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Multinational Corporations, Value Chains and Knowledge Spillovers in the Global Aircraft Industry

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Abstract: The commercial aircraft manufacturing industry is starting a process of delocalization from developed to developing countries. From its original strongholds in the United States, Western Europe and Canada, it is now moving towards the largest new industrial countries of Brazil, Russia, India and China. The technology transfer channels include investment by multinational corporations, participation in global value chains, and outsourcing by large prime contractors based in North America and Western Europe. The process through which technological learning occurs has been studied in economics as international knowledge spillovers. In management, similar processes have been studied under outsourcing and global value chains. Drawing hypotheses from theory, the paper analyzes the patterns of trade, foreign direct investment and outsourcing in the global aircraft manufacturing industry. The evidence amassed shows that through these mechanisms, North American and Western European aircraft industries risk now losing their dominance to the developing countries.

Keywords: multinational corporations, aircraft industry, modularity, value chain, spillovers

JEL classifications: L93, O14, O31, O33

1. Introduction

Catching up in the international economy is basically a learning process. Organizations, most often private firms, learn through their interactions with other organizations based in more advanced countries. Channels of technology transfer and learning are usually large firms, most often multinational corporations. The process through which such learning occurs has been studied in the economics literature as international knowledge spillovers (Branstetter, 2001). However, in the management literature similar processes have been studied under the label of outsourcing and global value chains (Quinn, 1999). The first part of this paper recalls some milestones in the development of these parallel theoretical literatures, and draws some hypotheses from them.

The second part analyzes the patterns of trade, foreign direct investment and outsourcing in the global aircraft manufacturing industry. The paper concludes that there is significant evidence that through all these mechanisms, North American and Western European aircraft industries are now losing their dominance over this sector and that the production of aircraft is following the same route as many other sectors before, from developed to developing countries. From a theoretical point of view, it concludes that the economics and management literatures on spillover effects should converge toward one another, and merge into a single theoretical current.

2. Theory

Multinational corporations (MNCs) are not the only vehicle of globalization, but probably the most conspicuous one. They are usually large firms that conduct international trade and foreign direct investment within and across countries. Dunning (1998) summarized much of the economic theory of the MNC under the three basic factors of ownership viz.: proprietary advantages (knowledge, technology or other); location (of subsidiaries and foreign direct investment); and internalization (transfer of such advantages within the firm). The Ownership-Location-Internalization (OLI) paradigm provides a solid starting point for any analysis of the MNC.

Yet differences among scholars subsist and they are important. One such debate is linked to the nature of the firm and the role of knowledge in MNC. Winter (2006) set the foundations of knowledge-based theory of the firm. In his innovative 1968 article, the firm is seen not as an organization employing a universally known set of production techniques, as it would be in conventional economics, but more a community of people having different sets of knowledge and using them most often in routine activities, sometimes in novel combinations. Firms gradually learn new production methods, or devise new products. Thus, their knowledge is not embodied in a set of manuals, blueprints, software or physical technologies, but includes an important part of tacit and distributed knowledge. In his view, the firm is more than a list of resources, and involves the capability of producing goods and services in both routine and innovative ways. According to the knowledge theory of the firm, knowledge in the MNC is "sticky" and difficult to transfer across organizational, national and cultural boundaries (Kogut and Zander, 1993, 2003). If this is the case, then the absorptive capacity of the subsidiary is a key determinant of the ability of the MNC to transfer knowledge within the firm (Minbaeva *et al*., 2003). Winter's knowledge of the firm perspective has provided the basis for the present-day concept of the firm as a repository of technological capabilities; such capabilities allow firms to create, deploy and use intangible assets (Teece, 2007). Other authors, on the contrary, see these ownership knowledge advantages as easy to loose, and "leaky". The transaction-cost theory of the firm posits that multinational corporations exist to internalize and transfer knowledge, keeping it within the boundaries of the firm (Rugman and Verbeke, 2003).

Another issue concerns the nature and magnitude of knowledge spillovers from MNC in developing countries. The general trend is to identify an increasing number of channels for knowledge spillovers (Bloström and Kokko, 1998); among these channels, the three major ones are (1) movement of staff between MNC and domestic firms, during which employees of the MNC take with them knowledge from the foreign firm to local competitors; (2) demonstration effects of MNC to domestic firms, the latter learning superior technologies; and (3) competition from MNC forcing local firms to become more productive (Görg and Strobl, 2001). Yet other authors found a negative effect or no spillover at all. Local firms may disappear instead of learning from MNC, and the net result may be a reduction in total employment (Aitken and Harrison, 1999). Also, some authors found reduced but positive spillovers from MNCs, particularly through the mobility of technical and managerial personnel from foreign to domestic firms (Vera-Cruz and Dutrénit, 2005). In at least one case, the possibility of capturing such knowledge externalities depended on the absorptive capabilities of the local firms (Chudnovsky *et al*., 2008).

In the meantime, management thought outside the MNC economic debates has studied knowledge flows generated by the multinational firm across borders. One of the main channels for such flows is outsourcing. Outsourcing has now become a current practice of large and medium sized corporations, and is made possible by the modular characteristics of aircraft. "In engineering, a module is defined as a functional unit that is capable of maintaining its intrinsic properties irrespective of what it is connected to. This is an important concept because it allows engineers to connect diverse elements together while achieving predicable outcomes" (Sauro, 2008: 166). The use of modularity has two important advantages: first, it reduces costs and makes the design easier, and, second, it increases the possibility of managing complexity by reducing interaction between elements and tasks (Baldwin and Clark, 2000). Most important for outsourcing, modularity allows different parts of a large design to be built simultaneously, thus reducing the time required to work a complex system. In other words, modularity reduces the development time of a complex system such as an aircraft. Also, modularity facilitates incremental innovation, by allowing changes in modules. This characteristic makes the concept of modularity particularly useful in biology, as it contributes to explain evolution. Finally, modularity alters the boundaries of the firm, because independent firms can work simultaneously on a given complex product on the basis of a given design (Acha and Brusoni, 2008).

Outsourcing is defined as a strategic activity through which companies substitute external purchases for internal activities (thus engaging in some kind of vertical disintegration) and/or subcontracts to independent providers' parts, components or subsystems that they could produce inside the organization (Gilley and Rasheed, 2000). Through outsourcing, producers of complex systems such as aircraft, cars, machinery and software, can transfer to the supply chain the production of some modules they previously produced or could produce in-house. Such strategy allows prime contractors to accelerate new product development (NPD), share costs and risks in NPD, gain economies of specialization, while at the same time learning form the suppliers (Mikkola, 2003). However, other authors have underlined the hidden risks and challenges involved in outsourcing. Learning is a two way process: prime contractors (OEM) learn from suppliers who conduct R&D on specific modules and sub-systems. But at the same time, suppliers learn from the OEM that transfers to them designs of entire new airplanes, cars or software. In many cases, the OEM goes as far as transferring R&D and production methods and best practices to the supply chain partners. These training activities increase the technological capabilities of the supplier, and through this process they involve the risk that the OEM loses R&D capacity, competitive advantage, and ultimately control of the activity (Aubert *et al*., 1998).

Another current phenomenon is the global value chain (GVC) approach pioneered by Gereffi *et al*. (2005), Kaplinsky (2000) and Humphrey and Schmitz (2000). These authors noticed the fact that large multinational firms tend to vertically extend their activities across borders, subcontracting both to host-country firms and to captive subsidiaries and joint ventures. They also noted that such value chains are important channels for learning: through them, firms in developing countries are receiving substantial knowledge from their prime contractors. While their work most often focuses on traditional industries such as agro-food, textile, footwear, furniture, garment, and leather products, their conclusions can be applied to any industry.

