Provide Support to Chinese Customers

Currently, the Chinese commercial aircraft fleet accounts for 9.6 percent of the global fleet; Boeing projects that China will account for 16 percent of worldwide purchases of commercial aircraft over the next 20 years.[9] In light of the size and growth of the Chinese market, many foreign companies in the aircraft manufacturing industry have set up operations in China to serve their customers. For example, both Boeing and Airbus have set up training, logistics, and service centers in China to maintain their aircraft, sometimes in the form of joint ventures with their Chinese clients.[10] Tier One suppliers, companies that provide aircraft manufacturers with complete modules such as landing gear or engines, have followed suit to ensure that they can provide replacement parts and aftermarket service promptly. Rolls Royce and United Technology's Pratt & Whitney unit, for example, have joint ventures with Xi'an Aero Engine Group Co., Ltd., engaged in overhauling engines in China (Table 4.1).

China has become such an important market for many of these companies that they have located regional servicing hubs to China; some, like Honeywell and GE, have moved their Asian headquarters to the country. Honeywell operates a joint venture that provides repair and overhaul services on auxiliary power units, avionics, wheels, and brakes for its entire Asian market.[11] Rockwell Collins's joint venture with China Eastern repairs and replaces communication, navigation, and surveillance components for narrow-body jets—not only for China Eastern, but also for other airlines. Companies have concentrated service operations for Asia in China, partly because the facilities tend to be new and have been designed and built to take advantage of the latest designs for work flow and layout, resulting in higher efficiencies. Because so much work passes through these facilities, material and parts acquisition is easier than elsewhere, reducing repair and maintenance times.[12]

Competitive Source of Parts

Because the aviation manufacturing industry is more concerned about safety and performance than cost, it puts a priority on quality and reliability when purchasing components; cheap labor is insufficient to make a manufacturer competitive. This said, manufacturers do seek to constrain costs. China-based suppliers have become important sources of some components and modules. China-based manufacturers, especially those with expertise in machining, provide Tier I suppliers like Pratt & Whitney, Rolls Royce, and GE with technically challenging machined parts. Boeing and Airbus source secondary and interior components made from composite materials from China. As Tier II and Tier III suppliers, Chinese manufacturers also provide components—such as bulkheads, portions of the fuselage and wings, and other products—for foreign customers.

Subsidiaries of AVIC, foreign manufacturers with operations in China, and joint ventures between foreign manufacturers and these AVIC subsidiaries all supply materials and components to foreign manufacturers. The important role played by subsidiaries of foreign manufacturers or joint ventures in supplying the global aircraft industry stems from the tough certification requirements needed to become a supplier. Manufacturers of materials for the commercial

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[9] Boeing, *Current Market Outlook 2012–2031*, 2012, pp. 7, 20.

[10] Airbus, undated b.

[11] "Honeywell Names Briand Greer President of Honeywell Aerospace Asia Pacific," web page, December 5, 2011.

[12] Henry Canaday, "China's MRO Market Booming," *Air Transport World*, January 1, 2012.

aircraft manufacturing industry have to be certified by the FAA or EASA before they can be used in aircraft. As a consequence, traditional suppliers have an edge over new entrants, as they have the experience and certifications needed to sell to the international market. New Chinese entrants face a double hurdle of obtaining certification for the components they wish to manufacture and convincing potential customers to dump traditional suppliers. They also need to prove they can provide worldwide support for their customers. As assurances of quality, airworthiness, and availability are of most concern to the end user, breaking into the market primarily on the basis of cost is more difficult than in other industries.

Exclusively Chinese companies also face challenges because they have not mastered key technologies. Technologies for the most advanced products—such as turbine blades, composite materials, and complete, integrated systems—are closely held by the companies that have developed them. Most of these components are manufactured abroad or are imported for final assembly within China. Foreign partners do work with Chinese companies on production technologies for other types of products that are more widely available or easier to develop to ensure the product is manufactured with the requisite precision, quality, and efficiency. They also help by providing advice on best practices in procurement and supply chain management.

In recent years, some Chinese suppliers have faced cost pressures on existing contracts with foreign companies. The very sharp increases in the value of wages in China in dollars over the last several years have severely eroded profit margins. A number of foreign companies engaged in manufacturing commercial aviation components informed us that Chinese suppliers have turned to them with requests to renegotiate prices. As already discussed, AVIC Corporate was once willing to cover losses incurred by subsidiaries as they acquired new technologies as suppliers of components for foreign companies, but it is no longer willing or no longer has the resources to do so. Foreign customers have not usually been amenable to higher prices. However, they have transferred production technologies and know how to help their Chinese suppliers cut costs by reducing spoilage, streamlining manufacturing operations, and making labor more efficient.[13]

Generate Sales to Chinese Airlines

Some of the operations and joint ventures in China are undertaken as part of marketing strategies. Boeing's and Airbus's training centers in China often provide training to their clients free of charge. The training helps lock in customers by ensuring that their mechanics are knowledgeable and comfortable with servicing the training provider's aircraft.

Assembly operations set up by commercial aviation manufacturers are designed to lead to higher sales. As previously noted, it is doubtful that McDonnell Douglas would have successfully sold aircraft to China without the joint venture it set up to assemble the MD-80.[14] The opening of Airbus's assembly operation in Tianjin coincided with a surge in sales of Airbus aircraft to Chinese airlines, dramatically reducing the gap with Boeing in China.[15] Although an increase in Airbus sales was probably likely in any event (Airbus took global market share from Boeing during this time period), the assembly operation appears to have been helpful. In 1995, Boeing held a commanding lead over Airbus in the Chinese market, accounting for roughly

[13] Discussions with Western commercial aviation component manufacturers in China.

[14] For information on the SAIC-McDonnell Douglas partnership, see GlobalSecurity, undated b.

[15] Airbus, undated b.

60 percent of the Chinese commercial fleet and more than 80 percent of all new orders,[16] while Airbus held 7 percent of the market, with just 29 planes sold.[17] By 2010, Airbus's market share has risen to more than 43 percent, while Boeing's share has fallen to 55 percent.[18] In-country assembly operations do not guarantee sales, however. As already noted, Embraer's joint-venture production line struggled.

Purchase Chinese Components as a Marketing Tool to Encourage Chinese Purchases of Aircraft

Aircraft manufacturers frequently use purchases of components from the purchasing country as a marketing tool. The manufacturer commits or makes a good-faith effort to purchase components or other products to partially "offset" the purchase price of the aircraft.

In countries that have or are developing a domestic aircraft manufacturing industry, offsets help develop the domestic industry. Orders for simpler components from the foreign aircraft manufacturer can help fledgling companies in the purchasing countries. Over time, the industry in the purchasing country may be able to produce materials and modules as well as simpler components that are incorporated by the manufacturer into every aircraft in that line. In this instance, the purchasing country's industry becomes fully integrated into the manufacturer's operations.

However, sometimes the offset only applies to planes sold within the country. For example, the value added generated by the Airbus assembly joint venture in Tianjin is considered an offset. Because that aircraft is only sold in China, the plant is less integrated into the global operations of Airbus than are the operations of a supplier of modules for all A320s. In some instances, offsets have involved purchases of goods or services from the purchasing country that have nothing to do with aircraft. For example, Airbus purchased a barge, the *Ville de Bordeaux*, a roll-on/roll-off vessel from the Jinling shipyard in Nanjing, to deliver parts for the A380 for $30 million.[19] The aircraft manufacturer has to include the cost of selling these products into its calculations of the price it charges for its aircraft; the purchasing country may be better off economically if the two transactions are negotiated separately.

Despite this drawback, the Chinese government values offsets. Recognizing this interest of the Chinese government, both Airbus and Boeing have used offsets as part of their marketing strategies in China. The websites of both companies tout the types and often the value of components they purchase from China for inclusion in their aircraft.[20] Both companies have established joint ventures to manufacture parts in China, such as those to manufacture composite components, as already described. Airbus has transferred the technology to manufacture the entire composite wing of the A320 airliner to its joint-venture composite manufacturing center in Harbin.[21]

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[16] Boeing, "China and Boeing Partnership Delivering Value," The Boeing Company, October 12, 1995.

[17] Airbus, undated b.

[18] *Aviation Week*, "World Aerospace Database," web page, undated.

[19] Northrup Grumman, "Northrop Grumman Supplies Advanced Navigation, Communications Systems for Ville de Bordeaux," news release, June 7, 2004.

[20] Airbus, undated a; Boeing, undated a.

[21] Airbus, undated a.

Modern aircraft assembly relies heavily on modules manufactured by suppliers; so, for Airbus and Boeing to increase offsets from China, their suppliers need to source components from China as well. One company representative with whom we spoke noted that his company had set up an operation in China in part at the behest of their client, a foreign aircraft manufacturer. The client stressed the importance of the offset from China in its discussions with the supplier about setting up the facility.[22]

Reflecting the factors that foreign aircraft manufacturing companies must take into account when considering investing in China, a *New York Times* article states,

> With China poised to become the world's biggest civil aviation market, many Western manufacturers are trying to figure out the best way to negotiate the country's complex business and political environment. Airplane makers are expected to establish a presence in the country and purchase supplies from the Chinese while exposing their engineering and technology to possible duplication by China's fledgling airplane manufacturing industry.[23]

Participation in the C919 Program

As already noted, COMAC stipulated as part of its solicitation for Tier One suppliers for its C919 project that winning suppliers set up joint ventures with Chinese companies to assemble the modules for the C919 in China. According to company representatives with whom we spoke, the joint ventures posted in Table 4.2 are primarily a consequence of this stipulation. For example, GE states that its joint venture in avionics with AVIC was launched to sell its products and services to the C919 program as well as from the desire of both companies to create a global, joint Tier One, commercial avionics supplier.[24]

U.S. government officials with whom we discussed the C919 program reported that U.S. firms had not protested this requirement; rather, they sought assistance from the U.S. government in crafting a winning bid, including the creation of a joint venture. Companies have been willing to set up joint ventures as a prerequisite for winning this contract because of the importance for companies of being designated a supplier for a new aircraft. Several company representatives with whom we spoke highlighted the importance attached by their company to supplying the ARJ-21 and, especially, the C919 programs.[25] They noted that aircraft modules and components are specialized products that can only be sold if they are chosen for installation on an aircraft. Consequently, suppliers compete fiercely to be qualified on new aircraft. Companies are especially interested in being designated the sole supplier, a condition to which COMAC has agreed for the C919 program.

Even suppliers that have been skeptical about the ultimate commercial success of the C919 argued that they need to be engaged in the program to ensure that they will be well-placed for COMAC's future projects. If COMAC does succeed in repeating the success of Airbus, these suppliers want to make sure that they will be the suppliers of the components and modules that will be used on COMAC's future aircraft.

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[22] Discussion with Western commercial aviation component manufacturer in China.

[23] Christine Negroni, "China Market Challenges Plane Makers," *New York Times*, May 14, 2012.

[24] "GE's China Avionics Deal: A Q&A with Lorraine Bolsinger," 2011.

[25] Discussions with Western commercial aviation component manufacturers in China.

Enhance Company's Image in China

In some instances, suppliers were skeptical that the C919 will be produced in any number. However, suppliers often have broader commercial interests in China, apart from the aviation industry. Interviewees noted that maintaining cordial relationships with Chinese government officials is important for operating in China. Bidding to participate in the C919 program was seen as an important indicator of the company's commitment to China. Consequently, because of the importance that the project has been given by the Chinese government, one company bid on the C919 project to preserve and enhance its corporate image with Chinese leadership. Even if the project fails, the company believes that it will have enhanced its corporate image in the eyes of China's leaders.

Challenges of Investing in China

As shown by the quotes from the CEOs of AVIC and COMAC, these executives are intent on establishing a global presence in the commercial aviation manufacturing industry. AVIC CEO Lin strongly believes that AVIC and COMAC should be the only providers of commercial aircraft and parts to China.[26] COMAC has set a goal of capturing a sizable share of the world market for commercial aircraft from Airbus and Boeing. AVIC intends to become a major supplier of aviation modules and components.

The foreign companies who have invested and set up joint ventures in China, including with AVIC subsidiaries, are well aware of the goals of these companies. We asked company representatives how the companies were responding to these efforts by their Chinese partners who plan on becoming competitors.

Protecting Intellectual Property Rights

All of the companies we interviewed had been active in China for years, and all were aware of the challenges of protecting technologies from Chinese competitors. One investor said, "Don't bring any technology to China that you are afraid to lose."[27] All had developed strategies and programs to safeguard their intellectual property and technologies.

The most common strategy for protecting technologies is to manufacture key components outside of China; the joint venture then imports the component for final assembly. Airbus manufactures all major parts at its plant in Hamburg and ships them to its joint venture in Tianjin.[28] Despite pressure from the Chinese government to set up plants in China, even Russian companies, who have tended to be more willing to transfer technologies to Chinese companies than other foreign firms, have refused to set up manufacturing lines for jet aircraft engines within China. Russia's United Aircraft Corporation set up assembly lines for the Sukhoi SU-27, but continued to import the engines to protect their jet engine manufacturing know-how, especially turbine blade manufacturing technology.[29]

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[26] Lin, 2012.

[27] Discussion with Western commercial aviation component manufacturer in China.

[28] Leithen Francis, "Airbus's China Gamble," *Flight International*, October 28, 2008.

[29] Keith Crane and Artur Usanov, "Role of High-Technology Industries," in *Russia After the Global Economic Crisis*, Anders Aslund, Sergei Guriev and Andrew Kuchins, eds., Washington, D.C., Peterson Institute of International Economics, May 2010, pp. 95–124.

In the case of less sophisticated components, some companies ensure that none of their Chinese employees know all the steps involved in manufacturing the product. For example, one company does not list the actual chemicals that go into a manufacturing process. Rather, the ingredients are simply listed as "A" and "B"—employees are only informed of how much of each ingredient should be mixed together. Other companies break up manufacturing processes so that Chinese employees only work on one stage of the process.

This said, the manufacturers were all fully aware that Chinese joint-venture partners and some employees were interested in absorbing technologies and know-how and transferring this knowledge to manufacturing operations at AVIC and COMAC. Several manufacturers felt that, as in the rest of their operations, the way to stay ahead of Chinese competitors is by continuously improving their products and processes. One manufacturer of less-complex components did say that competition from Chinese manufacturers was creating problems for them in a market segment for a less sophisticated product.[30]

Because all materials and components used on aircraft must be certified by aviation regulatory agencies such as the FAA and EASA, certification provides an additional check on theft of intellectual property rights. Scott Donnelly, CEO of Textron (the parent company of Cessna), notes that because of the extensive development and certification process involved in bringing new aircraft to market,

> If anybody's going to try to take our intellectual property and do a knockoff of our products, that's going to be a very, very public thing. It's years and years of development and a very, very difficult certification [process]. In our industry, with our kind of products, this [copying a product] is not an issue to worry about.[31]

Donnelly says he believes that collaboration with a domestic partner reduces the overall risk of intellectual property theft, arguing that a company is much more susceptible to theft and other problems with intellectual property if they are not in that market.

