of six aircraft fuselage-manufacturing companies. Three were giant conglomerates: MHI, KHI, and FHI[25] and two were medium-size corporations: Nippi and Showa Aircraft Industries. The first YS-11 test plane was produced in 1962. The production model received the FAA[26] certification in 1964. The YS-11 started flying regular commercial routes the following year (Maema, 1999: 36–37). The YS-11 project, however, ended in 1973 after producing only 182 planes. Mounting deficits created during the development, production, and operation had rendered the YS-11 financially unsound (Maema, 1999: 37). Since then, there has been no Japanese passenger aircraft developed except for business and utility planes until this day.

The Japanese government could not commit itself enough to establish a specialized aircraft company after the huge loss created by the YS-11 project. The YSX project in 1966 again tried to use NAMC consortium without a clear leadership and a specialized company. The project resulted in the cancellation in 1969.

Commitment to Achieve Economies of Scale

When the economies of scale are immense, massive initial investments are needed and therefore credible commitment of the government becomes an essential feature for inducing private sector interests into the industry (Table 2). When a government adopts a certain industrial policy, it gives out a national investment priority signal that private sectors react to, thus, affecting how industry formation will shape in the country. Obviously, the government's effects on the private sector will not be immediate. Quite frequently, the private sector is suspicious of what the government is trying to do and remains unresponsive to the government intentions.[27] Therefore, the government has to try to establish the perception that the government has made a "credible commitment". In the case of Brazil, the signal was more obvious, that was emitted from one ministry. The private sector took to the signal more seriously. In Japan, on the other hand, different signals came from various ministries. The private sector had been more suspicious of government credibility, for instance, there was a lack of interest in purchasing the YS-11 planes by the Japanese airlines for which the Japanese government could have been more forceful in bringing about more active local demand.

In Brazil, Embraer, as a company from a developing country, could be expected to face problems in financing sales. Aircrafts are expensive to buy and private financing would favor better known aircraft models from tested aircraft makers rather than a new aircraft producer without prior success. Brazil's Embraer have had thus to rely on Bank of Brazil's subsidy (Ramamurti, 1987; Sarathy, 1985) to finance its sales. Without this commitment by the government of Brazil so that long-term loans become available to airlines buyer, it would have been impossible for Embraer to sell its aircrafts.

This lack of similar unified support by the Japanese government, on the other hand, hindered the sales of the YS-11 (Maema, 1999b: 227–31). The divided Japanese government could not set up any financing scheme that resulted in massive deficits faced by the NAMC consortium that made the YS-11. The consortium itself had to, instead, finance the sales for customers. But private banks were reluctant to set up a financial scheme for NAMC without the guarantee of the Japanese government. Even member companies of the same consortium for the YS-11 were reluctant to provide collateral for loans from private banks.

When the new passenger aircraft project YSX started in 1966, the lack of credible commitment by the Japanese government was also apparent. MHI, which was the largest contractor of the YS-11 project, did not hesitate to criticize the lack of commitment by Japan's MITI. Already burned by the huge deficits due to the YS-11, MHI and other private sector participants were not going to take further risk in the new development project involving the YSX (Maema, 2002: 222–23). As a result, the YSX project never took off.

Credible commitments can also be derived by creating a situation such that both the company and the industry have to succeed under a do or die environment (Table 2). In other words, there would be no partial success solutions. No excuses for not performing well and yet survive. To bring about such an environment, it was vital to create a specialized company, in this case to build airframes in Brazil. It was extremely difficult for the private sector to commit itself in such a risky industry. Accordingly, the private sector has instead been fond of diversifying its business into product lines that are safer, more stable, and maybe even less R&D intensive to avoid investment risks. Embraer, was therefore entirely forced upon by the government but it gave wholehearted support. Part of the justification was that the government formed the most important customers in this industry and in many ways a sole procurator as would be the case for defense products.