Our paper suggests that these value chains are increasingly important and are unexplored channels of international technology transfer and positive externalities, and therefore of learning, from MNC. More precisely and on the basis of the above discussion, we suggest the following hypotheses.

Hypotheses

1. Knowledge of MNC flows through GVC and outsourcing processes, as these processes constitute important learning mechanisms for developing countries. As such, they have to be identified and linked to the literature on spillovers.

2. Due to the "sticky" character of knowledge, the absorptive capacity of the host country partner (whether independent domestic firm, joint venture or local subsidiary of the MNC) plays a major role in the success of the transfer.
3. Institutions, organizations and policies in the host developing country play a major role in increasing the absorptive capacity of local firms, particularly in high-technology industries.
4. Due to the "sticky" character of knowledge, the learning and spillover process involves substantial movements of personnel from the outsourcing firm to its supply chain partner in the developing country.
5. Such outsourcing processes can unleash a course of action through which host country firms may increase their own technological capabilities and move up in the value chain.

This paper will analyze the international aircraft literature in the last thirty years in order to test and possibly refine these hypotheses. These hypotheses are key to the understanding of the recent international diffusion and dispersion of the aircraft industry; after decades of economic and geographic concentration in a handful of countries this industry is now showing some similar patterns compared to many others.

3. Progress of the Aircraft Industry

The aircraft manufacturing industry has been an international sector from its very beginnings over a century ago, when the Wright brothers travelled to France and Italy to demonstrate their invention. Among its characteristics are increasing returns, high entry costs, oligopolistic market structure, and strong government support because of, among other reasons, the industry's obvious links with defence and military. Also, technological and management learning in this industry is a costly endeavour, as many different subsystems and production equipment need to be understood and managed, tested for years and certified in different countries. Quality control is mandatory for each prime contractor as well as for suppliers. Product development is long (usually five to ten years) and is a major entry barrier in itself. Finally, the commercial aircraft industry, with its strong and century old location in North America and Western Europe, seemed almost unassailable for developing countries.

Also, for the same reasons, many industrial and developing countries have at some time considered and supported industrial production of commercial and/or military aircraft. The list includes Argentina, Australia, Austria, Belgium, Czechoslovakia, Denmark, Egypt, Finland, Hungary, India, Indonesia, Mexico, Netherlands, Pakistan, Poland, Romania, Spain, Sweden, Switzerland, and Ukraine. Few of them still produce aircraft. The industry is concentrated in a handful of countries: Brazil, Canada, France, Germany, Japan, Russia, the United Kingdom and the United States of America.

3.1 Aircraft Industry Trends since the 1980s

Concentration has been a continuous process throughout the entire aircraft industry life cycle. The acceleration of the trend also constitutes a major aspect of the aircraft industry evolution since the 1980s. A few large firms have dominated the aircraft industry since World War II (Phillips, 1971). Aircraft producers must achieve a critical mass in order to survive the industry's cyclical downturns and afford the high learning costs, the ever-growing R&D expenses, and the establishment of a worldwide marketing and customer support services network. Large size is also advantageous for aircraft firms that depend heavily on government financial support, regulations, and assistance in foreign market penetration. In his study of the aircraft industry, Pattillo (1998) noticed that, till the 1960s, the hierarchy of American aircraft producers, in terms of their production share, has undergone important changes while the number of major producers itself has been limited (around twenty) and stable. This number of OEMs has considerably diminished after a wave of industry concentration that started in the mid-sixties. In the early 1990s, during a more severe consolidation wave, only four American military aircraft producers remained (Lockheed Martin, Raytheon, Northrop Grumman, and General Dynamics), while Boeing is the only surviving American producer of large civilian aircraft.

The same consolidating process has characterized the global commercial aircraft industry (Table 1). Airbus is the only company that has challenged Boeing dominance on the market of large civil aircraft (more than 100 seats). In the mid 1990s, there were still eight regional aircraft manufacturers, while now only Bombardier and Embraer compete in this segment: BAE and Saab exited the market; Beech/Raytheon focused on business jets; and Fairchild Dornier and Fokker went bankrupt (Aboulafia, 2008). The commercial jet engines market is shared among three American firms (namely, GE Aircraft Engines, United Technology Corporation – the Pratt & Whitney parent, and the Engine Alliance) and three Europeans groups (Rolls-Royce, SNECMA, and International Aero Engines). Thus, the number of major suppliers is limited to 8 American and 6 European firms. Figures 1 and 2 shows the major American and European prime contactors and supply chain firms, which represent more than 85 per cent of global aircraft industry production (U.S. Department of Commerce, International Trade Administration, 2005).

Outsourcing is the second major tendency that characterizes the last three decades of the aerospace industry. The deregulation and privatization of the air transportation industry in the late 1970 rendered American airline companies

Table 1: Main Mergers, Acquisitions and Consolidation in the World Aerospace Industry, 1959-2001

Country	Year	Concentration type	Firms involved in the consolidation / merger process
United Kingdom	1959	consolidation	Avro, Blackburn, de Havilland
United Kingdom	1959	consolidation	Hawker, Folland, Arstrong Whitworth / Gloster
United Kingdom	1960	consolidation	Vicker-Armstrong, Bristol Aeroplane Company, English Electric, Hunting
United Kingdom	1966	merger	Rolls Royce, Bristol Siddeley
United Kingdom	1977	consolidation	Hawker Siddeley Dynamics, Scottish Aviation, Hawker Siddeley Aviation, BAC
Germany	1963	merger	Bolkow Entwicklungen KG, Siebelwerke ATG GmbH
Germany	1964	merger	Weser Fluegzuegbau GmbH, Focke - Wulf GmbH, Ernst Heinkel Fluegzeugbau GmbH
Germany	1965	merger	BMW Triebwerkban GmbH, Man Turbomotoren GmbH
Germany	1968	merger	Messerschmitt Bwerke, Flugzeug Union Sud GmbH
Germany	1989	consolidation	Messerschmitt Bolkov GmbH, Dornier, MTU, AEG
Italy	1970	consolidation	Fiat, Finmexanica, Aerfer
Italy	1990	consolidation	Aeritalia, Selenia
France	1954	merger	Nationale de Constructions Aéronautiques du Nord (SNCAN), Société Française d'Etude et de Construction de Matériel Aéronautiques Spéciaux (SFECMAS)
France	1957	merger	Sud Est Aviation, Ouest Aviation
France	1967	consolidation	Breguet Aviation, General Aeronautique Marcel Dassault
France	1968	merger	Thomson - Houston, Compagnie générale de la télégraphie Sans Fil (CSF)
France	1970	merger	Gerance Potez, Gerance Sud Aviation, Sud Aviation, Nord Aviation, SEREB
United States	1954	merger	Consolidated Vulter Aircraft Corporation, Convair Corporation
United States	1964	consolidation	Hiller, Republic
United States	1967	merger	North American Aviation, Rockwell Standart
United States	1967	merger	McDonnell Aircraft Corporation, Douglas Aircraft Company
United States	1973	merger	North American Rockwell Company, Rockwell Manufacturing Company
United States	2001	merger	General Dynamics, Gulfstream Aerospace

Sources: Gormand (1993) and U.S. Department of Commerce (2005).