Protecting the Company's Investment from Joint Venture Partners

Interlocutors from foreign firms argued that they needed to be very careful in drawing up joint-venture agreements with their Chinese partners. All have had a long history of working in China and argued that they knew how to manage such relationships. They noted that even more care needs to be taken when they are an equal partner or own a minority stake. Aside from devoting close attention to mechanisms for corporate control, decisionmaking, and dispute resolution in the legal language in the agreement, the foreign companies also had to have good working relationships with their Chinese partner prior to the agreement.

GE's Bolsinger notes that GE has had a history of successful joint ventures in China. Their joint venture with AVIC is the fourth 50/50 joint partnership company for GE Aviation, albeit the first in China. Bolsinger argues that GE's experience and the safeguards it has incorporated into its agreement with AVIC will provide sufficient protection for GE's investment.[32]

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[30] Discussion with Western commercial aviation component manufacturer in China.

[31] Kerry Lynch, "Donnelly Dismisses Concerns of Technology Transfer Risks for Cessna in China," *The Weekly of Business Aviation*, Vol. 94, No. 16, April 23, 2012, p. 1.

[32] "GE's China Avionics Deal: A Q&A with Lorraine Bolsinger," 2011.

Remaining Competitive in the Chinese Market

Component manufacturers underlined the importance of innovation in preventing the emergence of Chinese competitors. We were informed that innovation is key not only in commercial aviation manufacturing, but in all industries in China, as Chinese companies are becoming more and more capable in highly specialized manufacturing processes and in replicating designs. By innovating, foreign companies stay a step ahead of their Chinese competitors. This is especially important in subcomponents where the barriers posed by certification are not as high.

Some of our interlocutors stated that their companies have adopted a corporate strategy of designing products specifically for China. They can no longer get by exporting products designed for Western customers to their Chinese clients, when Chinese clients have unique needs. Bidding to be a supplier for the C919 project is part of this strategy: Winning companies have to design and adapt their products for the new aircraft. A number of companies noted that they were competitive with their Chinese competition even at the lower end of the market. By focusing on quality, improving manufacturing efficiency, and distribution, they have been able to out-compete their Chinese competitors.

CHAPTER FIVE

Performance of the Chinese and U.S. Aircraft Manufacturing Industries

In this chapter, we describe key characteristics of the Chinese and U.S. aircraft manufacturing industries. For each industry, we track changes in output, employment, and exports. We also discuss technological capabilities. We discuss manufacturers from other countries as well, especially Airbus, focusing on exports and global market shares. We conclude with a comparative assessment of the Chinese and U.S. industries.

China's Industry

Output

As shown in Table 2.3 in Chapter Two, the output of China's civil aviation manufacturing industry rose 134 percent in 2005 dollars between 2005 and 2010, albeit with fluctuations from year to year.[1] Despite the large increase, output of the civil aviation manufacturing industry did not keep pace with the overall rate of growth in industrial output. Consequently, the share of civil aviation manufacturing in total industrial output actually fell over this period, from 0.22 percent in 2005 to 0.17 percent in 2010.

Exports

Exports of civil aviation products also rose between 2005 and 2010, climbing 52 percent. Compared to civil aircraft manufacturing in other countries, the share of exports in total sales in the Chinese industry has been low, running between 13 and 21 percent of total output. In most countries with a substantial civil aviation manufacturing industry, exports account for a much higher share of output. For example, in the United States, aerospace exports, civilian and military, accounted for 46 percent of industry shipments in 2010.[2]

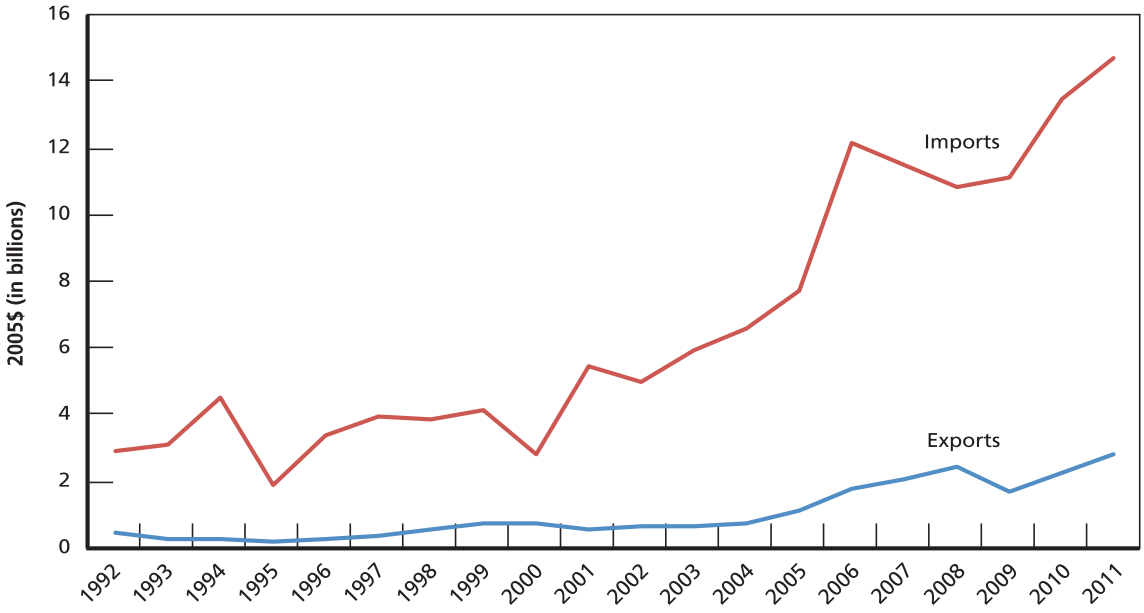
Figure 5.1 shows data from the United Nations' Comtrade database on China's exports and imports of commercial aviation products over the past 20 years.[3] As can be seen, between 1992 and 2011, the value of Chinese exports of aircraft and associated manufacturing parts in 2005 U.S. dollars increased from $300 million to $2.5 billion. These figures are somewhat larger than the figures reported in the *China Civil Aviation Industrial Statistical Yearbook*,

[1] The civil aviation manufacturing industry includes commercial aviation manufacturing industry (aircraft sold for commercial use, i.e., aircraft used to fly passengers who purchase tickets) and the general aviation manufacturing industry (smaller aircraft sold for private use or other general uses).

[2] International Trade Administration, "Key U.S. Aerospace Statistics," June 20, 2011.

[3] United Nations, *UN Comtrade Database*, web page, undated.

Figure 5.1
Chinese Imports and Exports of All Aircraft and Associated Parts, 1990–2011



SOURCE: United Nations, undated.
RAND *RR245-5.1*

probably because of differences in coverage: Some of the aircraft and aircraft components in the UN data may be for Chinese military aircraft. Nonetheless, through 2011, the role of China's aviation manufacturing industry in the world export market remained small (Figure 5.2). Between 1992 and 2011, China's share of global exports of aircraft and aviation components rose modestly, from less than 1.0 percent in 1992 to 1.3 percent by 2011.

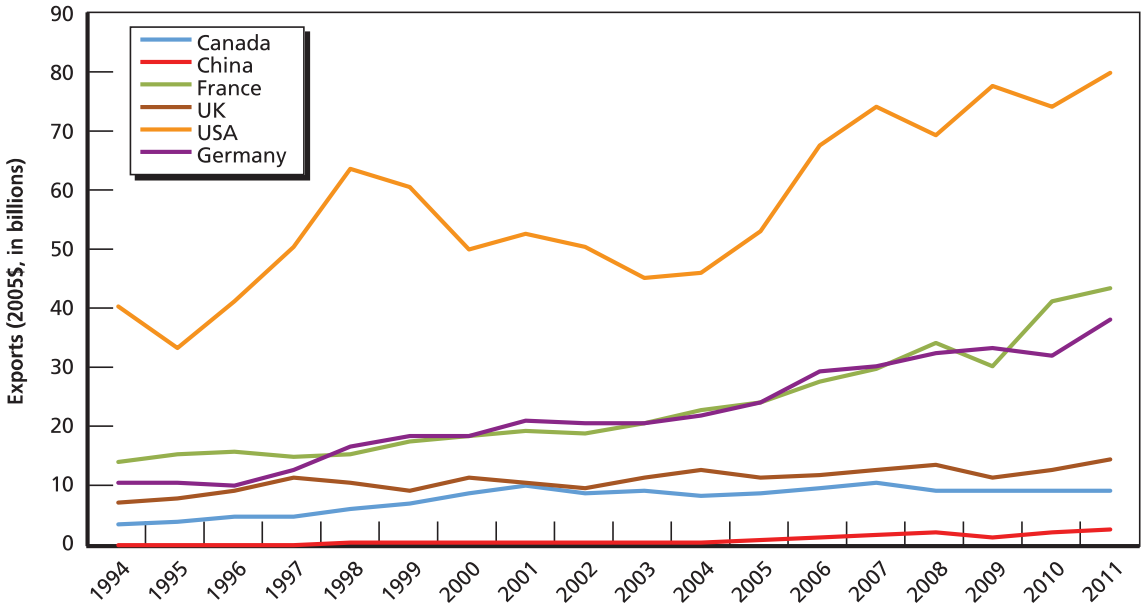
Employment

China employed 234,390 people in civil aviation manufacturing in 2005, and 254,844 in 2010.[4] Output rose 72 percent (as measured in constant price renminbi of 2005), while employment was up just 9 percent; thus, productivity has increased sharply, up 58 percent over the period, an average annual rate of increase of 9.6 percent. In 2010, AVIC employed most of the people in the industry—209,836, or 82 percent of the industry total.

Despite the increase in productivity over this period, China's workers are still much less productive than U.S. employees. The United States employed 477,100 workers in 2010 to generate $171.2 billion in output in the aviation manufacturing industry, or $358,800 per worker. The Chinese civil aviation industry employed 254,844 workers to generate $10.5 billion in output, or $41,200 per worker. In other words, the U.S. industry generated nine times more output per worker. China's statistics on employment in civil aviation manufacturing and U.S. statistics on employment in the aerospace industry are not completely analogous: the U.S. figures include employment in space and military aerospace manufacturing while the Chinese figures do not. Nonetheless, the difference in output per worker is illuminating.

[4] *China Civil Aviation Industrial Statistical Yearbook*, 2007–2011.

Figure 5.2
China and Top Five Exporters of All Aircraft and Associated Parts, 1990–2011



SOURCE: Authors' calculations based on data from United Nations, undated.
RAND *RR245-5.2*

Imports

In contrast to the small role China plays in the global commercial aviation export market, it is a very important market in terms of imports. China's imports rose from about $3–4 billion annually in 2005 dollars in the 1990s to more than $14 billion in 2005 dollars in 2011. In 1992, China's share of global imports of civil aviation products was 3.5 percent; by 2011 it had risen to 6.7 percent. China has emerged as the second-largest market for commercial aircraft in the world, following the United States.

Technology

Because technologies tend to be proprietary in more market-oriented economies, technological capabilities are driven by firms, not nations. Outside of military technologies, corporations are free to use their technologies in all of their global operations. As companies—especially larger, more technologically sophisticated companies—have become more international, it is increasingly difficult to assign a technology to a specific country. For example, although Siemens is headquartered in Munich, Germany, the technologies it employs in the medical devices, controls, and power plant equipment it sells have been developed in the R&D centers and production facilities it owns throughout the world. In this context, it is misleading to describe the technologies developed by Siemens as "German" technologies. The same argument holds for Nokia, Samsung, Honda, and Apple. It also holds for aircraft manufacturers. Although the corporate headquarters of these companies are located in a specific country and the governments of the countries in which they operate have some legal control over the transfer of the technologies they develop, assigning geographic origins to the technologies they employ and

sell is misleading. Thus, in market economies, assessments of technological capabilities focus on firms, not countries.[5]

In China, the state takes a more proprietary interest in technologies. The Chinese government sets goals for the acquisition of technological capabilities by Chinese firms, especially state-owned or state-controlled companies. Because of the dominance of state-owned enterprises in the aviation manufacturing industry in China and the deep involvement of the Chinese government and the Chinese Communist Party in selecting the management, directing and financing investments, and financing and controlling technologies developed by state-owned firms, it is useful to distinguish between "Chinese" technological capabilities (i.e., the technological capabilities of Chinese state-owned or state-controlled firms) from the technological capabilities of operations of foreign companies located in China. The American Chamber of Commerce in South China notes that, as opposed to other major countries, even if a company is incorporated in China, if it is not controlled by Chinese shareholders, the Chinese government does not consider it a domestic firm and does not treat it as such. Foreign-controlled firms, even if incorporated in China, face discrimination in terms of bidding and contracts. These protectionist policies have been a major concern for foreign investors in China.[6]

The technological capabilities of Chinese and foreign commercial aviation manufacturers have been quite different. According to managers of foreign aviation manufacturing companies with operations in China, AVIC subsidiaries have mastered a number of sophisticated industrial process technologies, such as intricate machining and working with composites. The production of parts and modules for the foreign aircraft industry has contributed to elevating industrial capabilities of AVIC's subsidiaries, helping them acquire relatively advanced manufacturing technologies, establish improved quality assurance systems, and adopt better management practices. For example, COMAC has benefited from the knowledge gained by Chinese managers and employees formerly employed in Airbus's joint venture in Tianjin. These individuals have been able to transfer lessons learned concerning final assembly from working in the joint venture.[7] Substantial investments in machinery and materials manufacturing financed by the Chinese state have contributed to the acquisition of these skills.

However, AVIC subsidiaries still face deficiencies in some technologies. China has not yet fully mastered manufacturing jet engines, especially the blades.[8] It has also had problems producing very high-quality materials, like aluminum needed to manufacture airframes.[9] The Chinese industry is also deficient in systems integration: designing and assembling a flightworthy aircraft. The difficulties that AVIC and COMAC have experienced with the ARJ-21

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[5] It is true that many industries tend to develop in clusters, the most frequently cited example being the information technology industry in Silicon Valley. However, technologies developed in clusters are still proprietary. Moreover, most large multinationals site R&D operations in more than one of the major geographical clusters characteristic of their industry. For example, Intel conducts R&D in information technology clusters in France, Israel, Romania, Russia, and China. Intel, "Research and Development Centers," web page, undated.

[6] American Chamber of Commerce in South China, *2012 Special Report on State of Business in South China*, Guangzhou: The American Chamber of Commerce in South China, 2012, p. 32.

[7] Discussion with Western commercial aviation component manufacturer in China.

[8] Gabe Collins and Andrew Erickson, "Is China About to Get Its Military Jet Engine Program Off the Ground?" *Wall Street Journal China*, May 14, 2012.