When Embraer was established as a national company, the mission was clear: establishing both civilian and military airframe (fuselage) industry. It was a strategic choice to give up its 1930s and 1940s dream of producing everything (Cassiolato et al., 2002: 9). It did not vacillate among various business options and remained focused. "Embraer consistently focused on the design of aircraft, the manufacture of the fuselage, and the final assembly operations, staying away from the manufacture of high value, high technology inputs such as engines, landing gear, and avionics" (Ramamurti, 1987: 199)[28]. Although Embraer was considered as an SOE until it was privatized in 1994, its ownership was very unique taking advantage of both private and public enterprise (Ramamurti, 1987). The Brazilian government "forced" private corporations to own certain share of the stock while the government maintained at least 51% of voting shares of the company. To sweeten private participation, Brazilian corporations were given a unique fiscal incentive: up to one percent of the income tax owed to the federal government could be offset by investing instead into Embraer. By making Embraer semi-private, the government was able to avoid legally binding bureaucratic control procedures of wholly government-owned enterprise like Petrobras and Electrobras (Ramamurti, 1987).

The Japanese consortium experience had been very different from Brazil's Embraer. Consortium members were conglomerates with highly diversified business interests. None of the three major contractors, MHI, FHI, and KHI, was a specialized firm for aircraft design. Such a conglomerate approach created two problems. First, the aircraft division received pressures from other divisions of the same company whenever huge initial investments that did not generate profits were made. The consortium's priorities tended to center on making profits as would be expected rather than to foster the growth of a new national industry, in this case the making Japanese airplanes. MHI's aircraft division's sale consisted merely 10% of the parent company's total now and, when the YS-11 project was initiated, this share was even smaller (Maema, 1999b: 244). Indeed, MHI had to eventually withdraw from the MU 300 business jet aircraft project in 1988 due to the pressures from other divisions (Maema, 2002: 203–208). The consortium approach bites both ways. For instance, the aircraft division could merely slack and not performing well, since other divisions can compensate losses made in the aircraft division. In this sense therefore the consortium setting will results in the lack of seriousness and commitment which are critical elements needed for an industry like making aircraft to succeed (Maema, 2002: 319, 107–109).

The lack of commitment from members of consortium was significant (Maema, 2000: 107–109). For instance, when NAMC decided on who should be the chief designer for the YS-11 in 1958, a consensus could not be achieved among member companies. Instead an academic, Mr. Kimura, was eventually assigned so that no company would complain (Maema, 1996a: 201–202). This was a typical problem of the lack of unequivocal leadership in any consortium approach. NAMC was organized in such a way that no single company was powerful enough to play a dominant over the rest and take the leadership position. Without clear leadership, companies member became reluctant to commit themselves and were preoccupied with failure instead of success (Ibid., 220–221).

In the case of MHI, had it committed itself not only as an overall designer of YS-11 but also as chief financial controller, the YS-11 project could have produced a better result. MHI was responsible of 54.2% of design and manufacturing, followed by KHI (25.3%) and FHI (10.3%). The remaining was carried out by many small manufacturers (Maema, 2002: 168). MHI's commitment to the YS-11 project was extremely weak. The chief designer of the YS-11, Mr. Tojo, from MHI, had this to say, "This project would end up just producing one or two test airplanes… The YS-11 project can last no longer than ten years. We do not have to think about making YS-11 as a series to make the life-span longer…We are forced into this project by the government and need not to be responsible of it. We are the victims." Later, MHI's President, Mr. Makita, added, "YS-11 was a government, not a private, project. We should not be responsible of the huge deficit that this project has created. The government should take care of it." This last comment by Makita was one of the most important factors that led to the termination of Japan's YS-11 project.

A member of the House of Representatives, Mikio Abe of the Japan Socialist Party[29], pointed out the nature of consortium in this industry in the House Budget Committee meeting in 1972. He claimed that the reason why the YS-11 project went into deficit was that major participants of the consortium entered all the financial losses into the project instead of dividing the losses across the respective company's accounts, as "somebody" including MITI, would eventually absorb the deficits (Maema, 2000: 83).