Figure 1: European Aircraft Industry Prime and Major Suppliers

EUROPEAN PRIME MANUFACTURERS

EADS
(Airbus)
Develops and produces jet aircraft

LARGE COMMERCIAL JET ENGINES

ROLLS-ROYCE GROUP PLC
Develops and produces aircraft engines

SNECMA GROUP
(62% owned by government of France)
Develops and manufactures aircraft engines, supplies a wide range of aircraft equipment

INTERNATIONAL AERO ENGINES
Multinational consortium registered in Zurich, Switzerland. Partners includes: Pratt & Whitney, Rolls-Royce, Japanese Aero Engines, and MTU Aero Engines.
Develops and produces aircraft

EUROPEAN MAJOR SUPPLIERS

BAE SYSTEMS PLC
Avionics and other commercial aerospace operations

FINMECCANICA SPA
Air traffic management, avionics and fuselage components

KOHLBERG KRAVIS ROBERTS & COMPANY
(Parent: U.S.-based private equity firm)
MTU Aero Engines

SMITHS GROUP PLC
Advanced avionics and mechanical and electrical equipment

THALES
(Government of France owns 33%)
Air traffic management, avionics, computer hardware and software

VOLVO AERO
Develops and produces aircraft engines

Source: U.S. Department of Commerce (2005).

Figure 2: U.S. Aircraft Industry Prime and Major Suppliers

UNITED STATES PRIME MANUFACTURER

BOEING
Develops and produces jet aircraft

LARGE COMMERCIAL JET ENGINES

GE AIRCRAFT ENGINES
Develops and produces aircraft engines

UNITED TECHNOLOGIES CORP.
(parent)
PRATT & WHITNEY
Develops and produces aircraft engines

THE ENGINE ALLIANCE
A 50/50 joint venture between General Electric Aircraft Engines and Pratt & Whitney to produce the GP7200 engine for the Airbus A380 engines

U.S. MAJOR SUPPLIERS

THE CARLYLE GROUP
(parent)
VOUGHT INDUSTRIES
Designs and manufactures major airframe structures

EATON CORPORATION
Hydraulic and fluid power products for aerospace

GOODRICH CORPORATION
Airframe systems, engine systems, electronic systems, landing systems

HARRIS CORPORATION
Communications equipment and systems
Develops and produces aircraft

HONEYWELL INTERNATIONAL, INC.
Turbofan and turboprop engines, flight safety systems

PARKER HANNIFIN CORPORATION
Designs, builds and supports systems

ROCKWELL COLLINS, INC.
Aviation communications

UNITED TECHNOLOGIES, CO.
(Parent)
HAMILTON SUNDSTRAND
Engine, flight, and environmental controls

Source: U.S. Department of Commerce (2005).

extremely sensitive to cost and price issues (Morrison and Winston, 1995; Philip and Thornton, 2005). In addition, the end of the Cold War caused important reductions of defence aerospace programs. These changes forced the restructuring of the aircraft industry. Mergers and acquisitions were necessary but not sufficient to adapt industry to these new and particularly demanding conditions. So, since the 1980s, American OEMs undertook the rationalization of their activity by focusing on their core business (design, development and systems integration) while outsourcing the non-core subsystems to their suppliers. Since the 1990s, European companies have followed the same path. Outsourcing is a multi-step and multilayer process:

- In the first step, large aircraft firms borrowed from automotive industry and introduced progressively in their management practices the principles of the Toyota Lean Business Model. During this period, the primary concern in large firms was the definition of their own core business. From these firms' strategic point of view, focalization on these core activities corresponded to divestment from their ancillary and peripheral business, the merger and acquisition of other firms being presumed to reinforce the firms' core capabilities and the finding of reliable subcontractors for the outsourcing of non-core but still closely related business (Mowery, 1997; Brown, 2000; Giunta, 2000; Smith and Tranfield, 2005).
- During the second step, under ever-growing cost pressure, large firms kept pursuing the rationalization objective of their supply chain by reducing the number of their suppliers. This led to the reconfiguration of prime-suppliers relationships from the one-too-many toward the one-too-few type. Between 2000 and 2005, Boeing reduced the number of its direct suppliers from 3,600 to 1,200 (Nolan *et al*., 2008). In 2006, Airbus announced its intention to cut the number of suppliers by 83 per cent, going from 3,000 to around 500 (*The New York Times*, 7/11/2006). In the mid-1990s, British Aerospace reduced the size of its supply chain from 11,000 to 4,000 firms (Smith and Tranfield, 2005). While aircraft prime contractors tend to restrict their relationships to only first-tier suppliers, they also become the catalyst of a cascade effect by inciting the latter to adopt the same strategy by concentrating on their own core-business and establishing their own reliable supply chain. This process has changed the role of first-tier suppliers whose contribution to the innovation, flexibility and strength of the prime company has become crucial. The implementation by the industry of a "system-buying" mode of procurement has extended first-tier suppliers' responsibility from the development and production of individual components toward those of entire subsystems or aircraft modules (Paliwoda and Bonaccorsi, 1993; Giunta, 2000; Smith and Tranfield, 2005).

- Furthermore, the effectiveness of the aircraft supply chain is linked not only to the quantitative restriction of the suppliers' base but also (and mostly) to the nature and quality of prime-suppliers' relationships which have been deeply transformed during the last two decades. The aircraft industry is complex and extremely demanding in terms of technological change, quality, flexibility, and on-time production. By building high-dependency relationships with their suppliers, aircraft producers were forced to spend much time and effort on improving the efficiency of resource utilization and quality control of both upstream and downstream levels of their supply chain. So, the traditionally sporadic interactions among buyers and suppliers were replaced by a modern type of relationship built on intensive, proactive and long-term cooperation (Lefebvre *et al*., 1993; Bourgault, 1997; Rose-Anderssen *et al*., 2007). In this context, the early integration of suppliers in the design and development processes becomes a determinant factor of OEMs' ability to successfully leverage the knowledge base of their suppliers (Bozdogan *et al*., 1998; Brussoni *et al*., 2001; Bilczo *et al*., 2006). According to Nolan *et al*. (2008), the close collaboration and tight control exerted by aircraft OEM on their suppliers has blurred the boundaries of firms. So, the concept of the extended enterprise becomes appropriate to describe the efforts of OEMs to adopt an efficient and responsive model which exhibits continuous improvement all through their supply chain. This model seems to have forced a powerful and deep vertical integration movement among OEMs and their suppliers.

Internationalization is the third major trend of the aircraft industry evolution since the 1980s. From a demand perspective, the aircraft industry has always been international. Today, commercial aircraft production is mainly for export. Table 2 presents the US aerospace industry foreign trade balance.

Table 2: US Aircraft Industry Foreign Trade Balance
(Billions of current dollars)

Trade balance	2002	2003	2004	2005	2006	2007
Value of exports	54.5	51.1	54.1	65.0	82.6	82.6
Export/Shipments (% of total values)	43.7	42.2	44.7	47.3	58.0	51.3
Value of imports	25.9	24.3	24.7	26.5	29.1	35.2
Balance of trade	26.6	26.8	29.4	38.5	53.5	47.4

Source: U.S. Department of Commerce, Bureau of the Census.