[9] Bradley Perrett, "Aleris Expands Aerospace Aluminum Sphere To China," *Aviation Week and Space Technology*, May 27, 2013a, p. 37.

is evidence of this problem; the ongoing problems with the design and assembly of the C919 show that these problems have not yet been overcome. In addition, although exports have grown, Chinese companies (AVIC's subsidiaries in particular) have not yet become major suppliers of certified materials for the global aviation industry, although they are making inroads into the global market for components.

In contrast, the subsidiaries of multinationals have access to the range of proprietary technologies and know-how of the parent firm. To the extent the parent company is willing (and legally permitted) to bring a manufacturing or product technology to China, subsidiaries have been able to utilize the technology or manufacture the new product. Given the design, time, and production equipment, subsidiaries face few if any barriers to manufacturing sophisticated products. However, decisions to bring advanced proprietary production processes to China and share corporate technologies and know-how with Chinese staff are made at the corporate level. We were informed by many of the experts with whom we met in the course of this research that these decisions are made with the knowledge of the potential threat posed to intellectual property by bringing it to China. Export controls on dual-use technologies also limit what can be manufactured in these plants.

Joint ventures operate in an in-between space. Key parts of joint venture agreements often include stipulations on technologies provided to the joint venture, including ownership and use of transferred and new intellectual property rights by the venture. Our interlocutors all agreed that given the necessary information, time, and investment, their joint ventures would be able to master virtually all the technologies involved in manufacturing their products. The key constraint on technological transfer is the willingness of the foreign partner to share technologies.

The U.S. Industry

One of the questions this study attempts to answer is whether and how the rise of China's commercial aviation manufacturing industry has affected or is likely to affect the U.S. commercial aviation manufacturing industry. We have collected and analyzed some descriptive statistics concerning the U.S. industry to shed light on this question.

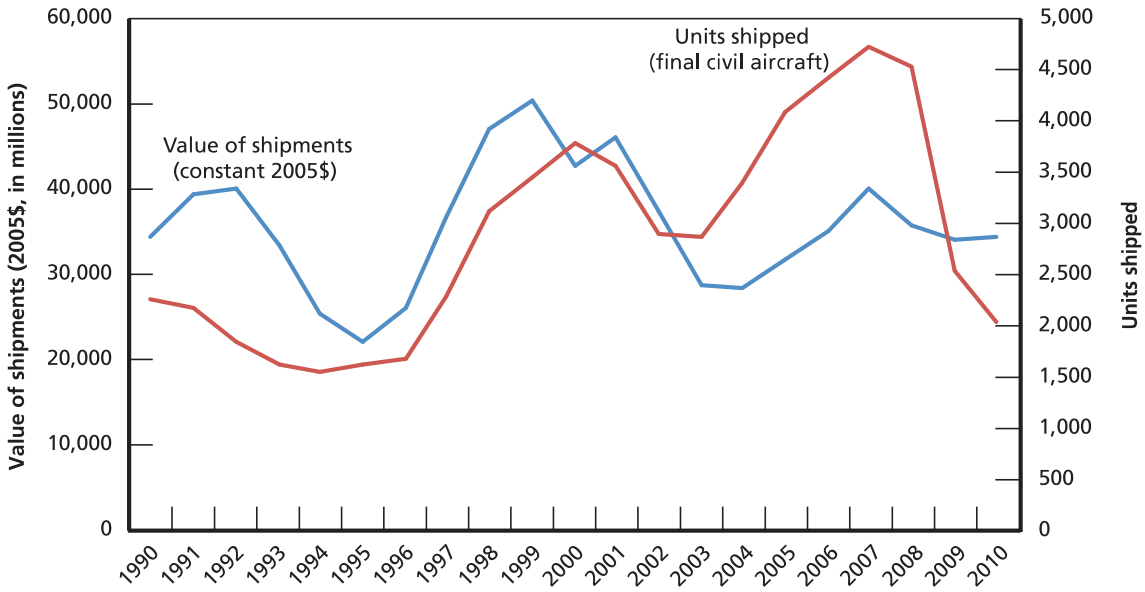
Output

The aviation manufacturing industry plays a much more important role in U.S. manufacturing than it does in China (Figures 5.3 and 5.4). In 2010, shipments of aircraft and parts totaled $132.7 billion in 2005 dollars and accounted for 3 percent of U.S. manufacturing output, compared to the less than 0.2 percent of China's industrial output generated by its civil aviation industry. This comparison is not apples to apples, as the U.S. figures include military aircraft and parts, whereas the Chinese figures include civilian aviation only. However, in 2007, a year for which we do have data, the output of the U.S. civil aviation industry generated $71.5 billion in output, equivalent to 1.4 percent of total U.S. manufacturing output in that year, several times more than the industry contributes to industrial output in China.[10]

Figure 5.3 shows the value of U.S. shipments of civil aircraft (excluding components and parts) in 2005 dollars and the total number of units shipped for the years 1990 through 2010.

[10] U.S. Department of Transportation, Federal Aviation Administration, *The Economic Impact of Civil Aviation on the U.S. Economy*, Washington, D.C., December 2009, p. 27.

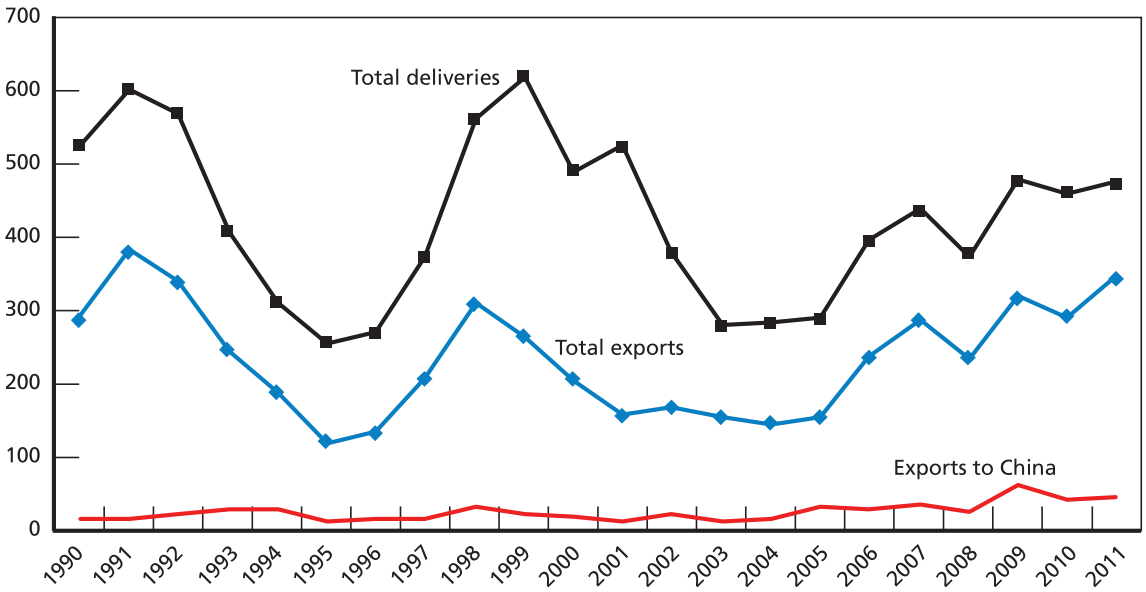
Figure 5.3
Shipments of Complete Civil Aircraft and Value of Shipments of Complete Civil Aircraft for the United States, 1990–2010



SOURCE: Authors' calculations based on ITA data. International Trade Administration, *Shipments of Complete U.S. Aircraft, 1971–2010*, undated.

RAND *RR245-5.3*

Figure 5.4
Boeing Deliveries and Exports



SOURCE: Based on authors' calculations using Boeing delivery data from January 1, 1990 through August 31, 2012 from Boeing, "Orders and Deliveries," undated.

RAND *RR245-5.4*

Despite the importance of aviation for U.S. manufacturing, the industry has not enjoyed steady growth. The value of shipments in 2010 was almost identical to that in 1990 in constant dollars, with sharp fluctuations in the intervening two decades. Shipments slumped in 1993 and 1994, then peaked between 1996 and 1999, falling sharply after September 11, 2001. The story is the same when looking at the entire aircraft and aircraft parts industry, military as well as civil. In 2010, shipments in 2005 dollars were the same as in 1990. This contrasts with an increase in gross manufacturing output in the United States of 50 percent over this same period.[11]

Unit deliveries (the red line in Figure 5.3) have been even more volatile than the value of shipments. The numbers of aircraft shipped are driven by the general aviation industry: As can be seen in Figure 5.4, Boeing has delivered 600 aircraft in a very good year; a more normal level of production ranges between 400 and 500 aircraft a year. Thus, most of the 2,000 to 5,000 units shipped annually consist of smaller airplanes and jets sold to private purchasers or for general aviation. The sharp declines in unit sales in 2009 and 2010 stemmed from the collapse in sales of these aircraft during the Great Recession.

Exports

Figure 5.2 shows U.S. exports of aviation products, military as well as civil, in the context of global trade in this category. As can be seen, the United States is the dominant exporter, although in aggregate the EU is now larger, accounting for more than 44 percent of world exports compared to the United States' 37 percent. In contrast to the absence of long-term growth in total output, exports have risen sharply over the last two decades, up from $40 billion 2005 dollars in 1994 to more than $80 billion 2005 dollars in 2011. Not only is the United States the world's largest exporter in this category, it runs a large trade surplus, the largest surplus of any U.S. manufacturing industry.[12]

Although U.S. aviation component manufacturers contribute to these exports and surplus, Boeing is the single largest source. Exports have been crucial for Boeing's business. The share of Boeing aircraft that is exported has trended upward, especially after the U.S. airline industry fell on hard times following September 11, 2001. In 1990, 56 percent of Boeing commercial aircraft were exported; in 2011, 73 percent were.[13]

China has been an important market for Boeing. As shown in Figure 5.4, the share of Boeing's aircraft exports headed to Chinese airlines (excluding Hong Kong-owned airline Cathay Pacific) has increased from 5 percent in 1990 to 14 percent in 2011. In 2005 and 2009, it ran 20 percent.[14]

Employment

Figure 5.5 shows total employment and employment of production workers in the aerospace industry in the United States between 1989 and 2010. As can be seen, total employment

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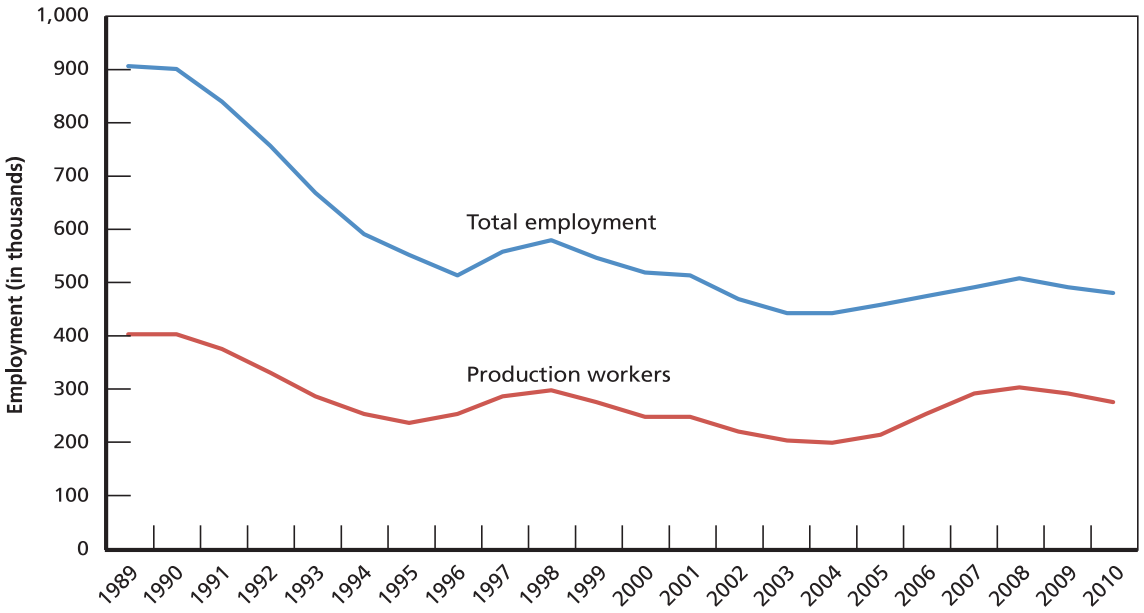
[11] Calculated from Council of Economic Advisers, *Economic Report of the President, 2012*, Washington, D.C., 2012, Table B-51. Industrial output indexes for 1990 to 1995 and from 2005 to 2010 were averaged, and the percentage change for the two periods was calculated.

[12] International Trade Administration, 2010.

[13] Percentages calculated from Boeing delivery data from January 1, 1990 through August 31, 2012, from Boeing, "Order and Deliveries," undated.

[14] Based on authors' calculations using Boeing delivery data from January 1, 1990 through August 31, 2012, from Boeing, 2013.

Figure 5.5
U.S. Aerospace Industry Employment, 1989–2010



SOURCE: Authors' calculations based on ITA data.
RAND *RR245-5.5*

dropped sharply over these two decades; by 2010, total employment had almost halved compared to 1989. The decline in production workers was more modest, falling from about 400,000 in 1989 to a little less than 300,000 in 2010. Total employment fell most sharply between 1990 and 1996, after the fall of the Berlin Wall and the subsequent post–Cold War reductions in U.S. military procurement. During this period, most of the reductions in employment were associated with declines in the production of military aircraft, not civil aviation. However, commercial aviation employment has also experienced declines over the last two decades. For example, Boeing in 2012 employed 4,050 machinists in its Renton, Wash., plant; that number was 6,022 in July 2001.[15] Steady improvements in productivity over this period have contributed to these declines in overall employment. At Boeing, outsourcing also appears to have played a role. Increased imports of components have reduced demand for U.S. labor.