While the YS-11 failed as a business, it did achieve technological success. The engineers who worked on the project knew one another during World War II while they were designing military aircrafts (Maema, 1996a: 253–254). There was *esprit de corps* among these engineers motivated by passion to revive a once active Japanese aviation industry. But the YS-11 project faced a far from ideal institutional setting. It could have been a lot different if MITI had been able to establish a national champion firm, or at least to convince Mitsubishi to be a sole contractor rather than to be a part of the consortium. Although in some other industries such as semiconductors, automobiles, and personal computers did not require a single national champion firm in order to succeed, the aircraft industry was different because of the huge initial costs sunk and the requirement of long-term state commitment.

In the "domestic" consortium approach adopted for building airplanes in Japan, there were too many companies for starting a new national aircraft industry. No country in the world ever started with three major companies and two mid-size companies all sharing the same airframe production market except for Japan (Maema, 2002: 319). Such a "five-firm configuration" was not economically rational but they nevertheless existed alongside one another because of the nature of defense procurement—a kind of "politics" between the aircraft industrial complex and the government "client".

System Technology—Strategy Choice and Industrial Organization

An aircraft design would need a system technology set up rather than the aggregation of parts technology (Table 2). The know-how needed to design and integrate aircraft components and parts are quite different and cannot be obtained merely by producing the entire range of different components and parts that make an aircraft. Making planes is very different from making computers.

For security reasons as well as for a national pride, the military aircraft development is the segment that the government wants to achieve self-sufficiency. Even Japan, after giving up designing a whole civilian aircraft after the YS-11, still maintained a strong desire to achieve self-sufficiency in the military field. As recent as the FSX (the current F-2) project in the 1980s, the Japanese government and defense contractors fought a battle against US pressures to license an American made fighter jet instead of one entirely of Japanese origin[30].

Had the military segment of the government and the civilian side been under a single administrative structure like was the case in Brazil, there would have been a strong incentive to nurture a domestic system design capability for making airplanes within Japan. Nonetheless, the Japanese institutional setting was a problem. The JDA, which was responsible for defense but not for industrial development, had two choices either to procure defense equipment needs domestically or import them. Almost all Japanese aircraft manufacturing companies had gained (astonishing 75% of revenues) from defense sales. Thus domestic equipment sourcing should have been the optimal choice that would have had spin-off potential to civil aviation applications. Yet, defense needs that are not exactly concomitant to the requirements for the civilian applications aside, JDA preferred procuring more foreign made weapons deemed to be less expensive than those produced locally. MITI, which on the other hand was responsible for the civil aviation industry would prefer instead building up Japanese aviation technologies. Indeed, there had always been many difficult negotiations between JDA and MITI whenever a new aircraft development was planned. JDA had always insisted on the military capabilities of aircraft to be designed but it was not fully committed to building a domestic aviation technology capabilities. Instead JDA often yielded to pressures by the Ministry of Foreign Affairs (MOFA) to buy US made weaponry in order to help reduce diplomatic tensions between America and Japan over Japan's significant trade surplus with America. Although MITI faced the same pressures in relation to Japan-American trade, JDA had been more prone to them because, first, the military equipment is one of the few segments in which the U.S. has had a trade surplus with Japan, and help compensate overall American trade deficits. Second, JDA did not have a clear mission to develop domestic industries the way MITI had. Furthermore, JDA had only an agency status in the Japanese government rather than the Ministry status that MITI enjoyed.

The advantage for nurturing system technology that a single company had over a consortium was quite apparent (Table 2). The core competency of a single national champion firm laid in its ability to integrate various components mostly available in the world market and design an aircraft whole. While, even in a consortium, there could be only one company given the responsibility for the entire design of an aircraft, but unlike a single champion firm, there would be less commitment from the other uninvolved consortium members. For example, Boeing also adopted an international consortium of firms to reduce risks from huge R&D spending in its 767 and 777 projects. But in Boeing's case, the company is already an experienced aircraft designer and maker. Boeing would never release core technologies and know-how of the overall design to other members and retains its authority to control the whole design. Thus, this kind of consortium was rather a form of subcontracting, offering a business opportunity to Boeing's foreign partners in exchange for sharing part of the development investment risks, rather than a contract of equal members, the way NAMC's consortium was.