Canada, for instance, exports 82 per cent of its aircraft production, followed by the United States and the European Union, whose export shares of the commercial aircraft sector are 58 and 53 per cent, respectively (AIA, 2007). Yet, a change is happening with respect to the geography of export markets. In terms of worldwide demand, the Asia-Pacific region is expected to experience the most rapid growth rate in the next ten to fifteen years (Airbus, 2004). These countries still have to overcome some main obstacles to growth, like the underdevelopment of their aviation infrastructures; the shortage of qualified pilots; the inadequate set of regulations; and fiscal policies. However, all the world aircraft prime manufacturers have taken concrete steps in order to cross the barriers to these promising future markets. Table 3 presents the top twenty US aerospace export markets.

From a firm perspective, the main driving factor of internationalization in the aircraft industry has been the constant increase of development costs, which may represent up to 25 per cent of overall aircraft costs (Iaurif, 2005). Associated to the low volume of sales, extravagant R&D costs have a negative impact on industry profitability. It is estimated that it takes from 10 to 18 years for an aircraft to become profitable. In these conditions, there is no aircraft producer who can stay in the technological race without government support. In 2001, governmental financial support covered 41 per cent of R&D expenditures in the European aircraft industry. The Unites States government financed 48 per cent of R&D investments in their national aircraft industry (GIFAS, 2004; National Science Foundation, 2006). Meanwhile, cost issues are still crucial for OEMs, since the launching of every new aircraft programme has become a "bet the company" type of decision. It is typical for OEMs to find a way and exploit any opportunity of obtaining additional resources. So, leveraging available foreign government funding or industrial infrastructure has been a key factor in the steady international spread of aircraft production. Esposito (2004) has pointed out the following phases of aircraft internationalization:

- Till the 1950s, the industry was characterized by home-based production;
- A few international collaborations started during the 1960s, mostly among European countries, some of which revealed many inherent difficulties linked with international cooperation. The case of the Concord is the most glaring example of such difficulties. Nevertheless, through several collaboration failures and achievements, European countries learned to work together and in the 1970s they created the only international consortium that has been able to challenge Boeing's solid supremacy.
- The 1980s correspond to the worldwide co-operation phase. More present and successful in the engine production segment of the industry, international cooperation was less practiced among OEMs. Several

Table 3: Top Twenty US Aerospace Export Markets

	1989			1999			2007		
	Market	Value	% of total values	Market	Value	% of total values	Market	Value	% of total values
1	United Kingdom	3520	11	United Kingdom	7845	13	Japan	8376	9
2	Germany	3134	10	Japan	5401	9	France	7901	8
3	France	2764	9	France	5322	9	China	7481	8
4	Japan	2700	8	Germany	4325	7	United Kingdom	6778	7
5	Canada	2137	7	Canada	3438	6	India	6223	6
6	Netherlands	1448	5	Saudi Arabia	3299	5	Canada	5862	6
7	Australia	1271	4	China	2491	4	Germany	5419	6
8	South Korea	1257	4	Taiwan	2237	4	Brazil	4698	5
9	Singapore	1133	4	Singapore	2069	3	Singapore	4163	4
10	Spain	1104	3	Korea	1899	3	Korea	3841	4
11	Sweden	815	3	Israel	1789	3	UAE	3625	4
12	Brazil	813	3	Brazil	1575	3	Ireland	2658	3
13	China	664	2	Netherlands	1566	3	Taiwan	2043	2
14	Italy	625	2	Australia	1426	2	Netherlands	2028	2
15	Belgium	502	2	Italy	1426	2	Israel	1818	2
16	Taiwan	460	1	Spain	1305	2	Hong Kong	1319	1
17	Switzerland	458	1	Sweden	1295	2	Australia	1281	1
18	Israel	453	1	Turkey	957	2	Mexico	1274	1
19	Egypt	438	1	UAE	851	1	Poland	1245	1
20	Mexico	432	1	Luxembourg	732	1	Spain	1008	1

Source: U.S. Department of Commerce, Bureau of the Census.

cooperation initiatives among manufacturers from both sides of the Atlantic failed to produce any substantial progress. The cyclical downturn of the industry in the 1990s contributed to transform the competition between Boeing and Airbus into an aggressive commercial war (Irwin and Pavcnik, 2004).

- The most recent phase of aircraft industry internationalization is driven by a growing interest of OEMs in some non-traditional aircraft producers and low cost countries (LCC) like China, India, Mexico, Russia and South Korea (Vera-Cruz and Dutrénit, 2005). This period corresponds to the growing interest of a few emergent countries whose concrete, continuous and solid efforts are being rewarded by the growth of a domestic aircraft industry. Table 4 presents the evolution of the geography of U.S. major aerospace foreign suppliers.

Niosi and Zhegu (2005) found that international knowledge spillovers are prevailing in the aircraft industry. High R&D costs have increasingly pressed large OEMs to engage in strategic alliances and risk sharing contracts with foreign partners. Strategic alliances have contributed as an important source of resources, learning, and thereby competitive advantage (Hayward, 1994; Dussage and Barrette, 1996; Thornton, 1996). Offsets agreements have been another important internationalization mechanism, which has involved several industry stakeholders including aircraft firms, national and international governments and industry associations. [Offsets are arrangements between sellers and buyers of aerospace equipment, where the selling firm provides by contract additional benefits to the buyers, beyond the equipment itself (Mowery, 1997; Falco, 1998)]. These agreements have affected the U.S. aircraft industry more than any other major economic sector. From 1993 to 2006, aircraft industry related offsets agreements represent more than 50 per cent of the total volume of U.S. offsets (BIS, 2007). Offsets constitute a powerful mechanism of international knowledge diffusion, which is carried out through several offset components such as foreign subcontracts, technology transfer, co-production with foreign partners, FDI, training transactions or licensed production. Table 5 presents the composition of U.S. offset agreements for the period 1993-2006.

In many cases, governments are owners of the national airlines industry and they have used offset agreements to speed up the catching up of their aircraft industry. Meanwhile, Table 6 reveals an uneven geographic distribution of such agreements. During the period 1993-2006, European countries and Canada have been able to leverage a volume of offsets contracts representing 98.4 and 97 per cent, respectively, of their U.S. aerospace imports, while this ratio is only 39.1 per cent for the Asia-Pacific region (BIS, 2007). The number of U.S. exporters involved in offsets agreements

Table 4: Top Twenty Aerospace Suppliers to the U.S. (in current US million dollars)

	1989			1999			2007		
Rank	Supplier	Value	% of total values	Supplier	Value	% of total values	Supplier	Value	% of total values
1	France	3290	32.3	France	6316	25	France	9475	25.8
2	United Kingdom	2055	20.2	Canada	5127	20	Canada	8744	23.8
3	Canada	1918	18.8	United Kingdom	4985	20	United Kingdom	4235	11.5
4	Japan	474	4.6	Germany	2710	11	Japan	3068	8.3
5	Germany	419	4.1	Japan	1711	7	Germany	2642	7.2
6	Italy	300	2.9	Brazil	1285	5	Brazil	1737.5	4.7
7	Sweden	257	2.5	Italy	786	3	Israel	1304	3.6
8	Netherlands	255	2.5	Israel	428	2	Italy	936.6	2.6
9	Brazil	204	2.0	Korea	186	1	Korea	515	1.4
10	Israel	186	1.8	Switzerland	164	1	Mexico	490.3	1.3
11	Singapore	114	1.1	Netherlands	162	1	China	368.4	1.0
12	Australia	109	0.8	Mexico	158	1	Singapore	283.7	0.8
13	Spain	85	1.1	Australia	149	1	Sweden	259.5	0.7
14	Mexico	83	0.8	Sweden	147	1	Netherlands	253.1	0.7
15	Korea, South	72	0.7	Belgium	115	0	Switzerland	237.8	0.7
16	Norway	54	0.5	Ireland	93	0	Belgium	233.9	0.6
17	Belgium	41	0.4	Singapore	87	0	Czech Republic	219.3	0.6
18	Switzerland	29	0.3	Spain	79	0	Australia	208	0.6
19	Denmark	18	0.2	Malaysia	67	0	Poland	207.7	0.6
20	Ireland	17	0.2	China	49	0	Turkey	192.7	0.5

Source: U.S. Department of Commerce, Bureau of the Census.