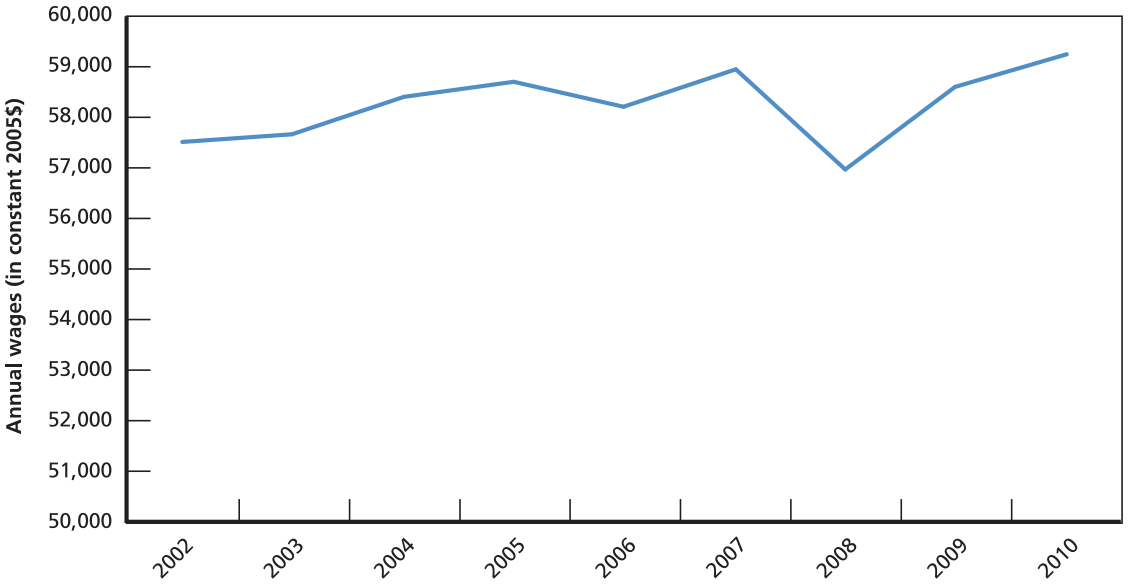
Figure 5.6 shows average wages in the aerospace industry over the last decade. Reflecting the tough labor market conditions, similar to much of the rest of U.S. manufacturing, wages have grown modestly over the last decade; they experienced a dip in 2008 and 2009 during the deepest part of the Great Recession. However, the graph also illustrates the attractiveness of the industry as a source of jobs, as average wages are substantially higher than in many other U.S. industries.

Technology

As already argued, it is more appropriate to judge technological capabilities in integrated, global industries at the company level than the national level. All the major manufactur-

[15] Allison Linn, "Hundreds of Suppliers, One Boeing 737 Airplane," NBC News, April 28, 2012.

Figure 5.6
U.S. Aerospace Industry Mean Annual Wages, 2002–2010



SOURCE: Authors' calculations based on data from Bureau of Labor Statistics, "Occupational Employment Statistics" web page, May 2010.
RAND *RR245-5.6*

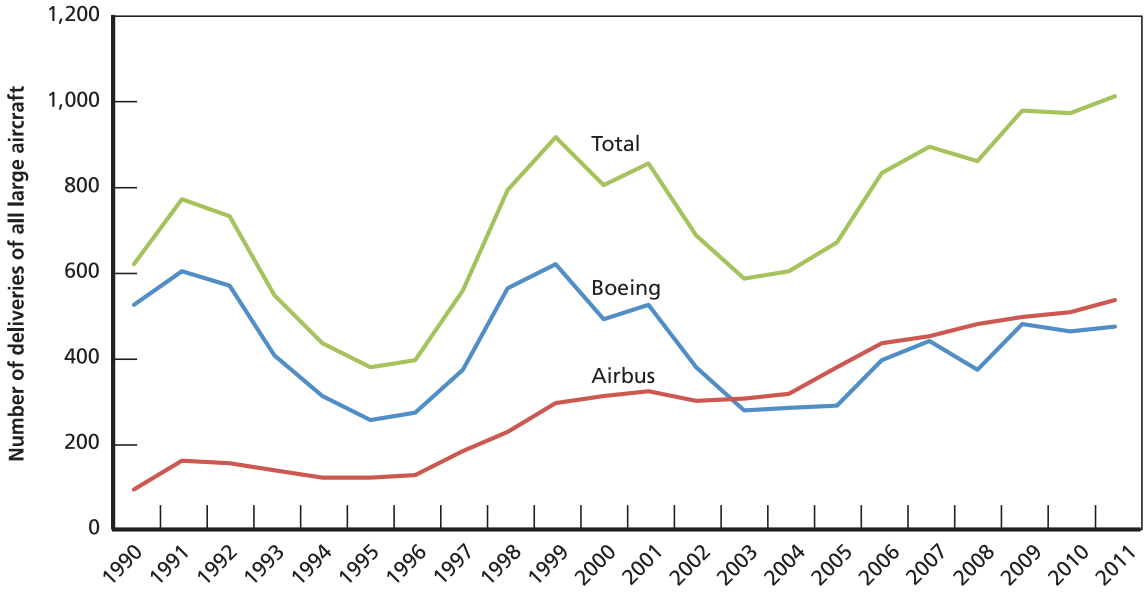
ers of commercial aircraft and aircraft components are multinational, with plants located in several countries. To ascribe the technological successes of these companies to a single location or country ignores how these companies conduct their product development activities, which tend to be integrated efforts involving personnel, design facilities, and plants that span the company's operations. Although one may quibble about which company's products are the most technologically sophisticated, the market success of companies headquartered in the United States attests to their technological competitiveness. GE and Pratt & Whitney are two of the most successful jet engine manufacturers. Despite the teething problems of Boeing's 787, the plane is recognized as having made a technological leap. Companies headquartered in the United States remain at the forefront of the global industry.

Competitive Position of the U.S. Industry

Despite the strong technological position of U.S. aircraft product manufacturers, and despite the prominence of the industry, the U.S. aviation manufacturing industry has not done well over the past two decades as measured by output and employment. The post–Cold War declines in demand for military aircraft are one reason for the initial declines in output in the industry; the fall in demand for general aviation aircraft is another. However, the inroads Airbus has made in the world commercial aviation market have also been an important factor. Since 2003, Boeing's global market share has fallen to less than 50 percent from 85 percent in 1990 (Figure 5.7).[16] Airbus delivered more aircraft than Boeing between 2003 and 2011. Only in 2012 did

[16] Based on authors' calculations using downloadable data from Boeing's and Airbus' websites. This calculation assumes Boeing and Airbus compete only with each other in the market for large aircraft.

Figure 5.7
Global Production of Commercial Aircraft, 1990–2011



SOURCE: Authors' calculations using downloadable data from Boeing's and Airbus' websites.
RAND *RR245-5.7*

Boeing once again overtake Airbus as the world's largest supplier of aircraft; for the first time in many years, Boeing also overtook Airbus in the number of new orders received.[17] Part of the decline in Boeing's global market share is due to declines in purchases of aircraft in the U.S. market, historically, the world's largest, which Boeing has dominated. Inroads by Airbus into the U.S. domestic market have also been a factor.

Nonetheless, the U.S. commercial aviation manufacturing industry remains highly competitive. Although prominent companies such as Airbus Group, Rolls Royce, and Liebherr are headquartered in Europe, most major companies in the industry are headquartered in the United States. As shown in Figure 5.2, U.S. exports of aircraft and aircraft components have grown substantially, doubling over the course of the last two decades, and the United States remains the largest exporter of aircraft and aircraft components.

[17] Rich Smith, "Airbus Announces Final 2012 Airplane Order Tally," The Motley Fool, January 17, 2013.

CHAPTER SIX

Net Assessment of the Effectiveness of China's Industrial Policies for Commercial Aviation Manufacturing

As described in Chapter Three, the Chinese government is making a concerted effort to create a commercial aviation manufacturing industry that will be competitive with Airbus and Boeing. In this chapter, we evaluate the likely effectiveness of China's industrial policies in pursuit of this goal. We first review the successes and failures of the Chinese policy of creating national champions in three other high-technology industries: high-speed trains, wind power, and automobiles. We then discuss the characteristics of commercial aviation manufacturing that may serve to protect foreign incumbents, contrasting commercial aviation with other high-technology industries where China has enjoyed more success in expanding output, domestic market share, and exports. We then evaluate the respective strengths and weaknesses of China and foreign incumbents in the various factors that are likely to determine the success of a Chinese industry: technology, labor and management, finance, and marketing. We conclude with a net assessment of the success of China's industrial policies in commercial aviation manufacturing and the effectiveness of the strategies pursued by foreign manufacturers as they seek to expand sales while protecting core technologies and market shares.

Are Chinese Industrial Policies Likely to Be as Effective in the Commercial Aviation Manufacturing Industry as in Other Industries?

As shown by the statistics in Chapter Five, the Chinese commercial aviation manufacturing industry has yet to make serious inroads into the global aviation industry, although it has enjoyed solid growth and improved process technologies. Will Chinese commercial aviation manufacturers be more successful in the coming decade, or will the ambitions of AVIC and COMAC founder? To investigate potential trends in the Chinese industry, we assess the effectiveness of China's industrial policies in three high-technology industries that the Chinese government has emphasized over the past two decades. We then contrast the specific features of these industries with those of the global aviation manufacturing industry to ascertain the likely success of China's policies in that industry.

High-Speed Trains

Since China opened its first high-speed rail line in 2007, it has built a network of 9,300 kilometers, the longest in the world. The Chinese government plans to expand the network to 25,000 kilometers by 2020, at a total cost of $300 billion. This program has made China the world's

largest market for high-speed trains.[1] This program began in 2004, when China's Ministry of Railways solicited bids for 200 high-speed trains. Four companies—a Japanese consortium led by Kawasaki Heavy Industries, Alstom, Siemens, and Bombardier—responded to the tender, recognizing that China would be the largest market by far for high-speed trains for the foreseeable future. Winning firms were required to have a local Chinese partner to manufacture trains in China. All of the bidders received a portion of the contract except Siemens, with the Japanese consortium receiving the largest portion, consisting of 480 cars arranged in 60 eight-car trains, of which three were directly imported from Japan, six were assembled from kits by CSR Sifang Locomotive (the consortium's partner), and the remaining 51 were to be manufactured in China using technology transferred from the Kawasaki consortium and incorporating Chinese and imported parts.[2]

Within a few years the partnerships fell apart. China did not purchase all the 200 trains in the tender; the Chinese partners now manufacture their own trains. Foreign companies allege that their technologies have been stolen and that they have been shut out of contracts by the state-owned purchasers, China's state-owned railroads. The Chinese state-owned manufacturers insist their trains are of Chinese design and not based on foreign intellectual property. CSR Sifang Locomotive claims that within two years of partnering with Kawasaki, it had "digested" all the technology required to manufacture the trains on its own. It has gone on to claim that it subsequently improved the design so much that its current product has "nothing at all to do with *Shinkansen*"—even if the trains look identical to the Japanese design. Representatives from the Kawasaki consortium say 98 percent of the technology and designs used in the Chinese trains are Japanese. The Kawasaki consortium management feels it has little recourse. According to an outside observer, ". . . they know well it would be a waste of time and money to fight the Chinese government."[3]

Wind-Power Generation

China became the world's largest manufacturer of wind turbines in 2009 and has maintained that position. Yet, as late as 2005, China was not a major player in the industry. In that year, China passed the National Renewable Energy Law, which provided a number of subsidies and other forms of government support for the industry.[4] China also designated wind turbines as a strategic industry. By 2012, China had installed 15.9 gigawatts of wind-power capacity, the largest increase in installed capacity in the world, followed by the United States. Almost all the units installed in China in 2012 were manufactured by domestic companies, not joint ventures.[5]

The Chinese government has relied on a combination of domestic subsidies, licensing agreements, acquisitions of foreign companies, and joint ventures with established foreign

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1 Steven Jiang, "China's High-Speed Trains Attract Frustrated Fliers," CNN, April 12, 2013.

2 Szamosszegi and Kyle, 2011, pp. 67–70.

3 Mure Dickie, "Japan Inc. Shoots Itself in Foot on Bullet Train," *Financial Times*, July 9, 2010, p. 14.

4 Joanna Lewis, "Building a National Wind Turbine Industry: Experiences from China, India and South Korea," *International Journal of Technology and Globalisation*, Vol. 5, Nos. 3/4, 2011, pp. 281–305.

5 Feifei Shen, "China Had 35 percent of Onshore Wind Capacity Last Year, BNEF Says," *Bloomberg News*, February 3, 2013.

manufacturers to develop the industry.[6] As in the United States and the EU, wind power in China is still only competitive if power generators receive subsidies or face renewable energy mandates. In China, wind developers receive subsidies from the Special Fund for Wind Power Manufacturing.[7] The subsidies have been contingent on meeting local content requirements. To benefit from the subsidies, for all intents and purposes, manufacturers must use parts and components made in China rather than abroad. This requirement appears to fall under the category of prohibited subsidies in the Agreement on Subsidies and Countervailing Measures (SCM Agreement) to which China is a party under its obligations under the WTO.[8] Joint ventures involving foreign manufacturers have found that they are unable to benefit from this subsidy while the independent operations of their Chinese partners have.

Joint ventures with foreign manufacturers have been an important source of technologies for their Chinese partners. American Superconductor Corporation (ASC) accuses Sinovel, its former joint venture partner and now one of China's three largest wind turbine manufacturers, of stealing its technologies. ASC and Sinovel fell out in 2011, when Sinovel abruptly refused shipments of ASC's wind turbine electrical systems and control software. ASC later discovered that one of its employees was given a $1.5 million bribe by Sinovel to share key technology secrets. The employee confessed to the crime and is now serving time in a U.S. prison. ASC alleges that 70 percent of its business evaporated due to the theft of its intellectual property by Sinovel, as well as Chinese government policies favoring Chinese domestic suppliers, as opposed to joint ventures. For its part, Sinovel claims it stopped accepting components from ASC because of quality problems and has launched a countersuit.[9] However, quality problems appear to plague Chinese manufacturers rather than the products of their foreign counterparts.

According to Thomas F. Holt Jr., who teaches international intellectual property law at Tufts University's Fletcher School of Law and Diplomacy, this case underscores the importance for companies investing in China of protecting their intellectual property. He notes:

> Chinese companies, once they acquire the needed technology, will often abandon their Western partners on the pretext the technology or product failed to meet Chinese governmental regulations. This is yet another example of a Chinese industrial policy aimed at procuring, by virtually any means, technology in order to provide Chinese domestic industries with a competitive advantage.[10]

Automobile Manufacturing

China became the world's largest market for new car sales by volume in 2009.[11] The size and growth of China's domestic automobile market makes it highly attractive for foreign automotive manufacturers. However, to sell profitably into this market in volume, manufacturers need

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6 Lewis, 2011.

7 U.S. Trade Representative, "United States Requests WTO Dispute Settlement Consultations on China's Subsidies for Wind Power Equipment Manufacturers," press release, December 2010.

8 European Commission, Trade Directorate, "Countries and Regions: China" May 29, 2013.

9 Jonathan Weisman, "Xi to Get an Education in Trade-Secret Theft; Wind Turbine Company Foundered After Worker Sold Its Secrets to China," *International Herald Tribune*, February 16, 2012.

10 Erin Ailworth, "Data Theft Case May Test US, China Ties," *Boston Globe*, September 19, 2011.

11 Mark Mobius, "Personal Wealth: Exciting Times for China's Auto Industry," *The Edge Singapore*, July 23, 2012.

to set up assembly operations in China. To do so, the Chinese government requires foreign automakers to have a Chinese joint venture partner that holds at least 50 percent of the equity in the assembly operation.[12] Despite this stipulation, virtually every established automobile manufacturer from the United States, Europe, and Japan has set up a joint venture to manufacture cars in China.