User-Active Innovations

User-active innovations concern the relation between the production side and the operation side. As the customers of passenger aircrafts are the major airlines in the world, the manufacturers need to maintain good reciprocal relationship with airlines. Obviously, if the administration for both a production and an operation side is united, the coordination would be much simpler. When they are separated instead, the bureaucratic bickering can break down the progress of nurturing industry, which was the experience in Japan (Table 2).

In Brazil, the Ministry of Aeronautics was given charge of aircraft operations as well as production. Therefore, while Embraer was yet to develop capabilities that would allow competition in the world aviation market, Brazil's government was able to put pressures alongside incentives for domestic airlines to use Embraer products. Basically, government regulations can be fine-tuned to help enhance Embraer's competitiveness. Although the Ministry still had to face various forms of opposition within the Brazilian government, such as the Ministry of Foreign Affairs and the Ministry of Commerce that have other priorities, such as easing trade tensions with the United States and other powerful foreign countries, the resistance that the Brazil aviation industry had to meet was obviously much less than what Japanese airplane makers had to encounter.

Fighting between Japan's MITI and the Ministry of Transportation resulted in shortcomings in the development of user-active innovations. Unlike in the ship-building industry where the Ministry of Transportation controlled both manufacturing and operation, Japanese aircraft industry was instead divided between MITI, given responsibility for production, and the Ministry of Transportation, which was responsible for regulations and operations. However, this division was not harmonious. The Ministry of Transportation had sought to take complete control of Japan's aircraft industry.

After the YS-11 began to sell to the airlines, the Ministry of Transportation could have helped improve the quality of the aircraft through user-active innovations that covers some of the core technology regimes in the aircraft industry. But, the Ministry of Transportation, with its confusing and overlapping roles with MITI showed little willingness to help do this. User-active relations between an aircraft maker and aircraft customer users had thus to be maintained without proper government support. Japanese airlines had to organize themselves without the help of the Ministry of Transportation to help provide customer feedbacks and design inputs to

Japanese aircraft makers and negotiate to improve the quality of the recent YS-11 aircraft (Maema, 2000: 184–185)[31].

On the question of how the type of industrial organization affects user-active innovations in Brazil and Japan (Table 2), such lack of commitment was reflected in YS-11's approach to the customers: airlines. The first Chief Executive Officer (CEO) of the consortium, Teruo Tojo of MHI, considered the project as a test project in which only less than twenty aircrafts would be produced. Thus, he had no idea how to accommodate the design demands made by user airlines (Maema, 2000: 129). This is due to the fact that MHI considered this project not as its own, but rather one that had been forced upon by MITI. Instead of user-active innovations what happened in reality were negative relations between a manufacturer and customers. Those airlines that were arm-twisted into buying and using the YS-11 by MITI had to then spend a lot of time and energy, as well as patience, to obtain after-sales support with the airplane's manufacturer, NAMC, which showed much reluctance to effectively serve its airline customers. It therefore became natural that Japanese airlines do not ask for further continuous development of Japanese made aircrafts. The user-innovation environment was just not there.

This problem did not emerge in the case of Embraer. It was a sole channel for airlines to communicate for trouble-shooting, suggest improving the products, and plan for the future lines of products based on the collaboration. Embraer developed the customer's service centers in major export destinations and continue working with customer airlines.

IMPLICATIONS OF THIS STUDY

We learn that it is very difficult for governments and private companies to understand the technological regime ahead of time so that industry can also be accordingly organized in advance. The same was also learnt in the author's previous study on the development of the Information and Technology (IT) industry in both Taiwan and South Korea (Kanatsu, 2002). When the governments from both these countries tried to develop a broad IT hardware industry including various types of semiconductors as well as personal computers, they adopted the existing industrial organization upon which the new industries were built. As a result, South Korea became a successful producer of semiconductors for computer memories but not Taiwan which found success instead in developing the Application Specific Integrated Circuit (ASIC).