Table 5: Offset Transactions by Category, 1993-2006

Type of Transactions	Values (in million of current dollars)	% of Total Values
Purchase	16034	38.2
Subcontract	9327	22.2
Technology Transfer	6920	16.5
Miscellaneous	2526	6.0
Co-production	2815	6.7
Credit Transfer	1932	4.6
Overseas Investment	1161	2.8
Training	901	2.2
Licensed Production	351	0.8
Total	41967	100

Source: U.S. Department of Commerce, Bureau of Industry and Security (2007).

is limited to a few large firms and reflects the concentration of the industry. Only five U.S. aerospace exporters have accounted for 73 per cent of all offset agreements reported in the 14-year period (1993-2006).

Two opposing views have arisen in the literature with respect to the concentration and the growing internationalization of the aircraft industry. One perspective points out the increasing risk of a “hollowing out” effect consisting of a gradual divestment of traditional aircraft producer countries form this strategic industry. In the meantime, a few other countries keep absorbing international spillovers and in this way have cumulated enough knowledge and technology to upgrade their own aircraft industry to the point of successfully integrating the global supply chain (Scott, 1999; Almeida, 2002; Pritchard and MacPherson, 2007). The other perspective considers that the extremely high concentration of aerospace industry which has been spread from the upstream tiers of the industry toward the downstream tiers has reinforced the dominance of a few of companies that incidentally are all (except Embraer) in high-income revenues countries. According to Nolan *et al*. (2008), liberalization policies of the developing economies have allowed the establishment of a few gigantic oligopolistic firms that occupy both market segments, namely system integration and subsystem production segments. In this context, in the authors’ view, it will be very difficult for newcomer firms to successfully enter the industry.

The following part of the paper concentrates on the case of some very successful catching-up countries whose long-term and well-suited political, strategic and institutional choices have contributed to transform them into important global players of the aircraft industry.

Table 6: U.S. Aircraft Industry Offset Percentages by Country and Groups, 1993-2006

Country, Groups	Offset Percents	Country, Groups	Offset Percents
1. EUROPE		2. NORTH AND SOUTH AMERICA	
Austria	172	Brazil	W
Belgium	80	Canada	97
Bulgaria	100	Chile	W
Czech Republic	20		
Denmark	27	3. MIDDLE EAST AND AFRICA	
Finland	100	Egypt	N/R
France	84	Israel	48
Germany	100	Kuwait	32
Greece	114	Saudi Arabia	W
Hungary	100	South Africa	116
Italy	93	Turkey	46
Lithuania	100		
NATO	55	4. ASIA-PACIFIC	
The Netherlands	117	Australia	45
Norway	101	Indonesia	N/R
Poland	167	Malaysia	37
Portugal	48	New Zealand	W
Romania	87	Philippines	100
Slovakia	89	Singapore	W
Slovenia	58	Republic of Korea	58
Spain	89	Taiwan*	22
Sweden	103	Thailand	26
Switzerland	78		
United Kingdom	82		

Notes: "Offset Percents" is an average percentage which is calculated by dividing the offset value by the export value.
N/A = Not Applicable.
N/R = None Reported.
W = Withheld to protect company-proprietary information.
* For the purposes of BIS reports, when "country" is mentioned and Taiwan is included in the discussion, "country" refers to both countries and economies.

Source: U.S. Department of Commerce, Bureau of Industry and Security (2007).

3.2 Four National Studies of Emerging Competitors

In the last ten years, new competitors have appeared on the horizon of incumbents in the commercial aircraft production industry. Three of them come from the largest emerging countries (Brazil, China and Russia) and the fourth signals the entry of Japan into the production of commercial aircraft.

Brazil Flies High

In 1969, the government of Brazil founded EMBRAER in order to produce attack and training military aircraft for the Brazilian air force. During the 1970s, EMBRAER produced a 19-seat turboprop, which was originally sold to the Brazilian Department of Defense, and a few units to private airlines. The national government subsidized the production of the Bandeirante. By the late 1970s, the aircraft started to be sold in international markets: more than 500 units were sold in 36 countries. By the mid-1970s, EMBRAER designed two other small aircraft and started producing the Italian trainer Aermacchi and US Piper aircraft under license. In 1980, the maiden flight of the Tucano took place: the Tucano is a military trainer that was sold to the Brazilian air force, but also to foreign countries. The next product was a regional civil turboprop, the Brasilia, of which 350 units were sold between 1985 and 2002. Then, EMBRAER co-developed the AMX fighter with Aeritalia and Aermacchi: launched in 1985, the AMX gave EMBRAER access to new technologies, including pressurization technologies.

The next project was another regional aircraft, the Vector, co-developed with Argentina's FMA in the 1980s. The project was a failure and in 1990 EMBRAER faced a major financial crisis as the national government reduced its subsidies. Employment fell from 12,600 to 3,200 in a few years. In 1994, EMBRAER was privatized, while developing a family of new regional airlines, the ERJ, a turbofan seating between 37 and 50 passengers, on the ERJ-145 platform. In early 2008, over 900 units of the regional jets based on that platform were sold.

For the development of this aircraft, EMBRAER partnered with several European and US companies. There were many reasons for such a strategy. First, despite the efforts deployed by the Brazilian government, the local supply chain did not develop. Aircrafts require high quality certified manufacturing: few local companies were able to attain such standards. Second, the technological capabilities of most Brazilian manufacturers were far below what was required to produce, even under license, the most complex sub-systems of the planes. Finally, the use of imported parts facilitated the penetration of foreign markets and reduced the costs and the risks of every new plane. Thus, by the late 1980s, over two-thirds of the value of the plane was imported (Dagnino and Proenza, 1989). For example, the ERJ platform used Honeywell avionics, Rolls-Royce engines, and EDE and Liebherr landing gear.

In 1999, EMBRAER announced the development of a family of regional jets from 70 to 122 seats, the E-Jet family. The first of this new family was the ERJ-170 (70 seats) whose maiden flight took place in 2002. The ERJ-175 (78 to 88 seas) first flew in 2003. The ERJ-195 was certified in 2006. With this new family of regional jets, EMBRAER was seriously competing for first place in the world market for this type of aircraft, against Gulfstream of the United States and Bombardier of Canada. EMBRAER forecast correctly that the market was moving towards larger regional jets, and they were the first to move into the 100-120 seats category, where they compete with the small, but older, Airbus 318 and Boeing 717 aircraft. By October 2007, 300 units had been delivered and there were some 800 options and 420 firm orders, making the family a huge commercial success. The new family is developed with 16 risk-sharing partners and 22 main suppliers. These include GE (engines), Honeywell (avionics) Sonaca (parts of wings and fuselages), Liebherr (landing gear) and others. EMBRAER has a strategic alliance with the European Aerospace and Defense Group (EADS). Some of its risk-sharing partners have invested in new plants in Brazil in order to co-develop products with the OEM. They include Liebherr, Sonaca and Kawasaki. According to some analysts, co-location of the foreign partners has been a major factor in the reduced cost and rapid development of the E-Jet family (Beelaerts *et al*., 2008).