The Chinese government has implemented a number of other policies to bolster domestic manufacturers. The Chinese government has recently attempted to restrict purchases of vehicles by government agencies to domestic Chinese models. This regulation has been hotly contested by Volkswagen, whose Audi subsidiary has successfully sold a substantial number of vehicles to Chinese government agencies.[13] The Chinese government has also attempted to increase sales of electric and hybrid vehicles, to reduce greenhouse gas emissions. To do so, it offers a subsidy of up to $19,300 per car, but has restricted the subsidies to vehicles manufactured by Chinese companies. When General Motors made plans to import its U.S.-manufactured Chevrolet Volt hybrid car, the Chinese government pressured General Motors to share its technology as a pre-condition for qualifying for the subsidy.[14]

In the case of the automotive industry, Chinese industrial policies have not yet led to the emergence of strong Chinese national champions. Over the course of the last decade, domestic models have lost ground to models manufactured by joint ventures that continue to dominate the Chinese market.[15] Foreign firms have seen their joint venture partners acquire the technologies and know-how to manufacture modern vehicles. In 2006, the Shanghai Automotive Industry Corporation (the longtime Chinese partner of General Motors and Volkswagen) set up a wholly owned subsidiary, SAIC Motor, to build and independently market its own cars.[16] Although some joint venture partners manufacture their own products, like SAIC Motor, most rely on production from their joint ventures and have very small shares of the Chinese market for their own domestic brands. These joint-venture partners would be hard pressed to develop models on their own that would be competitive with those of their foreign partners. Chinese consumers still prefer foreign brands because of their better reputations for reliability, performance, and prestige, so most executives of Chinese joint-venture partners have focused their energy on maximizing sales of foreign brands and increasing profits rather than on Chinese designs and brand development. In short, Chinese industrial policies to foster the production of motor vehicles in China have been successful insofar as joint ventures have dramatically increased production. However, those policies do not appear to have been successful in fostering the growth of a purely domestic industry.

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[12] Keith Bradsher, "China Automaker Sets Out on Its Own: GM and Volkswagen Find Their Partner Plans to Build Itself into a Competitor," *International Herald Tribune*, April 11, 2006, p. 1.

[13] "Audi-Led Global Carmakers May Be Shut Out of China's Fleet," *Bloomberg News*, February 27, 2012.

[14] Keith Bradsher, "China Seeks Trade-Off for Entry of GM Hybrid Car: Automaker Pressured to Share Its Technology in Exchange for Subsidies," *International Herald Tribune*, September 7, 2011, Finance section, p. 1.

[15] Patti Waldmeir, "Auto Industry: Carmakers Compete in a Crowded Market," *Financial Times*, December 11, 2012.

[16] Bradsher, 2006.

Lessons from These Three Sectors

In all three of these industries, partnerships or joint ventures have been used as steps to create Chinese national champions. The success with which partnerships or joint ventures have been used in these three industries has varied. In the case of high-speed trains and wind turbines, Chinese firms now dominate the domestic market. In the case of the automobile industry, not only do foreign brands account for the vast majority of sales, but their share of the market has increased over the last several years.

Industry structure appears to be an important factor affecting the success of China's policies to create national champions in strategic industries. In industries where state-owned enterprises are the purchasers and Chinese government policies drive purchases (as in the case of wind-power generation) or where the state-owned purchaser provides a monopoly service (as in the railway sector), the Chinese government has been able to induce firms to buy products manufactured by Chinese companies, even when products are available from joint ventures with foreign manufacturers. The state-owned purchasers have not been concerned about disputes about ownership of the technologies underlying these products.

In contrast, the automobile industry sells to Chinese consumers who are free to choose which vehicle they prefer. In this industry, foreign brands manufactured by joint ventures continue to dominate the market. For a variety of reasons, foreign partners in the automotive industry have been better able to control their intellectual property than those for wind power and high-speed rail. One, they have well-known brands with reputations for safety and reliability, which Chinese brands have yet to achieve. Two, they have built dealership networks and invested in marketing in China, solidifying their position in the market. Three, they are able to spread research and development costs over their global operations, reducing the cost per vehicle of developing new models. Four, in many ways, a joint partner with a foreign automotive firm has an easier time than a Chinese outfit trying to sell vehicles on its own.

The commercial aviation manufacturing industry falls somewhere between these two examples. The Chinese government influences the choice of aircraft purchased by China's state-owned airlines. The CEOs of these airlines are selected by the government. However, government pressure is only one influence on purchase decisions by these executives. Chinese airlines have to compete with each other; they sell airplane tickets directly to consumers. They are highly conscious of the need to keep their aircraft flying and to assure their customers their planes are safe. Although the CEOs of these airlines are cognizant of government desires for them to purchase aircraft manufactured by COMAC, they are also well aware that their own careers depend on ensuring that their airlines operate safely and profitably. Because of its dated design, the C919 will be more expensive to operate than next-generation Boeing and Airbus narrow-body aircraft. These differences in operating costs will directly affect the airlines' profitability. As noted by one of our interlocutors, the CEOs of the three main state-owned airlines will continue to purchase aircraft that ensure the continued success of their operations, regardless of pressure to purchase Chinese products.[17]

[17] Interview in China with expert on Chinese airline industry.

Strengths and Weaknesses of China's Industry and Its Foreign Competitors

Manufacturing commercial aircraft, the goal of China's industry, is a complex operation. The two remaining global competitors in this industry, Boeing and Airbus, have had to master sophisticated, cutting-edge manufacturing technologies, manage complicated design and development programs, attract and retain the skilled labor needed to build and design aircraft, arrange the funding needed to finance these programs, marshal the finance needed to sell these expensive machines, and set up and operate a worldwide service and support network to ensure that if mechanical problems occur, planes can be quickly repaired. Below, we contrast China's strengths and weaknesses in these areas with those of the established manufacturers.

Technologies

China

Strengths

Managers of foreign companies in the aircraft manufacturing industry with operations in China stated that their Chinese suppliers have become increasingly proficient at process technologies. Chinese companies have mastered the highly technical machining needed for gearboxes and other complicated metal components, and are becoming more proficient at working with composites.[18]

Supplier relationships and joint ventures have helped improve the technological capabilities of Chinese enterprises. Foreign customers of Chinese components have forced Chinese suppliers to become more efficient. In some cases, the foreign purchaser has provided direct assistance in improving manufacturing technologies and quality control. Joint ventures have provided the Chinese partner with opportunities to learn how to efficiently manufacture product lines they had not previously had the capability to produce. Joint ventures have also helped provide the know-how acquired from repeatedly manufacturing the same component and from being forced to meet Western quality standards. In manufacturing joint ventures, the foreign partner typically supplies the production design and management expertise, while the Chinese partner provides the facility and labor. As the Chinese partner gains experience, its engineering and management skills tend to improve. However, joint ventures do not guarantee that the Chinese partner improves its capabilities. The joint venture is often effectively controlled by the foreign partner, which limits the Chinese partner's ability to steer the venture toward product areas that are of interest to the Chinese parent.[19]

The Chinese industry has also acquired new product and process technologies and markets through the acquisition of foreign firms. As noted above, AVIC, with the assistance of the Chinese government, has embarked on an ambitious program of developing China's general aviation (private aircraft) manufacturing capabilities through its subsidiary, CAIGA. Through CAIGA's acquisition of Cirrus, CAIGA has gained access to Cirrus's manufacturing technology and R&D capabilities for general aviation. CAIGA is also setting up an assembly plant for Cessna's Citation jet in Guangdong. CAIGA is intent on learning manufacturing technologies associated with assembling the Citation and bringing an increasing share of the assembly work to China. Cessna's interest in the joint venture is driven in part by the potential of AVIC to

[18] Interviews in China with Western aviation component manufacturers.

[19] Cliff et al., 2011, p. 36.

assist in inducing regulatory changes in China concerning use of airspace and flight notification times that would make purchases of corporate jets more attractive in China.[20]

Weaknesses

As noted, China has yet to master some key advanced technologies, like those used to manufacture jet turbine blades. Consequently, it has yet to develop and manufacture major subsystems for commercial aircraft, such as engines and avionics. For the time being, these will have to be imported.

Because of the stresses to which aircraft are subject and the premium placed on safety and reliability, the FAA and EASA stipulate that components and the materials from which they are manufactured be tested and certified before being used. Entry into the materials business, in particular, is often more difficult than in many other industries because of the technological challenges and costs of manufacturing materials to high standards. For a number of key materials, Chinese aerospace raw material suppliers have not yet been able to produce materials of a quality that could be certified. Chinese aviation component manufacturers face a competitive disadvantage because they must import materials from the same suppliers as their foreign competitors with the attendant shipping costs.

The ARJ-21 is becoming increasingly technologically obsolete because of the difficulties COMAC has had in certifying the plane, and the resulting additional time needed to develop the plane. In the interim, Embraer and Bombardier have introduced more advanced products into the market. Because of these delays, a Chinese industry insider notes, "the ARJ-21 will probably pass the airworthiness certification. But it is difficult to tell whether or not the aircraft will eventually be put into commercial operations."[21]

Because the Chinese government has put a higher priority on technological achievements than on commercial considerations when it comes to national champions, firms have been encouraged to focus on technological achievements over profits. One interlocutor noted that the large, state-owned airlines in China now perform their own maintenance so as to showcase their technological prowess as they compete for governmental approval. Yet, in-house maintenance is often more costly than outsourcing this activity.[22] These additional costs result in lower profits or potentially financial losses.

Foreign Companies

Strengths

Incumbent North American, European, and Japanese suppliers enjoy a strong advantage vis-à-vis potential Chinese competitors, because the materials and components they manufacture have already been certified. To enter the market, Chinese companies have to first go through the certification process and then attempt to edge out foreign suppliers. New entrants have a hard time displacing incumbents on the basis of price because of the premium that purchasers place on quality.

Our interlocutors frankly acknowledged the importance of proprietary technologies to their commercial success. One noted that the survival of his company depended on continually

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[20] Interviews in China with Western aviation product manufacturer.

[21] Zhang, 2012a.

[22] Interview with Western aviation component manufacturer, September 3, 2012.

developing new technologies, to stay on the cutting edge of the industry.[23] Company managers noted that their corporations had developed systems for creating new technologies and incorporating them into new products. These systems were a key feature in their companies' success. They stated that their Chinese competitors were proficient at copying and often improving on existing technologies. But by continually improving their products, their companies have kept their technological edge.

Weaknesses

Certification is not a permanent barrier to entry for competitors. COMAC, for example, is learning how to get through the certification process with both the FAA and the Civil Aviation Administration of China. Once Chinese companies master this process, they will be better placed to develop into global suppliers.

All the managers of foreign companies with whom we spoke were concerned about the theft of their intellectual property. Once technologies have been mastered by Chinese competitors, the companies fear they will lose some of their competitive advantage.

Labor

China

Strengths

All of our interlocutors stated that Chinese machinists and workers in composite materials are proficient. Design and engineering talent were rated highly. Chinese universities and technical schools are turning out substantial numbers of well-trained technicians and engineers.[24]

The Chinese national and provincial governments have played an important role in improving the quality of Chinese engineering and technical schools, providing the necessary funding to create and support the aeronautical engineering and technical programs needed to teach these skills. With the support of AVIC, the Ministry of Education and provincial departments of higher education have improved curricula and set higher standards for students. Institutions of higher education have also improved the quality of their staff, recruiting expatriate Chinese engineers and professors to return to China to teach in these institutions. State support in the form of higher salaries and attractive benefit packages has been important to provide these inducements to attract these individuals.[25]

Weaknesses

Although our interlocutors spoke highly of the manufacturing and engineering skills available in China, they spoke less highly of Chinese project management skills. In particular, they noted that COMAC has been struggling with systems integration in the design of the C919. Interlocutors noted that most of COMAC's design team is younger than 30 and lacks experience with integrating complex systems into an aircraft.[26] The generally hierarchical management style of Chinese state-owned enterprises is also a problem, impeding the cross-communication and delegation of decisionmaking necessary for moving complex projects forward in a timely, thoughtful manner.

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[23] Interview in China with Western aviation component manufacturer.

[24] Interviews in China with Western aviation component manufacturers.

[25] Interviews in China with Chinese and Western aviation industry manufacturers.

[26] Interviews in China with managers of commercial aviation manufacturers.

Deficiencies in corporate and project management impose substantial costs. Our interlocutors noted that resources were being thrown at the C919 program without much regard to efficiency or costs. As aviation analyst Richard Aboulafia states, "China has tremendous resources and tremendous talent but the government-directed technology-copying system produces disaster."[27]

Foreign component manufacturers noted the rising cost of skilled aviation manufacturing technicians and engineers in China. Demand from COMAC has inflated starting salaries for aeronautical engineers, for example. Because of high demand for these skills, labor turnover is often high. Foreign (and Chinese) manufacturers spend considerable effort to retain skilled Chinese labor, as training new staff is expensive.[28] Faced with these increases in wages, AVIC subsidiaries have turned to their foreign clients and requested increases in prices, to which the clients have generally not acquiesced.[29]

Foreign Companies

Strengths

In both the United States and Europe, clusters have emerged where commercial and private aircraft are designed and assembled. These areas (Seattle, Washington; Wichita, Kansas; and Toulouse, France) are now home to large, well-trained labor forces with the skills and experience to manufacture and assemble aircraft with the requisite regard for precision and quality. In addition, local suppliers have emerged in these areas, providing the materials, parts, and support services required by aircraft manufacturers. This co-location of companies, suppliers, and workers provides a competitive edge to manufacturers in these centers, which is difficult for new entrants to overcome.

All of our interlocutors stated that they had a competitive advantage in management. In addition to their ability to manage technological development, the companies are highly proficient at managing their production lines. Long experience with integrating components into modules and designing modules to meet the needs of aircraft manufacturers also provides a competitive edge.

By manufacturing in and designing for China, company managers stated that superior management has made it possible for them to compete with their Chinese counterparts on price, as well as quality and technology. A number of managers stated that they ran their production lines more efficiently than Chinese competitors. One manager stated proudly that in one non-aviation industry, his company has remained competitive with Chinese companies in manufacturing lower-technology products. The company has been better able to control costs and spoilage than its Chinese competitors who manufactured a similar product. In the past, Chinese competitors have been able to manufacture knock-off products more cheaply, although not with the same level of quality.

Weaknesses

Although wages in China have been rising rapidly, European, Japanese, and North American wages for production workers in the aviation manufacturing sector are still substantially higher than for similar Chinese workers. Engineering wages are also lower in China, although the

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[27] Negroni, 2012.

[28] Interviews in China with Western aviation component manufacturers.

[29] Interviews in China with Western aviation component manufacturers.

gap is shrinking, according to our interlocutors. To the extent that manufacturers in China approach productivity and quality levels in foreign plants, foreign manufacturers will face competitive cost pressures from cheaper Chinese labor.

Finance

Developing a new aircraft is expensive. The development by Airbus and Boeing of the A380 and the 787, respectively, ran several billion dollars each. As noted above, initial available financing for the C919 exceeded $7 billion.