It will be difficult for any government to construct a new industrial organization within a nation from scratch. Usually when a country ventures into a new industry, there is usually an industrial organization already in existence equipped with huge business interests in place. In this study on the approach that a country might follow to develop a national aircraft industry, it was found that various other Brazilian industries were also developed with the same industrial organization as its aircraft industry. In the case of computers for example, Brazil's government also established a national champion firm called the COBRA much like Embraer as the champion firm for its aircraft industry. The government protected the domestic market from a foreign competition, and put pressures on the domestic companies to purchase domestically produced computers instead of international brands. Japan, which on the other hand preferred the consortium approach, also developed its aircraft industry based on the industrial organization already in existence in Japan. The fundamental philosophy behind Japanese consortiums is the ability to diversify risks associated with a huge high-tech investment, because there will be a mixture of different business types, such that failure in certain business can be offset but success in other business within the same consortium.

Some might go on to suggest that foreign pressures might also have an influence on the approaches chosen in Brazil and in Japan. While it may be true that aircraft manufacturers from both the United States and Europe did exert pressures on both Japan and Brazil on issues of trade imbalance, both countries were similarly affected and therefore such pressures would not result in one approach adopted by Brazil and another approach by Japan.

But the main lesson is the following: Why Brazil succeeded but Japan did not in developing a national aircraft industry is because the aircraft industry will only work on certain types of industrial organization but not other types. It will work with Brazil's government supported champion firm but not with Japanese consortiums. There has been hardly any success after the YS-11 in Japan. But Japanese corporations appeared not to have learnt their lessons: that system technology needed for making aircraft is different from the aggregation of parts technology applicable to most other types of industries. As one can see from the very success of automobile industry in Japan, it is not the case that the Japanese companies cannot master system technology. Instead, the core strength of the Japanese auto-manufacturing developed in typical Japanese consortium fashion is just simply not suitable for making airplanes.

CONCLUSIONS

From accounts related in this paper, it is possible to learn and conclude that the institutional setting as well industrial organization in existence for particular countries can become overriding factors that eventually determine whether the level of technological prowess available on hand in these countries can in fact be translated into industrial success for these countries. This study compares Brazil to Japan by looking at the making of airframes for the civil aviation market. While most might accept Brazil to be technologically less advanced than Japan, Brazil's relative success in developing a national airframe industry over Japan has been the result of two factors. First, Brazil had a coherent government administrative structure to direct policies and strategies towards the development of this industry, instead of the fragmental bureaucratic structure involving multiple government ministries in Japan. Second, Brazil was able to organize a specialized national champion firm to develop this industry while Japan instead adopted a consortium approach involving many firms.[32]

Japan had started developing its aircraft industry at a much earlier period and on a much larger scale than Brazil. During the World War II, Japan manufactured a variety of military aircraft types. Pilots and other aircrew who fought against Japanese aircraft then have testified to various aspects of flight and combat superiority of Japanese fighters compared to those planes produced by Britain and the United States during the early period of the war[33]. When the war ended, Japan was prohibited from any form of aircraft-related industry for seven years. Later on Japan did try to develop a passenger aircraft industry under the YS-11 project between 1959 and 1973 but the project ended after accumulating huge deficits. There was not any successful commercial passenger aircraft development in Japan since then except under subsidiary or licensed manufacturer arrangements with American manufacturers. Brazil's venture into its Bandeirante aircraft project, which appeared only years after Japan, had on the other hand, been more successful. The Embraer Brazilia that followed the Bandeirante turned up even more popular among American commuter airliners. Today, Brazil's Embraer has successfully built on its customer confidence from these two turboprop aircraft, the Bandeirante and the Brazilia to develop and sell full-jet commuter aircraft types: the EMB-135, EMB-145 and ERJ-170/5 that can be found flying commuter routes today in both North America and Europe. Besides civil aircraft, Embraer has also successfully developed and sell the T-27 Tucano turboprop military trainer/A-27 attack aircraft, this aircraft type also being licensed to Shorts in the UK to manufacture trainers for the Royal Air Force. In other words, despite Brazil's inferior technological beginnings, institutional settings and industrial organization had even allow it to take the lead, in the case of the Tucano, ahead of UK, a nation which has a history as an airplane manufacturer that goes back for nearly a century.