Finally, in 2001, EMBRAER entered the executive jet market with the Legacy, a 15-seat business jet announced in July 2000, whose maiden flight took place in April 2001. By early 2008, EMBRAER had sold 110 units of the new plane. Several international partners provided the engines (Rolls-Royce), fuel management system (Parker Hannifin), and landing gear (Liebherr). Two new models, the Phenom 100 and the 300, were in development in the very light and light segments.

By 2005, 70 per cent of EMBRAER sales were commercial aircraft, 17 per cent defence, 6 per cent corporate and 7 per cent services and parts. Having accumulated technological experience in the military market, EMBRAER moved successfully to the commercial segment during its 15-year period as a private firm.

Japan's Comeback

Between 1945 and 1952, Japan did not produce any type of aircraft. After the ban on aircraft production was lifted, Japan passed the Aircraft Manufacturing Law in 1952. In the 1950s, Japanese companies started production of military aircraft (F-86 fighter and T-33 trainer) under US license. By the end of production of these two models, Japan's share of the total value of the domestic aircraft was 60 and 65 per cent, respectively, showing rapid learning. Very soon, the four large companies involved in aircraft production before WWII regained their dominant position as domestic manufacturers. They were Mitsubishi Heavy Industries (MHI), Kawasaki Heavy Industries (KHI), Ishikawajima Heavy Industries (IHI), and Fuji Heavy Industries (FHI). IHI concentrated on engines and the three others on airframe structures. By the late 1950s, the Japanese industry and government decided to independently design and build a commercial airplane, the YS-11, with 64 seats. However, the project was abandoned in 1974, with only 182 aircraft built (far behind the break-even point) and enormous losses. However, some learning took place through such an industrial experience (Kimura, 2006).

The Japanese government kept its financial support to the industry, but changed its strategy. In 1986, MITI decided to build the domestic industry through international collaboration, after the main initiative to produce commercial aircraft independently had failed. Japanese authorities seemed convinced that Japan had few advantages in this industry: its internal market, representing only about 5 per cent of world traffic, could not support either a commercial or a military aircraft industry. Selling such complex and quality-dependent products in the international markets was not easy. The close international oligopoly of the four producers of airplanes, the three producers of engines and the three major producers of helicopters added to the difficulty of entering the industry. And the country lacked a major defence system that could offset some of the R&D expenditures of the civilian industry. The only chance for building a Japanese local sector was through long-term outsourcing and technology transfer agreements with Western producers.

The following learning processes occurred again through US-Japan military cooperation: the F-15 fighter aircraft designed by McDonnell Douglas and launched in 1972 was produced by MHI under license. By the late 1980s, Japan turned to the F-16 designed by General Dynamics. In such projects, the Japanese manufacturers received billions of dollars of aircraft production technology from different US companies. The cost of producing such planes in Japan was more than double the price that the Japanese government would have paid if the planes were bought straight from the US (Frenkel, 1984). But the Japanese authorities assumed the cost in order to foster technological learning by local firms. By 2001, however, after several trade disputes with the United States on the sale and diffusion of US military technology, Mitsubishi produced its own jet fighter, the Mitsubishi F-2, in cooperation with Lockheed Martin.

In the meantime, for three decades, several Japanese companies including FHI, KHI and MHI have been subcontractors to MacDonnell Douglas and

Boeing in the production of commercial aircraft. Already in 1969, MHI produced engine carriages for the Boeing 747. Later, some 15 per cent of the Boeing 767, whose maiden flight occurred in 1981, was produced in Japan by the above-mentioned Nippon firms. In 2002, FHI, KHI, MHI and The Japan Aircraft Development Corporation (JADC) signed agreements to conduct joint R&D for the Sonic Cruiser being developed by Boeing in the early 2000s. The same companies have designed and are now producing approximately 35 per cent of the new Boeing 787 composite airframe. In addition, Boeing will outsource to Matsushita Avionics and Bridgestone the interior avionic system and the tires for the same plane.

Finally, MHI arrived to design a brand new regional jet, launched for sale in 2008, in which composites are a major part of the structure (Frenkel, 1984; Kimura, 2006). The new jet will be in production in 2012, in competition with Embraer E-jets and Bombardier CRJ700. The Mitsubishi Regional Jet (MRJ) will be the first regional plane made in composites (similar to those used by MHI to produce wings for the new Boeing 787) and will be the first to use the new Pratt & Whitney geared turbofan engine that is expected to be 10-15 per cent more fuel efficient than current engines.

The Rise of China

Following the rapprochement between the United States and China in the 1970s, China started a long process of transformation of its military government departments into public corporations (Frankenstein and Gill, 1996). One such corporation was the Aviation Industries of China (AVIC) that spun off in 1993 from the Aerospace Ministry. In 1996, AVIC became a holding company for hundreds of public industrial corporations. By 1997, AVIC was manufacturing all sorts of goods from automobiles to aircraft, machinery, household appliances and white goods, and its aircraft sales were modest when compared with such leading aircraft producers as Boeing, Lockheed Martin, Northrop or United Technologies (Nolan and Zhang, 2002). In 1997, 62 per cent of AVIC sales were automobiles, auto-parts and motorcycles.

Parallel to its organizational changes, in the 1970s and 1980s, China reduced its military expenditure and left its aerospace sector lagging behind. However, in the early 1990s, US military activities in the Middle East started their upward course, and China again increased its investment in military technology, particularly in aerospace. China designed and built several commercial aircraft, of which the Y-7 and the Y-10 deserve mention. The former was designed, produced and launched in the 1990s. It was a mid-sized jet propelled by P&W turbines. But only 130 units of it were produced, and in 2000 one Y-7 exploded in the air, triggering the retirement of the entire Y-7 fleet. A larger model was designed, the Y-10 of which only two copes were built, as Chinese airlines refused to buy it because it was too heavy compared to the Boeing 707. Several preliminary agreements with MacDonnell Douglas and Airbus to co-produce large civilian aircraft in China failed by the end of the 1990s.

New organizational changes followed, two of them critical. The first was the move toward subcontracting to the international aircraft industry, particularly Boeing, but also BAe, Bombardier and Lockheed Martin. Its subsidiary, Xian Aero Engines, was doing subcontracting work for Rolls Royce. By 1995, AVIC had signed contracts for outsourcing for a total value of $1.5 billion. Thus, China started competing with Israel and Japan for US and Western Europe aerospace subcontracting. The second major change was reorganization: both AVIC I and II were created in 1999, resulting from the division of AVIC. They are government holding corporations. In 1999, AVIC and its manufacturing subsidiaries had 560,000 employees producing aircraft, aircraft machinery, aircraft parts, weapons, missile, aircraft engines, but also all sorts of industrial goods. The two new aircraft holdings started their corporate streamlining, and new plans for locally designed aircraft were developed.

AVIC I focused on large aircraft. It controls some 50 large and medium sized firms, as well as the four Tier 1 suppliers of China: Shanghai Aviation Industrial Group (SAIC), Chengdu Aircraft Industrial Group (CAC), Shenyang Aircraft Corporation (SAC) and Xian Aircraft Industrial Group (XAC). All of them improved the quality and efficiency of their products through massive technology transfers from Boeing, and more recently from Airbus. In 2006, AVIC I had aerospace sales of US$5.6 billion and 23,000 employees.