China

Strengths

AVIC and COMAC have enjoyed substantial help from China's government in obtaining the financing and resources needed to enter the commercial aviation market. Despite the lack of a track record as a commercial aviation manufacturer, COMAC has not experienced financing constraints, though purchasers reportedly have not made down payments on aircraft orders.[30] Through the use of appropriations from the state budget, equity investments from national and local governments and state-owned enterprises, loans from state-owned banks, retained earnings from non-aviation activities, and land and other assistance provided by local communities, AVIC and COMAC have marshaled the resources needed to design, develop, and invest in new products and manufacturing facilities. In particular, like other state-owned enterprises in strategic industries, COMAC and AVIC have enjoyed preferential access to loans at below-market interest rates from state-owned banks.[31]

China's strategy of providing the necessary resources to create national champions gives state-owned aviation manufacturers the luxury of sufficient time and resources to work through the complexities of developing and manufacturing a new aircraft. Financial support has been—and will be—essential to cover the extended periods of time and provide the resources needed to solve the developmental problems associated with a new aircraft.[32]

Weaknesses

Financial support from the Chinese state is not unlimited. We were told that the ARJ-21 has fallen out of favor and is not receiving similar levels of support as the C919.[33] Engineers and managers have been shifted from the ARJ-21 program to the C919 because of the higher priority ascribed to the C919. As a consequence, fixing the remaining problems on the ARJ-21 that have prevented the plane from being certified as air worthy has lagged.

Foreign Companies

Strengths

Boeing and Airbus Group and all of the Tier One commercial aviation component suppliers are large, financially sound companies. Boeing has been able to raise financing for new product

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[30] Interviews in China with experts on the Chinese aviation manufacturing industry.

[31] Szamosszegi and Kyle, 2011.

[32] Harrison, 2011, p. 4.

[33] Interviews in China with experts on the Chinese aviation manufacturing industry.

developments from retained earnings or commercial lenders. Airbus Group is also able to tap international financial markets, although it has also benefited from state financial support.[34]

The cost of purchasing aircraft is only recouped after many years of operation. These long payback periods have made it necessary for aircraft manufacturers to arrange financing for their customers. Boeing and Airbus are able to arrange financing for purchasers of their aircraft from a wide variety of sources. In addition to commercial lending, both companies are able to tap government-supported export financing institutions like the U.S. Export-Import Bank for loans.

Weaknesses

Aircraft manufacturing is a cyclical business, as shown by the number of deliveries of Boeing aircraft in Figure 5.7. During downturns, manufacturers face severe financial pressures. Moreover, at least for publicly traded companies in the United States, CEOs face strong financial pressures to generate rates of return on capital competitive with other industries. As a result, U.S. aircraft manufacturers face financial pressures that COMAC and AVIC do not. In the case of general aviation, these pressures have resulted in the sale of one manufacturer, Cirrus, to CAIGA and discussions with a Chinese investor to purchase another manufacturer, Hawker-Beechcraft, which went bankrupt.[35]

Marketing

China

Strengths

China has used its diplomatic leverage and state financing to induce a few airlines in developing countries in Southeast Asia to place orders for the ARJ-21. For example, Lao Air has ordered two (Table 3.1).

Weaknesses

New aircraft are purchased by the limited number of airlines or leasing companies with the revenues, financial standing, and experience to obtain the finance needed for these expensive items. Successful aircraft manufacturers have developed marketing departments that are able to spend the time and have the credibility to conclude sales contracts with this limited group of buyers. Setting up such a sales network and establishing the credibility to induce buyers to purchase a new aircraft will take COMAC considerable time to develop.

COMAC also lacks a global logistics network for its new aircraft. This is an especially acute problem in the aircraft industry. Planes are expensive. To make a profit, airlines have to keep their aircraft flying. Manufacturers and suppliers have to ensure that airlines are able to obtain the requisite parts in short order to get their aircraft back into the air quickly. COMAC is already focused on building a domestic supply network. Building an international supply network will be expensive and challenging, but also necessary. Despite the size of the internal Chinese market, Chinese aircraft will need to be able to operate outside the country; COMAC also hopes to sell more planes abroad.[36] To do so, COMAC will need to invest in distribution,

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[34] WTO, "European Communities—Measures Affecting Trade in Large Civil Aircraft," dispute settlement, Dispute DS316, April 13, 2012.

[35] Lynch, 2012.

[36] International Trade Administration, 2010, p. 58.

customer support, and training facilities, investments that Airbus and Boeing have already long since made. These expenses will add appreciably to COMAC's costs.

COMAC faces an additional challenge because of its current lack of a marketing network: competition from used aircraft. In most industries, entering a new market involves providing a product better than, or of equal quality with, incumbent products at a lower price. In the case of aircraft, the C919 will be competing against used Boeing and Airbus aircraft as well as their newer models. In most industries, buyers would prefer a competitively priced new aircraft to a used product, but because of the global service networks of Boeing, Airbus, and their suppliers, used Boeing and Airbus aircraft are attractive to price-conscious buyers because they can be serviced so easily. Without an extensive service network, COMAC products will have difficulty in breaking into the global market.

To add to COMAC's challenges, reliability is an essential feature of an aircraft. Because the C919 uses only internationally certified components from well-regarded firms, some concerns about reliability will be allayed. However, until the C919 establishes a track record for reliability, foreign buyers are likely to remain wary.

Foreign Companies

Strengths

One of the strongest competitive advantages of Airbus and Boeing and their major suppliers is their worldwide service and distribution networks. All the major manufacturers can guarantee delivery of key components to airlines at any major airport in the world in very short order. In most cases, key parts are already available at the airport. These distribution and support systems are a key sales argument because of the importance to aircraft owners of keeping their commercial aircraft flying.[37]

Weaknesses

Agreements restricting subsidies available for trade financing among the United States, the EU member states, and other developed countries limit the ability of Boeing and Airbus to match financing packages that COMAC may be able to offer to potential clients in developing countries.[38]

Net Assessment

China

The CEOs of AVIC and COMAC are striving to become major players in the global commercial aircraft industry, AVIC in components and COMAC in aircraft. The Chinese government has pursued a range of policies to support the creation of these incipient national champions. It has provided substantial financial support for launching the C919. Through the purchasing authority of the China Aviation Supplies Import and Export Group Corporation (CASC), the Chinese state is able to compel state-owned airlines to purchase aircraft favored by the national government. By making purchases of Chinese-made components an important criterion for aircraft purchase decisions, the Chinese government has helped generate orders for components manufactured by Chinese companies. Foreign module and component suppliers who

[37] Harrison, 2011.

[38] Organisation for Economic Co-operation and Development, "Sector Understanding on Export Credits for Civil Aircraft," Paris, August 31, 2011

have been selected by COMAC for the C919 program have been required set up joint ventures in China to manufacture components for the airplane.

In our view, the success of these policies has been limited. Although output from China's civil aviation industry (general and commercial) has grown rapidly over the last several years, China's industry remains small both in relation to output in China and in comparison with other countries in the world. Between 1992 and 2011, China increased its share of the world export market for aviation products to 1.3 percent from a little less than 1 percent in 1992. Over the same period of time, China's GDP rose from 2.0 percent of world total to 10.4 percent.[39]

The ARJ-21 is largely constructed from imported modules and components; the modules for the C919 will be manufactured in China, but most of these will be manufactured by joint ventures with major foreign companies who own and control key technologies. Many key components of those modules will be imported. COMAC continues to struggle with systems integration: Projected dates for the certification of the ARJ-21 have been postponed several times; the C919 has also been delayed. COMAC has yet to show that it will be able to produce commercially viable aircraft, much less show that it can become a commercially competitive aircraft manufacturer. AVIC's commercial aviation component manufacturing businesses have been more successful as stand-alone entities, but penetration into the global market for aircraft components has been slow and partially driven by pressure on Airbus and Boeing to purchase Chinese-made components.

All of our interlocutors believed that Chinese manufacturers will continue to improve the quality and technological sophistication of their products in the coming years. All believed that COMAC will succeed in certifying the C919. Opinions differed concerning likely numbers of aircraft sold and delivered. One expert noted that the current sales contracts are quite "soft" and that there are several ways buyers can avoid consummating the final sale, not least by canceling orders because of delivery delays. Moreover, by the time the C919 is in full production, it will be technologically outdated compared to Airbus's and Boeing's new competing models, the A320neo and 737 Max, respectively, which are much more efficient. Most of our interlocutors felt that COMAC will not truly be able to break into the international commercial aircraft market until it manufactures another plane following the C919. The company is in the early stages of designing a wide-bodied aircraft in collaboration with Russia, designated the C929.[40] To develop such an aircraft, COMAC will need another commitment of massive financial support from the Chinese government for a long period of time. Even then, many of our interlocutors, if not most, were skeptical that COMAC could compete successfully with wide-body Airbus and Boeing models. As one aviation insider interviewed for this project stated, "The challenge for China is not 'Can you build an [airplane]?' but 'Can you run a company that produces [airplanes] that [are] consistently competitive over time?' Chinese manufacturers can definitely do the former if they throw enough money at it; they cannot clearly do the latter [even if they throw a large amount of money at the problem]."[41] As another aviation

[39] Calculated from current dollar GDP statistics from International Monetary Fund, "World Economic Outlook Database," web page, undated.

[40] "Boeing President Deems China Biggest Emerging Competitor," CNN, June 8, 2012.

[41] Interview in China with Western aviation component manufacturer.

expert noted, "There's a big difference between making COMAC viable and making it 'commercially viable.'"[42]

One key factor in the future success of COMAC is the extent to which China's state-owned airlines will purchase COMAC's planes when they do become available. Historically, the Chinese government has decided on the purchase and distribution of foreign aircraft among the various Chinese airlines through CASC; although CASC's role is diminishing, the Chinese government has already successfully pressured Chinese airlines to make commitments to purchase the ARJ-21 and the C919.[43] According to Boeing, China will need upward of 5,000 airplanes during this same time span, of which 3,650 are projected to be in the single-aisle class to which the C919 will belong.[44] According to one source, COMAC anticipates delivery of more than 2,300 C919 aircraft over the 20-year life of the program, capturing almost two-thirds of projected domestic demand for these aircraft.[45] As noted above, Chinese airline executives would prefer aircraft from Boeing and Airbus. Based on current orders for aircraft from all three companies, it appears that COMAC will have a difficult time competing against the incumbents, even in China.

COMAC officials have stated that they plan to source more components from China's domestic aircraft manufacturing industry, once products by Chinese manufacturers have been certified.[46] Eventually COMAC hopes to use domestically manufactured engines to power both the ARJ-21 and C919. AVIC has opened an R&D center in Shanghai to develop engines for domestically produced aircraft with this goal in mind.[47]

Despite these initiatives, the hurdles posed by certification, the economies of scale that foreign manufacturers enjoy by selling to Airbus and Boeing rather than just to the Chinese market, and the ongoing investments by the incumbent manufacturers in improving technologies are likely to make it difficult for AVIC subsidiaries to push out joint-venture competitors, as Chinese partners were able to do in the wind turbine and high-speed train manufacturing industries. COMAC is likely to prefer to source from joint ventures rather than shift to strictly Chinese suppliers. As in the automotive industry, AVIC's subsidiaries, China's most technologically sophisticated aircraft component manufacturers, may prefer to maintain successful partnerships with foreign partners rather than strike out on their own. The access to technologies, foreign markets, and management is likely to trump pressure to develop independent commercial aircraft capabilities, although Chinese companies will continue to improve their capabilities in the military aircraft industry.

China may well intensify its use of acquisitions to acquire technologies and expand sales to the international civil aviation market. Although most of the large Tier One suppliers seem

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[42] Interview in China with Western aviation component manufacturer.

[43] International Trade Administration, 2010, p. 57; interview with Western analyst of Chinese aircraft manufacturing industry.

[44] Projections by Boeing sourced from Boeing, *Long-Term Market: Current Market Outlook 2012–2031,"* web site, undated b, p. 20.

[45] "GE's China Avionics Deal: A Q&A with President/CEO Lorraine Bolsinger," 2011.

[46] Harrison, 2011. Also see COMAC, "C919 Program," undated a. The basic principles of developing C919 includes "strategic cooperation. We will commit to national and international cooperation based on the 'airframe-suppliers' model to share risks and benefits, and build a system of both national and international suppliers for trunk liners, and eventually establish relatively complete service and industrial chains in the commercial airplane business."

[47] International Trade Administration, 2010, p. 31.

poised to remain independent, China is a likely buyer of financially ailing Tier Two suppliers. One barrier to China in these acquisitions is the extent to which these companies produce for the U.S. military or to which their technologies are considered dual use.

One area where China has been buying its way into the international market is general aviation. More companies participate in this market than in commercial aviation, and the industry is also more cyclical. As shown by CAIGA's acquisition of Cirrus and China's interest in purchasing Hawker Beechcraft, this is an industry in which China has a keen interest in acquiring foreign technologies and is likely to continue to do so.

Foreign Companies

Most major international commercial aviation manufacturers now have joint ventures in China. Foreign companies have set up these operations for a variety of reasons, but Chinese pressure on Boeing and Airbus to procure components from Chinese suppliers and stipulations that suppliers to the C919 project set up joint ventures in China have definitely played a role in these decisions. Over the course of the next decade, it would be surprising if these facilities are not fully integrated into the global manufacturing operations of the foreign manufacturers. Although some facilities, like Airbus's assembly operation in Tianjin, may remain dedicated to serving the Chinese market, over the course of the next decade we expect to see more supplier facilities specialize in specific products or modules and supply these to the foreign partner's global operations.

Many of the managers of foreign manufacturers with whom we held discussions argued strongly that sales of products manufactured by joint ventures in China do not compete with imports from the United States or Europe. They argued that they would not have been able to sell into China without a joint venture with a Chinese partner. According to these companies, because joint ventures use imported components from the parent company, they serve to create, not destroy, jobs in their home countries. For example, GE has set up a joint venture with AVIC in Shanghai to develop and manufacture the new avionics system for the C919. As the joint venture expands its business in China, GE expects the number of jobs in the United States will grow, translating into employment of about 1,800 high-technology jobs by GE in the United States.[48]

Glenn Harrison, an analyst at the U.S. Congressional Research Service, takes a different view concerning joint ventures. He states:

> Such partnerships may benefit the various partners in the short run, but as the new aircraft firms gain confidence and market share . . . Chinese companies are likely to seek higher levels of national (or indigenous) competency and competitiveness across the range of advanced technologies (e.g., engines, wing, and avionics and other systems) and after-sale support.[49]

All our interlocutors stated that their partners were becoming more technologically sophisticated. They recognized that any technology brought to China will be subject to theft. However, as already noted, they have taken a variety of steps to protect their intellectual property rights, most notably by keeping the manufacture of components involving key technolo-

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[48] "GE and China: Growing Market Overseas, More Jobs at Home," *GE Reports*, August 25, 2011.