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NOTES

1. Airframe industry to be exact as many other parts of the plane including engines are developed and manufactured outside of Brazil, which itself provides us with a very intriguing question on the nature of this industry.

2. The Brazilian passenger-aircraft manufacturer Embraer is the crown jewel of the Brazilian high-technology industry. "Since 1995, Embraer exported US$11.95 billion in products and services, while having been Brazil's largest exporter from 1999 to 2001" (Embraer, 2003: 5) and the second largest only following Rio Doce steel company with annual gross revenue US$2,676 million in 2002 (Ibid.: 10). This only follows the Canadian Bombardier, a major rival of Embraer in regional jet manufacturing, of Canadian $11,307 million (Aerospace Division: equivalent of US$8,230 million as of June, 2004) in 2003 (fiscal year ending January 2004). The revenue of the largest manufacture Boeing Commercial Airplanes Division is US$22,408 million in 2003. There have been many trials and ongoing efforts in Asia: China, Japan, South Korea, Taiwan and Indonesia have been trying to develop the aircraft industry. However, none of them so far has established a sustainable airframe or an aircraft engine industry although most of them participated in the industry as parts and material suppliers.

3. Brazil itself had a failed experience with the establishment of a national champion firm COBRA (*Computadores e Sistemas Brasileiros*) in the computer industry. Note, however, there are many competitive national champion firms in the world including POSCO of South Korea and some formerly nationally owned firms in Taiwan. When a firm is judged by its export performance, it is not necessarily true that a national champion firm is less competitive.

4. Ministry of International Trade and Industry, renamed as Ministry of Economy, Trade, and Industry (METI) in 2001.

5. Mistubishi Heavy Industries, Kawasaki Heavy Industries, Ishikawajima-Harima Heavy Industries, and Fuji Heavy Industries respectively

6. The discussion on the relations between the type of products and successful innovation has a long history. Some of the discussions started in the 1960s on how the technology evolved from a new to a matured one, typically represented in the "technology life-cycle" theory (Vernon, 1966; Abernathy & Utterback, 1978). Similarly, there have been discussions regarding the industrial organization and the innovation. Some of them are concerned about the size of the firms (Chandler, 1962) while others discussed the network among engineers such as the one in the Silicon Valley (Saxenian, 1994). More significantly for this research, Keith Pavitt attempted the taxonomy of the type of products and innovation (1984).

7. Aircraft industry can be divided into three segments; airframe, engine and related electronics and other supporting industries. It is rare that one single company manufacture the two core parts of aircraft, namely airframes and engines, as each segment requires completely different technologies. This study focuses on airframe development as three manufacturers (two US and one British) are dominating engine development.

8. A commodity defined as a product where process development to make the item cheaper is a predominant competitive edge over product development. In other words, a commodity is a product with matured technology.

9. This means minimum efficient scale of production is large.

10. The R&D of the Japanese Military Aircraft after the World War II was conducted at the Laboratory Three of the Technical Research and Development Institute, known as the Department of Air Systems Development (Shear, 1994: 3). The annual budget of military R&D is nothing but meager, totaling about $518 million. (Note: Bernardes' account is about twice bigger than Shear's. If the total amount spent for military R&D including for land and maritime defense forces, Bernardes' account is correct.) The equivalent of Pentagon reaches $35 to $40 billion dollars (Shear, 1994: 4).

11. For example, the technology to develop a fighter jet is quite different from the technology needed for large commercial aircraft. Also, some new technologies such as stealth do not have an immediate application for commercial usage.

12. Note that this figure involves not only aircraft but also other military R&D such as maritime and land. However, the largest potion of military R&D is spent by aerospace technology.

13. The Italian aircraft industry is focusing on military planes including jet fighters. However, in 1984, EADS (the parent company of Airbus Industries) and Alena

Aeronautica started a joint venture company called ATR to produce turbo-prop ATR 42/72.