In 2000, China launched the M-60, a 56 to 60-seat turboprop aircraft evolved from the Y-7. But once again, the market did not rush to buy the new airplane. Yet, in September 2007, AVIC I had sold 98 M-60 to ten different countries since 2004 (*China Daily*, 4/9/2007). Smaller turboprops (The Harbin Y 11 and Y 12) were also produced. The most successful, the Y-12, first flew in 1984, and received Chinese certification in 1985 by the Harbin Aircraft Manufacturing Corporation. It is powered by P & WC engines, and accommodates a maximum of 17 passengers. It is used as a light commuter, and was certified in the UK in 1990 and the US in 1995. By the end of 2000, China started to plan a new regional jet.

Today, AVIC I designs, develops and manufactures fighters, fighter-bombers, bombers, transports, trainer aircraft, reconnaissance aircraft, turbojet engines, turbo fan engines, air-to-air missiles and ground-to-air missiles, as well as machinery and other types of weapons. AVIC I is now developing the Advanced Regional Jet (ARJ21), a jet with AVIC I IPR. The ARJ21 will use Rockwell Collins avionics, and GE engines co-produced in China with one

AVIC I subsidiary. Bombardier will cooperate with AVIC I for the ARJ21 900 model. Also, the Chinese firm may have started to produce structural parts for the C-Series that Bombardier announced in 2008. In the meantime, the maiden flight of the ARJ21 was supposed to take place in September or October 2008, and mass production in 2009. AVIC I claim that already, 181 orders of the ARJ21 have been placed by Chinese domestic airlines. GE engines will power the regional jet that will use Liebherr landing gear, Rockwell Collins avionics, and Honeywell flight controls.

AVIC II focused on smaller aircraft and helicopters. In 1999 AVIC II owned 54 large and medium-sized industrial enterprises and three scientific research institutes involved in helicopter, airplane, engine and airborne equipment. They controlled an additional 22 enterprises, institutes and specialized companies including China Aviation Technology Import and Export Corporation. They employ 210,000 workers, and control assets of 31.5 billion RMB. Boeing and McDonnell Douglas have been collaborating with different companies for over 35 years. These include the Harbin Aircraft Manufacturing Corporation (HAMC), the AVIC II subsidiary that manufactured the most successful civilian aircraft ever produced in China (Y-12).

HAMC also produces military helicopters under Russian and European licenses, and is now developing a new model of helicopters in collaboration with Eurocopter. In addition, HAMC co-developed a 5-seat light helicopter, the EC 120 Colibri, with both civil and military applications. The result of a collaborative project between China's CATIC, Eurocopter, and Singapore Aerospace Technologies Corporation, the EC 120 first flew in 1995. HAMC was responsible for the body, Singapore Aerospace for the tail and France-based Eurocopter for the engine (Turbomeca). Its production started in France in 1997. Three different plants – in Australia, China (through HAMC) and France – now produce the EC 120. Eurocopter installed the Chinese assembly line, which commenced production in 2004. It was the first time that China participated in an investment and risk-sharing agreement with foreign partners in the production of helicopters. Also, China ordered 150 of these helicopters for the Army Aviation Unit.

In 2007, Changhe Aircraft Industries Corporation (CAIC), another subsidiary of AVIC II, signed an agreement with US Sikorsky to co-develop a 1-ton light helicopter, under a risk-sharing partnership. CAIC will supply key parts of the airframe and conduct part of the final assembly. To start with, CAIC was expected to assemble imported parts of the S-76C helicopter, and then move to manufacturing in 2009. Sikorsky and CAIC have been cooperating since 1995, when CAIC was chosen to provide subassemblies for a larger helicopter, the S-92, produced in the US. Sikorsky forecasts that China will buy 1000 helicopters in the decade between 2007 and 2017.

In sum, China's Tier 1 suppliers of subsystems (such as several AVIC I and AVIC II subsidiaries) are learning through massive outsourcing fuelled by the growth of the Chinese market, and observers foresee that Tier 2 Chinese companies will also increase their technological capabilities through increasing contracts for maintenance, repair and overhaul of the fast-growing Chinese fleets. In addition, China has been designing aircraft for decades, and its learning curve shows an upward movement even if past attempts were not commercial successes. Now with the domestic market being the most dynamic in the world, conditions may be set for the development of a Chinese aircraft industry with foreign cooperation.

The Russians Are Coming Back

The Russian aircraft industry has been developing since the early 20th Century. By 1953 there were 25 aircraft design bureaus in the USSR; these were state companies that could build prototypes but not manage mass production of aircraft. Among the most famous of them are Antonov (main base in Ukraine), Beriev, Illyushin, Klimov, Mikoyan, Sukhoi, Tupolev, and Yakovlev. Airplanes were produced in separate plants such as the Irkut, the Smolensk or the Sokol manufacturing establishments.

At the time of the fall of the Soviet Union and the rise of the CIS (Commonwealth of Independent States), several aircraft designers (such as Illyushin and Tupolev) and several manufacturers still existed in Russia. By 2007, two major groups were emerging: the Sukhoi and the Irkut holding companies. Sukhoi is the major Russian aircraft designer and producer, while Irkut is the second largest Russian aircraft designer and manufacturer.

In 2006, the Russian aircraft industry was composed of 300 companies and design bureaus, employing some 500,000 people. By early 2008, the Russian government was planning to merge both Sukhoi and Irkut with the other designers and manufacturers such as Beriev, Mikoyan, Tupolev and Yakovlev into a single company, the United Aircraft Building Corporation (UABC). UABC is a government-owned company created in 2006 with the goal of consolidating all designers and manufacturers of aircraft in Russia. The mission of such a company would be to restore and update Russia's capabilities in the production of military and civilian aircraft.

In the meantime, however, a merger and acquisition movement started independently in the aircraft sector. The Irkut Corporation (the only Russian aerospace private firm quoted in the Moscow stock exchange) started its own consolidation process through the acquisition of the Beriev and Yakovlev design bureaus, and began efforts to attract both Illyushin and Tupolev design offices into the alliance. In 2006, Irkut was a large firm, but not comparable to its Western competitors; it had a revenue of US$832 million, 90 per cent of which was from military aircrafts and components. The group had three major design and R&D bureaus (Beriev, Russian Avionics and Yakovlev), as well as several manufacturing plants and three marketing subsidiaries. The group's exports represents over 90 per cent of its overall sales with estimated R&D expenditures ranging from US$35-40 million per annum (5 per cent of sales). Irkut produces and sells components for Airbus 319, 320 and 321, and licenses one of its models for assembly in India. EADS is a minority shareholder in Irkut, while the control of the company resides with its management.

Irkut's main project is the MS-21, for which Irkut will be the lead designer. Partners are designers Illyushin, Tupolev and Yakovlev, as well as Aviastar (lead manufacturer). This is a single-aisle civilian plane, with 130 to 170 seats, and a 5,000-km autonomy. The engines would be Russian and developed by the Salut (from Russia) and Motor Sich (from the Ukraine) companies. The aircraft should be in service in 2012.