[49] Harrison, 2011, p. 4.

gies outside China. They stated that their primary competitive advantage is their ability to innovate. As long as they continue to do so—a core feature of the corporate cultures of all the companies we interviewed—they were confident they would be able to keep their technological lead, although a few voiced fears of losing their edge to Chinese companies. Their extensive marketing networks, incorporation of their products on aircraft manufactured by Airbus, and Boeing, and manufacturing know-how provide them with strong incumbent advantages.

Foreign companies also noted that they have other competitive advantages, notably the extensive certification process required for all parts on an airplane before it is licensed to fly. Independent Chinese manufacturers will have to certify all components. If a foreign company claims that a component was manufactured using a technology that was improperly obtained, the process of obtaining certification from the FAA or EASA would provide an opportunity for the foreign company to have legal recourse outside of China.

If COMAC is more successful than we expect, Airbus and Boeing face a conundrum. China will remain one of the largest—if not the largest—market in the world for aircraft. In addition to narrow-bodied aircraft, it will be a major purchaser of wide-body aircraft, which COMAC will not be able to produce for the next decade or more. Whatever the eventual success of COMAC for narrow-bodied aircraft, there will still be room for sales of Airbus and Boeing products. One of our interlocutors noted,

> Of course, the Chinese market is sufficiently large that it should be capable of supporting domestic production and imports. The question is whether China will protect the market for its own narrow-body and regional jet aircraft while continuing to purchase aircraft that it cannot yet produce (i.e., wide-body medium and large aircraft). Whether Airbus or Boeing could challenge such an approach without fear of retaliation (loss of sales of large airliners to large state-owned airlines) remains to be seen.[50]

[50] Interview with Western aviation component manufacturer.

CHAPTER SEVEN

Policy Implications

China's government is committed to developing high-technology industries like commercial aircraft manufacturing. It uses a variety of policies to create national champions, its preferred approach to fostering the growth of these industries. When successful, these new industries have taken market share from foreign competitors in China and in the rest of the world with detrimental effects on employment and profits for those competitors. But investing in these industries, especially the commercial aviation manufacturing industry, is expensive. Overinvestment in industries like solar panels has led to large economic and commercial losses, reducing wealth and welfare in China.

In this chapter, we discuss policy options that foreign governments may wish to adopt in the event that China's commercial aircraft manufacturing industry successfully penetrates the Chinese and foreign markets. We also highlight the opportunity costs to China of current policies and discuss the implications of pursuing more market-oriented policies.

Policy Implications for the United States and the European Union

The United States and the EU are the two largest manufacturers of commercial aviation products in the world. They are also China's two most important trading partners. In the 1980s and 1990s, they experienced sharp reductions in output and employment in some industries that compete with Chinese imports, including shoes, clothing, tools, and furniture. More recently, they have faced competition in more technologically sophisticated products like computer chips, telecommunications equipment, and solar panels. Since 2001, when China joined the WTO, both have used this venue to address trade and other commercial disputes with China. In a number of instances, they have charged China with employing industrial policies and practices forbidden under the WTO to enhance the competitive position of Chinese industries. The United States and the EU argue that these policies have worked to the detriment of their own industries and are contrary to international trade rules. We first review the major trade issues pertaining to China's policies for fostering the growth of the commercial aviation manufacturing industry. We then describe the ways in which both the United States and the EU address trade disputes with China. We conclude with options for addressing current and future concerns over trade in commercial aviation products.

China's Industrial Policies in Commercial Aviation Manufacturing and the WTO

Prior to China's entry into the WTO in 2001, the country had little in the way of a commercial aircraft manufacturing industry. Consequently, opening up the country's aviation manufac-

turing sector was not covered in specific provisions in China's accession agreement. Specific provisions in the agreement with reference to aviation were confined to the liberalization of sales of aviation fuels and phasing out licensing quotas for machinery and equipment used in airports, like vehicles for aircraft refueling, recharging, or de-icing.[1]

Even though trade in commercial aircraft was not covered under specific provisions of China's accession agreement, the WTO is designed to constrain use of domestic subsidies, barriers to imports, and other trade-distorting measures so that foreign and domestic manufacturers are treated on a more equal basis in commercial decisions. However, as reported by the WTO Secretariat in 2010, China still uses several non-tariff measures to affect commercial decisions. These include government procurement practices, licensing requirements for imports and exports, quotas, prohibitions on imports and exports of specific products, export and import taxes, and state trading.[2] Many of these policy instruments have been employed to foster the development of China's commercial aviation manufacturing industry.

State Subsidies

The Agreement on Subsidies and Countervailing Measures (SCM Agreement) under the WTO defines a subsidy as a financial contribution by a government or public body that confers a benefit on the recipient. Subsidies consist of any transactions—direct transfers, loans at interest rates lower than those commercially available, provisions of goods or services at less than market prices, purchases of products from the industry at higher than market prices, income or price supports, or tax rebates—that are specific to an enterprise, industry, or region.[3] China has provided substantial subsidies to COMAC and other national champions in the form of injections of equity, R&D grants, and state-subsidized lending. These subsidies do not appear to be compliant with WTO provisions.

The WTO has special rules for government subsidies to state-owned enterprises that depart from normal WTO rules. Under these special rules, countries that perceive themselves harmed by subsidies granted to China's state-owned enterprises can take action in response under the SCM Agreement.[4] They can impose countervailing duties on subsidized products. In the future, countries or entities that are home to manufacturers of aircraft that compete with the ARJ-21 (e.g., Canada and Brazil) or the C919 (e.g., the United States and the EU) may have grounds to levy countervailing duties on Chinese aircraft under this rule.

Government Procurement and Purchases of Aircraft

The WTO principle of nondiscrimination between imports and domestic products (national treatment) does not apply to government procurement, except for countries that have signed the plurilateral Agreement on Government Procurement, which China has not.[5] However, purchases by state-owned enterprises are not considered government procurement under China's accession agreement. Consequently, government dictates through CASC on decisions by

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1 WTO, "Accession Protocol of the People's Republic of China to the World Trade Organization," November 10, 2001.

2 WTO, Trade Policy Review Body, "Trade Policy Review: Report by the Secretariat – China (Revision)," WT/TPR/S/230/Rev.1, 5 July 2010, Section III, paragraphs 3–6.

3 Directorate-General for External Policies for the Union, Policy Department, 2011, p. 45.

4 Directorate-General for External Policies for the Union, Policy Department, 2011, p. 44.

5 Directorate-General for External Policies for the Union, Policy Department, 2011, p. 41.

China's state-owned airlines concerning aircraft purchases, like the C919, appear to be in violation of China's commitments under WTO not to use government influence to dictate procurement decisions by state-owned companies.

Stipulations on Foreign Investment

One of the primary vehicles used by the Chinese government to control foreign investment is its *Catalogue Guiding Foreign Investment Industry*. The catalogue divides China's industries into three categories (encouraged, restricted, and prohibited).[6] Enforcement of stipulations on direct foreign investment by industry in conformance with the Catalogue (including licensing) has been delegated to the local commerce authorities of the various provinces, autonomous regions, and municipalities. This decision was originally made to facilitate the approval of permits for foreign direct investments, but has resulted in more procedural complexity, if not corruption.[7] Although consistent with Chinese policy, stipulations that suppliers to COMAC must set up joint ventures to assemble components in China appear in violation of provisions under The Agreement on Trade-Related Investment Measures that foreign investors and foreign-owned enterprises are entitled to national treatment.

Chinese government officials reportedly use informal means to induce foreign companies to conduct research and development in China or transfer technology. They set performance requirements relating to exports or the use of local content, for example.[8] Managers of foreign company operations in China state that Chinese government officials have required them to transfer technology to secure investments approvals in violation of Chinese law and China's commitments under The Agreement on Trade-Related Investment Measures.[9] Stipulations that foreign suppliers to COMAC transfer technologies to joint-venture partners also appear in violation of WTO provisions on investment.[10]

United States

The primary government agency responsible for resolving U.S. trade disputes with China is the Office of the U.S. Trade Representative, which " is responsible for developing and coordinating U.S. international trade, commodity, and direct investment policy, and overseeing negotiations with other countries."[11] It is responsible for handling U.S. trade disputes and represents the U.S. government at the WTO.

The U.S. government also uses bilateral forums to discuss economic issues with the government of China, including resolving disputes over bilateral trade and economic matters. The U.S.-China Joint Commission on Commerce and Trade (JCCT) was established in 1983 and is co-chaired by the U.S. Secretary of Commerce and China's Minister of Commerce. It is a forum for ". . . high-level dialogue on bilateral trade issues and a vehicle for promoting commercial relations."[12] The Chinese government and the Obama administration set up a higher-

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6 Directorate-General for External Policies for the Union, Policy Department, 2011, p. 62.

7 Directorate-General for External Policies for the Union, Policy Department, 2011, p. 62.

8 U.S. Trade Representative, 2012, p. 9.

9 U.S. Trade Representative, 2012, p. 3.

10 WTO, 2001.

11 U.S. Trade Representative, "Mission of the USTR," web page, undated.

12 U.S. Department of Commerce, "US-China Joint Commission on Commerce and Trade (JCCT)," web page, undated.

level bilateral forum in April 2009: The U.S.-China Strategic and Economic Dialogue (S&ED) is chaired by the U.S. Secretary of the Treasury and the Vice Premier in charge of economic issues on China's side. It primarily focuses on broader economic issues, as opposed to the trade and commercial issues addressed by the JCCT.[13]

A key concern for U.S. leaders has been shifts of U.S. manufacturing activity to China. The U.S. government has used a variety of avenues to address the use of Chinese trade and industrial policies to block imports of U.S. products into China or subsidize Chinese exports of these products to the U.S. and other foreign markets. When U.S. manufacturers encounter barriers to sales to China or competition from Chinese exports to the United States, the U.S. Trade Representative can bring a complaint to the WTO, using that organization in its role as a forum for settling disputes. This approach has its drawbacks, especially if U.S. manufacturers need immediate relief; dispute resolutions tend to be lengthy. If China chooses not to comply, the United States may impose retaliatory duties on other Chinese exports to the United States, but if the problem is Chinese barriers to U.S. exports, this resolution does not provide much help to the U.S. manufacturer. The United States can accelerate the process by imposing retaliatory duties unilaterally, but unilateral measures are generally not in accord with the rules of the WTO, potentially putting many U.S. exporters at a disadvantage in China. Moreover, in this approach to dispute resolution, the damage has often been done in term of plant closures and losses in output or employment before China faces countermeasures.

The JCCT and, especially, the S&ED provide alternative forums for these types of issues. According to the Department of Treasury, the Chinese government agreed following meetings of the JCCT not to make technology transfers a precondition for market access and will correct any measures that were inconsistent with this commitment in a timely manner. China has reportedly also agreed to participate in negotiations on new rules on official export financing with the United States and other major exporters.[14]

But, as the U.S. Trade Representative notes,

> In 2012, a wide range of Chinese policies and practices continued to generate significant concerns among U.S. stakeholders. Major issues included China's export restraints, government subsidization, inappropriate use of trade remedy laws, indigenous innovation policies, technology transfer initiatives, serious problems with intellectual property rights enforcement, including in the area of trade secrets, and China's slow movement toward accession to the WTO Government Procurement Agreement.[15]

Moreover, China's regulatory authorities have penalized foreign firms by pursuing antidumping and countervailing duty investigations of their own and have imposed duties that appear to be for the purpose of striking back at trading partners who have exercised their WTO rights. The Office of the U.S. Trade Representative has alleged China's regulatory authorities have pursued investigations even when there is no factual basis for the charges.[16]

As one industry insider interviewed for this study remarked:

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[13] U.S. Department of the Treasury, "U.S.-China Strategic and Economic Dialogue," web page, updated July 12, 2013.

[14] U.S. Trade Representative, 2012, p. 5.

[15] U.S. Trade Representative, 2012, p. 3.

[16] U.S. Trade Representative, 2012, p. 3.

> WTO accession did not affect the basic mindset in China about what the goal or means to reaching it should be—catch up to the world leader, use industrial policy to do so, build every single thing that you can at home, and buy as little from abroad as possible. China's strategic industry promotion efforts are probably not WTO compliant, but they are probably not going to be challenged either.[17]

European Union

Like the United States, the EU is concerned about the effects of China's industrial policies on its domestic industries. The EU cites as areas of concern: Chinese industrial policies and non-tariff measures that may discriminate against foreign companies; a strong degree of government intervention in the economy, resulting in a dominant position of state-owned enterprises; unequal access to subsidies and cheap financing; and inadequate protection and enforcement of intellectual property rights.[18]

The EU addresses economic issues with China through several forums and meetings—of these (like the U.S.-China S&ED), the most important are the Annual Summits at the level of the Heads of State or Government. Unlike the S&ED, the Summits address other issues in addition to trade and other economic issues. Ranking next in importance are annual "executive-to-executive" meetings between the President of the Commission, accompanied by members of the European Commission and China's Premier, who is accompanied by members of the State Council.[19] In contrast, the EU-China High Level Economic and Trade Dialogue, which began in 2007, focuses solely on trade and economic issues. It consists of upward of 25 separate dialogues or working groups on economic issues, involving a substantial number of the Directorates of the European Commission and Chinese ministries.[20]

The EU has complained about Chinese subsidies and the illegitimate use of anti-dumping measures, which create problems for EU exports, especially of products that compete with goods dubbed by the Chinese as strategic or that enjoy special "protection" from the Chinese authorities. The EU argues that subsidies have contributed to China's rapid export growth. The EU also charges that China's Ministry of Commerce frequently fails to require Chinese companies that petition for anti-dumping measures to provide summaries of submissions open to the public. Consequently, European firms are unable to defend their interests in anti-dumping investigations.[21] The European Parliament is skeptical that current policies are effective. A recent report sponsored by the European Parliament notes:

> The EU could challenge some Chinese government measures taken to protect and develop its domestic producers as incompatible with WTO norms and rules. On occasions, these threaten the economic and social rights that constitute the basis of European societies. The prospects of bringing about changes in Chinese industrial policy are, however, not great, even if there were a consensus among member states on a firm policy line."[22]

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[17] Interview with Western expert on Chinese commercial aviation industry in China.

[18] European Commission, Trade Directorate, 2013.

[19] Directorate-General for External Policies for the Union, Policy Department, 2011, p. 27.

[20] European Commission, "Third Meeting of the EU-China High Level Economic and Trade Dialogue (HED) in Beijing," Memo/10/698, Brussels, December 21, 2010.

[21] Directorate-General for External Policies for the Union, Policy Department, 2011, pp. 43, 47.

[22] Directorate-General for External Policies for the Union, Policy Department, 2011, p. 22.