14. Mowery points out the significant disadvantage of joint venture approach for Japan in the post-YS 11 projects with Boeing, such as 767 and 777. "Technology transfer also may be controlled or regulated more effectively through joint ventures than through licensing. Whereas licensing transactions necessitate the sale of a complete package of technological capabilities in many instances, joint ventures enable partner firms to "unbundle" their portfolios of technological assets and selectively transfer individual components of this portfolio, *which in isolation may be worthless to a partner*" (Mowery, 1987: 12, italics added.).

15. Or in the same family. For example, Boeing 747 has various family members including 747-200, 747-SR, 747-400. Embraer's ERJ-140, 145, and 135 are in the same "family" and use many common parts and operation procedures.

16. "Technology characterized by "user-active" innovation, in Eric von Hippel's phrase" (Mowery, 1987: 9).

17 . Note that the author is NOT arguing that these two differences are SUFFICIENT reasons why Brazil succeeded while Japan failed. Rather, these two reasons are two of many other reasons needed for success.

18. The administrative unity mentioned above is complemented by the research and educational unity in Brazil. The Brazilian government established: (a) R&D institute *Centro Tecnico Aerospacial* (CTA) in 1945, and (b) an affiliated undergraduate educational/training institute, *Instituto Tecnologico de Aeronautica* (ITA) in 1947 (Cassiolato et al.: 7).

19. Currently METI (Ministry of Economy, Trade, and Industry).

20. In contrast, the shipbuilding and operation is under unitary control by the Ministry of Transportation.

21. The reasons are because it is monopoly and these firms usually require huge investment.

22. This is not necessarily a new finding. Amsden found the Korean national champion steel maker POSCO has been one of the most efficient producers of steel in the world (Amsden).

23. Later, Fokker of Holland and Belairbus of Belgian joined.

24. Of course, this can be considered as strength as a conglomerate can diversify the risks. Yet, to maintain high-cost division, each division is required to make profits to keep its position in a conglomerate UNLESS there is a strong political strength in money losing divisions.

25 . Mitsubishi Heavy Industry, Kawasaki Heavy Industry and Fuji Heavy Industry, respectively.

26. Federal Aviation Administration: The US governmental body that regulates safety of aircraft and related issues. The certificate from this agency is essential not only to operate in the United States, the largest aviation market, but as a proof and prestige of safety and quality everywhere in the world.

27. For example, the Taiwanese government failed to establish this commitment (due to political reasons rather than economic) in their PC and semiconductor development (Kanatsu, 2002).

28. "As a result, imported components account for a high proportion of the value of EMBRAER's products: 38 per cent of the Bandeirante, 41% of Xavante, 27% of Ipanema, and between 47 and 71% of various models of the Piper aircraft" (Ramamurti, 1987: 199). This problem of not having spillover effects to other industry is a different but significant issue when thinking about Brazil's *macro* technological catch-up.

29. Current SDP (Social Democratic Party).

30. See Lorrel and Shears for excellent accounts of this FSX project.

31. In spite of the difficulty that YS-11 faced, and after intense interaction between airlines and the consortium, the mechanical dispatch reliability reached 99.0% in 1972 and has been maintaining 99.6~99.8% (the highest among all aircrafts ANA has used) even now. Considering that YS-11 was designed more than forty years ago, this reliability is quite impressive (Maema, 2000: 185–189).

32. Needless to say, these two conditions are NOT the only requirements for the successful aircraft industry development. Brazil completed various basic homework assignments such as the training of engineers, importing certain technologies, and investing substantial R&D to achieve the success of aircraft industry. This becomes particularly clear when one compares the aircraft industry with other failures such as the computer industry. Still, it is important to recognize that the two conditions mentioned in this study played a significant role for the success of the Brazilian aircraft industry. Without them, the Brazilian case could have ended up like the Japanese failure. This is particularly true as most of the homework assignments that Brazil achieved were also completed well by the Japanese counterpart.

33. For example, Mitsubishi Zero was considered superior to Curtis P-40 and Grumman F4F Wildcat of the US as well as Hurricane of Royal Air Force.