Its competitor, Sukhoi (100% controlled by the Russian state) is the largest Russian producer of aircraft, with annual sales of over 1.5 billion US$, of which over 90 per cent is exported as military material (Sukhoi managed to buy some plants and design bureaus from the Soviet Union). With 28,000 employees in 2008, Sukhoi has control of the most promising project in Russian aerospace, the SuperJet 100 Jet (RRJ), with strong support from the national government. The RRJ was announced in 2001 and the first copy rolled out of the assembly plant in 2007. It is a 95-seat plane with variants between 78 and 98 passengers. Different manufacturing firms within the Sukhoi holding will manufacture the structure, wings, tails and nose. Thales of France will provide the avionics, while CMC Electronics of Canada will supply the Flight Management System. Engines co-produced by French SNECMA and Russia's NPO Saturn will power the RRJ. Intertechnique (France) supplies the fuel system, and US Honeywell, Hamilton Sunstrand and Curtiss Wright will provide power supply, electrical systems, and other components, while Messier Dowty (France) supplies the landing gear. The RRJ will be in service by the end of 2008. The RRJ is produced by Sukhoi Civil Aircraft, a subsidiary of Sukhoi, in which Turbomeca (the French producer of small gas turbines) has 25 per cent shares.

Russia's re-entry into the aerospace industry bears some similarities to the Brazilian entry. The national champion of Brazil is designing and manufacturing aircraft (structures, wings, tails, and noses), leaving the more technical part to multinational established foreign corporations. Similarly, the two Russian champions will concentrate on designing, producing and assembling airplane structures and will import the most complex sub-systems from world leaders. Also, in both Brazil and Russia, established producers have bought shares of the local companies in order to consolidate the long-term alliance of new entrants and incumbents.

The new entrants have adopted different strategies to learn and absorb foreign technology, and they design fairly different products, even if all of them have targeted the regional jet market as their entry path into the production of commercial aircraft. Tables 7 to 9 compare the companies and the products.

When contrasted with the first hypothesis, the cases of China and Japan are those that have more abundantly used GVC and outsourcing as learning mechanisms. Brazil and Russia have accumulated local capabilities through decades of working independently in the industry and are less active in GVC. The fifth hypothesis suggests that outsourcing can be a major mechanism for learning, but the extent of outsourcing seems to vary among the four countries. China and Japan have used insourcing, while Brazil is using outsourcing from large established corporations in order to bring foreign-made modules to Embraer.

As to the second and third hypotheses, the absorptive capacity of each of the four host countries is different. Brazil and Japan have more flexible, market-oriented organizations, and they should be able to capitalize on them, but China and Russia have inherited public corporations from their communist past and these may be less amenable to compete in world markets.

The fourth hypothesis also points to organizational flexibility, which may be easier to employ in international spillovers between private firms than

Table 7: The Newcomers Compared

Company	Country	Founded	Sales 2006 (US$B)	Employees (2007)	Mode of entry	Control
EMBRAER	Brazil	1969	3.807	23,367	Military to civil	Private
AVIC I*	China	1993/99)	5.6	23,000	Military to civil	Government
AVIC II*	China	1993/99)	4.3	210,000	Military to civil	Government
Sukhoi	Russia	1939	1.5	28,000	Military to civil	Government
Irkut	Russia	1932	0.832	15,424	Military to civil	Private
Mitsubishi Heavy Industries	Japan	1928**	24.6	62,212	Military to civil	Private

Notes: * Spun off as AVIC from Ministry of Aerospace in 1993, later split into AVICI and AVICII in 1999.
** Founded as Mitsubishi Aircraft, later merged with Mitsubishi Heavy Industries, and soon to be spun off as Mitsubishi Aerospace.
Sources: Web sites of firms.

Table 8: The Entrants Compared

Company (Founded)	New aircraft	Maiden flight	Entry in service	Outsourcing to	Foreign direct investment by incumbents	Risk-sharing agreements to co-develop new aircraft	Joint ventures with MNC	Joint R&D with MNC
EMBRAER	E-jets	2002-6	2002-7	–	EADS (20%)	16, including Liebherr, Sonaca	Yes: several	Liebherr
AVIC I	AJR21	2007	2011	Boeing	–	Bombardier	Airbus	P&WC
AVIC II*	EC 120 helicopter	1995	1997	Eurocopter	–	Eurocopter Singapore Aerospace	Airbus	Eurocopter
Sukhoi	SuperJet 100	2008	2008	Boeing Airbus	Turbomeca	17, including NPO, SNECMA, Thales, Messier Dowty	Alenia	–
Irkut	MS21	..	..	Airbus	EADS	..	Airbus	–
Mitsubishi**	MRJ	..	2013	Boeing	–	P&WC, Rockwell, Parker Aerospace, Hamilton Sundstrand, Sumitomo	–	Boeing

Notes: * Spun off as AVIC from Ministry of Aerospace in 1993, later split into AVICI and AVICII in 1999.
** Founded as Mitsubishi Aircraft, later merged with Mitsubishi Heavy Industries, and soon to be spun off as Mitsubishi Aerospace.

Table 9: The New Aircraft Compared

Company \ Seats	30	50	70	90	110	130
Airbus					X	X
Boeing					X	X
Bombardier		X	X	X	C-SERIES	
EMBRAER	X	X	X	X	X	
AVIC I (ARJ21)			X	X		
Sukhoi (RRJ)			X	X		
Mitsubishi (MRJ)			X	X		
IRKUT						MS21

Source: U.S. Department of Commerce (2005).

between government and private corporations. Organizational and institutional factors tend to suggest that Brazil and Japan may have an advantage over China and Russia.

4. Conclusions

The new entrants in the global commercial aircraft industry (Brazil, China, Japan and Russia) are using a large range of channels to acquire foreign technology and know-how. For them, the era of building aircraft under license seems to be over, and the new age is one in which they participate in international risk-sharing partnerships, outsourcing and inward foreign direct investment. It remains to be seen how many of these new entrants stay in the market within ten years, but the odds are that some of them, if not all, will remain. Several major factors weigh in their favour.

The first is the size of their markets. All of them, particularly China and Japan, have sizable and fast-growing domestic markets that will absorb a large proportion of their production. The second is the support of the local governments: in all cases, national authorities have generously financed product development by their nationals and national champions. The third is the emergence of new business models where international risk and financial partners co-develop most subsystems. The major advantage is that this model reduces the cost and time of learning. A new entrant does not need to be proficient in avionics, engine technology or landing gear production to produce aircraft. The fourth advantage, at least for Brazil, China and Russia, is cost. Labour costs in such countries are much lower than in North America or Western Europe. The fifth advantage is experience: MHI has produced aircraft since 1928 (but stopped between 1945 and the early 1960s); China has produced them since the 1950s; Brazil's EMBRAER since the early 1970s; and Russia since the 1920s. These companies and countries are thus not newcomers in the production of aircraft: they are, in some cases, newcomers in the area of producing commercial aircraft for the world markets. The sixth advantage, for Brazil and Japan, consists of market-oriented institutions and organizations that allow for easier knowledge transfer across borders. The final advantage is the labour pool: all these countries can count on a massive and rapidly growing skill base.

In sum, the commercial aircraft industry is following the same patterns of delocalization towards developing economies that Lall (1998) observed ten years ago for other high-technology sectors. The theoretical conclusions are straightforward. First, outsourcing and participation in global value chains are major spillover channels on the same level as foreign direct investment, personnel mobility and international trade. Second, these new and increasingly important processes of knowledge diffusion are intermingled with more traditional spillover channels. The next challenge, after their proper identification and integration into the spillover literature, will be to attempt a quantitative analysis of the relative weight of each channel. Finally, markets alone are not able to permit the entry of the new competitors in such a complex and protected industry. Government policies and funding will allow the new industrializing countries to gain a foothold in the production of commercial aircraft.

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