Policy Options for the United States and the European Union

Both the United States and the EU face a conundrum. China's leadership appears convinced of the efficacy of industrial policies to foster new industries and expand exports. In contrast, the United States and the EU have attempted to negotiate agreements to restrain such industrial policies because of their costs, lack of efficacy, and the interests of both the EU and the United States in creating a level playing field for businesses. Moreover, in both the United States and the EU, the "squeaky wheel" rule reigns: Trade issues are placed on bilateral agendas or brought to the WTO only if a domestic company complains. While U.S. and European firms still dominate a market, like commercial aviation manufacturing, trade negotiators tend to focus on other industries where competition from Chinese firms threatens to have more immediate consequences. It is no accident that solar panels and telecommunications emerged as major issues in 2012 and 2013, as European and U.S. firms were confronted with cheaper imports from China. In this environment, what can the U.S. government and the EU do to establish a level playing field for commercial aviation manufacturing?

Several of our interlocutors maintained that regardless of what policy measures may be taken, the United States and the EU will experience a slow shift in component manufacturing to China due to the proliferation of joint ventures to support the C919 project and because of operations in China designed to maintain aircraft and aircraft components in that large market. This said, there are measures that the U.S. government and the EU can take to try to reduce market-distorting effects of Chinese industrial policies on that migration:

- **Engage in bilateral negotiations with the EU to pressure Airbus and Boeing to reduce the use of purchases of components as a marketing tool.**

  Not surprisingly, aircraft manufacturers like to burnish their reputations in countries where they wish to make sales by highlighting their roles in the local economies. The creation of in-country jobs has been used as an important selling point. For example, in the recent competition between Airbus Group and Boeing for a major contract for refueling tankers, Airbus Group stated that the aircraft would be assembled in a plant in the United States. Through the WTO and bilateral discussions, the U.S. government and the European Commission could seek to strengthen current WTO provisions against local content clauses. They could also work with Boeing and Airbus to set informal rules of conduct in sales negotiations concerning promises for local procurement. A concerted effort on the part of the U.S. government and the Commission could work to reduce the role of promises to procure components from local manufacturers in sales negotiations with CASC, thereby improving the position of competing manufacturing facilities in the United States and the EU.
- **Push for more transparent tenders for purchases of aircraft by Chinese state-owned airlines.**

  Historically, state-owned CASC has had a decisive role in determining what commercial aircraft are purchased by state-owned airlines. Recent commitments by Chinese airlines to purchase the C919 were not made after open tender solicitations for new aircraft in this category. The U.S. government and the European Commission, separately or jointly, could publicly urge the Chinese government to make open tenders for new aircraft a matter of policy for China's state-owned airlines. Moreover, as purchases by state-owned airlines are not considered government procurement (China is not yet party to the

Government Procurement Agreement within the WTO), the U.S. government and the Commission may wish to voice concerns about whether commitments by China's airlines to purchase the C919 are taken on a commercial basis only, in accordance with China's commitments under its WTO agreement.

- **Ensure that Chinese aircraft components submitted for certification by the FAA or EASA do not incorporate intellectual property taken from other companies.**

  As the Chinese industry seeks to expand its presence in global markets for components, the FAA and EASA may wish to incorporate procedures into the certification process that help to ensure the technologies in these products do not belong to some other company. They can do so by tasking staff to compare technologies with those in previously certified components. If staff find reasons for concern, the FAA and EASA could provide this information to the proper authorities in the United States and EU, respectively, for formal investigations of the source of the technologies. Products using illicitly obtained technologies would of course not be eligible for certification.

- **Work with U.S.- and EU-based aircraft product manufacturers with operations in China to voluntarily report whether and how their investment decisions in China have been influenced by Chinese industrial policy.**

  Building a record of influence on investment decisions as a consequence of Chinese industrial policies will be important for future bilateral discussions and WTO proceedings. Both the U.S. government and the European Commission may wish to task civil servants in the International Trade Administration in the Department of Commerce and the Directorate-General of Trade, respectively, to monitor investments by commercial aviation manufacturing companies in China. If investments appear to be made at least partly in response to Chinese industrial policies, they should approach the companies involved to discuss the rationales for the investments. Based on these conversations, the U.S. government and the Commission may wish to bring up these policies in bilateral conversations with the Chinese government.

- **Monitor the development of the C919 and succeeding aircraft and intervene promptly through the WTO and bilateral forums in response to efforts to use subsidies or other supports to enter U.S. or EU markets.**

  In some industries, Chinese companies have expanded output very quickly and rapidly displaced foreign competitors in China and in export markets. Foreign competitors have had to close facilities and lay off workers before the appropriate agencies of the affected government have been able to take action through the WTO or through other measures. We encourage the U.S. Trade Representative and the Directorate-General of Trade to closely monitor sales efforts by COMAC and be prepared to launch formal proceedings if the Chinese government appears to be violating WTO rules in this industry.

- **Continue to press the Chinese government in bilateral forums and at the WTO to dispense with industry-specific industrial policies.**

  Without a dramatic change in China's "national champions" policy, none of these measures are likely to create a level playing field in China for Western manufacturers. However, persistent efforts to reduce the trade-distorting effects of China's industrial policies may serve to mitigate some of the policy's effects. The long-term health of the U.S. and European industries will depend on continued technological innovation by the parent companies and the ability of the home countries to provide a competitive environment for manufacturing aviation products. But efforts by home-country agencies to call

the Chinese government to account for industrial policies that run counter to WTO rules would increase transparency and build a record that would inform future adjudicatory procedures under the WTO.

Implications for the Government of China

As described above, the Chinese government is intent on creating a globally competitive commercial aircraft manufacturing industry. It has made substantial investments in a state-owned national champion, COMAC; it has devised and introduced several policies to induce foreign companies to set up joint ventures with state-owned companies; and it has pressured foreign companies to purchase aircraft components manufactured in China. These efforts have been undertaken with the goal of duplicating the success of Airbus in the case of COMAC and assisting AVIC to emerge as a major global manufacturer of commercial aircraft components.

China's widespread use of industrial policies reflects the conviction of Chinese government officials that state intervention is an effective way to foster the development of new industries and spur economic growth. Chinese policymakers and aviation manufacturing executives frequently cite Airbus as an example to be emulated. After starting as a consortium of European aircraft manufacturers in 1970, Airbus has developed and successfully sold a full range of commercial aircraft.[23] It has increased its share of the global market from less than 20 percent in 1990 to roughly half over the course of the last decade (Figure 5.6). State support in the form of subsidized loans to launch new aircraft, including the A300, Airbus's first aircraft, and the largest, the A380, played an important role in the growth of the venture despite complaints from the U.S. government and trade cases brought to the WTO. The French government, in particular, has provided support, but the British, Spanish, and German governments have done so as well.

China faces a number of hurdles in repeating the success of Airbus. The commercial aircraft market is highly competitive: Manufacturers such as Lockheed have exited the market; McDonnell Douglas and Hawker Siddeley have been absorbed by Boeing and British Aerospace, respectively, and no longer manufacture their own aircraft models. Airbus and Boeing have global support and marketing networks. COMAC will have to build such a network if it is to be successful, and will have to do so at a time when Bombardier and Embraer, regional jet manufacturers that already have existing networks, are also moving toward competing with Boeing and Airbus in the narrow-bodied commercial aircraft market. In light of these challenges, it is not clear that China's investment in this industry will pay off.

Despite the success of Airbus, industrial policies to support commercial aviation have also produced some spectacular failures. In the 1970s, the governments of the United States, France, the United Kingdom, and the Soviet Union invested large sums to develop supersonic transports. The United Kingdom and France initially funded independent efforts to develop a supersonic aircraft, but consolidated their efforts because of costs. With government support, the Concorde was eventually produced. But only 14 were aircraft were sold;[24] the Concorde never came close to recovering its development costs.[25] In the 1960s, in response to European

[23] Airbus, "The Success Story of Airbus," Airbus website, undated c.

[24] British Airways, "Concorde Retires: Retirement FAQs," web page, undated.

[25] Daniel S. Greenberg, "A Marketplace Disaster With Wings," *Chicago Tribune*, May 31, 1986.

efforts to develop the Concorde, the U.S. government provided funding to Lockheed and Boeing for design work for a supersonic transport. Boeing's design was selected, but the U.S. Congress cut off funding in 1971, primarily for reasons of cost but also because of projected noise pollution and damage to the ozone layer that the aircraft would have caused.[26] The Soviet Union's program also led to nothing but losses. The Tupolev Design Bureau built the TU-144. An early model crashed at the Paris Air Show in 1973, and a production version crashed in May 1978, just before delivery. When the last plane was retired in 1983, the entire model range had only flown 102 commercial flights.[27]

Industrial policies have failed in other industries as well. The U.S. government initiated several programs to manufacture synthetic fuels in response to the run-up in oil prices in the late 1970s. It set up the Synthetic Fuels Corporation in 1980, just as world market oil prices peaked. One venture, the Exxon-Tosco Colony Shale oil project, received a $1.15 billion loan guarantee from the U.S. Department of Energy. The facility was closed just before it went into production; the project was no longer commercially viable once oil prices dropped. Fortunately for the U.S. government, which would have been legally obligated to honor the loan guarantee, Exxon absorbed the loss of more than $1 billion.[28] The U.S. government also provided $100 million annually in grants to Sematech, a government-supported consortium of 14 computer chip manufacturers, for R&D on manufacturing computer chips. The grants failed to achieve their objective: Rather than triggering more research, U.S. government support appears to have replaced private-sector R&D expenditures with government funding.[29]

The purpose of these vignettes is to underline the costs and frequent failures of government policies targeted to support specific industries. While in some cases industrial policies have provided sufficient support to prop up a dying industry or have helped develop a new industry, in many cases (like the ones cited above), the government has failed to create commercially viable projects. Costs have often been high.

It is true that both the United States and member states of the EU have provided subsidies and support for commercial aviation.[30] But international trade agreements have constrained the use of subsidies and other industrial policies. As manufacturing has become increasingly integrated between the two partners, they have made formal commitments to limit industrial subsidies or protect domestic manufacturers in the interest of expanding trade. In Europe, trade policy has played a major role in reducing state support for specific industries. The adoption of the Single Market blueprint by the European Commission in 1985 paved the way to reducing remaining barriers to trade among member states.[31] As part of the creation of a single market, member countries had to agree to forgo subsidizing industries; otherwise, the single-market effort would have been derailed by squabbles among member states over government

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[26] "Showdown on the SST," *Time Magazine*, March 29, 1971.

[27] Yefim Gordon and Vladimir Rigmant, *OKB Tupolev: A History of the Design Bureau and Its Aircraft*, Birmingham, United Kingdom: Ian Allan Publishing, 2005.

[28] Congressional Research Service, *Oil Shale: History, Incentives, and Policy*, April 13, 2006, p. CRS10.

[29] Douglas A. Irwin and Peter J. Klenow, "Sematech: Purpose and Performance," *Proceedings of the National Academy of Sciences, USA*, Vol. 93, November 1996, pp. 12739–12742.

[30] Christopher Drew and Nicola Clark, "In Appeal, W.T.O. Upholds a Decision Against Boeing," *New York Times: Global Business*, March 12, 2012; Howard Schneider, "U.S. Claims Victory in Airbus-Boeing Case," *Washington Post*, May 18, 2011.

[31] European Commission, "The EU Single Market: Historical Overview," undated.

support and their impact on the competitiveness of their respective industries. In the United States, philosophical predilections have contributed to a reluctance to provide subsidies to manufacturers, although agriculture, energy, and other industries continue to enjoy various forms of U.S. government support.

Trade agreements have been an important instrument by which industrial supports have been limited. But in our view, the high costs and frequent failures of industrial policies have been the primary reasons why the U.S. and European governments have been willing to limit the use of industrial policies.[32] When governments target support to specific industries, political pressures often result in looking backward. European interventions in textiles, shipbuilding, and steel in the 1960s, 1970s, and 1980s did not save these industries. The U.S. government has also had a habit of adopting industrial policies to address problems that the market was already rectifying, such as the investments in synthetic fuels discussed above. Moreover, the cost of these industrial policies can be very high and the failures spectacular, with the incumbent political costs.

In our view, the Chinese government would benefit from carefully reviewing its current policies of government support for commercial aviation manufacturing and making a considered decision whether this activity is a good use of China's resources. Almost all our interlocutors believe that COMAC will successfully certify the C919. But most are skeptical that the C919 will be a commercial success. In light of the many hurdles facing COMAC, in our view, this is an opportune time for the Chinese government to shift from targeting specific industries to focusing its energies on creating a business environment friendly to all firms, private, foreign, and state-owned alike.

One of the lessons of the post–World War II era has been the importance of the free flow of ideas and people for technological advances. The rise of the modern multinational corporation has played a key role in these advances. These companies are adept at creating multinational teams, drawing on talent from across the globe, to develop new products and processes. They have devised systems for developing and deploying new technologies and products.

One of the goals of China's leadership has been to put the country at the forefront of global advances in science and technology. China has extraordinarily talented engineers and scientists and has registered significant advances in a large number of industries, including space and telecommunications. It also has a number of successful multinational companies of its own. However, to the extent foreign companies are not given the same treatment as their Chinese counterparts or are afraid that their intellectual property rights will not be safe, they will remain cautious about what technologies they bring to China. If China wishes to become fully integrated into the global commercial aviation manufacturing industry, China's government would be well advised to change its current policies to create a more equitable business environment for both foreign and Chinese commercial aviation manufacturers. The benefits of such a policy change for China would be considerable in terms of better allocation of investment, better integration into global technology supply chains, and the substantial savings of putting funds currently going to support national champions to better uses.

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[32] One frequently encounters the argument that industrial policies were effective and important drivers of economic growth in Japan and South Korea. We note that there is a very long literature debating whether that is true. (For a discussion of the effectiveness of Japanese industrial policies, see Michael E. Porter, Hirotaka Takeuchi, and Mariko Sakakibara, *Can Japan Compete?* New York: Basic Books, 2000; for Korea, see Alice H. Amsden, *Asia's Next Giant: South Korea and Late Industrialization*, Oxford, United Kingdom: Oxford University Press, 1989.) Because neither of those two countries is a major manufacturer of commercial aircraft, we do not enter that debate in this paper.

APPENDIX

Domestic and Foreign Aviation Manufacturing Companies in China

The tables on the following pages list further details about the major companies in aviation manufacturing and the international partners in the ARJ-21 program.

Table A.1
Major Chinese Companies in Aviation Manufacturing

Company Name	Major Aviation Area	Revenues (in $millions)	Employees	Major Commercial Aviation Products
Aviation Industry Corp. of China (AVIC—中国航空工业集团)	Military & commercial aviation	40,835 (2011)	~400,000	MA-60 Series; ARJ-21 Components; (J.V.) ERJ145, A320 Final Assembly; Components Subcontracting for Boeing, Airbus
Commercial Aircraft Corp. of China (COMAC—中国商用飞机公司)	Commercial airliners	Unknown	6,000+	ARJ-21 (in development); C919 (in development)
		Major AVIC Subsidiaries		
AVIC Aero-Equipment Co. (中航航空装备有限责任公司)	Military aircraft	5,573 (2011)	60,000+	ARJ-21 nose & tail assemblies; Components subcontracting for Boeing/Airbus
Chengdu Aircraft Industry Group (成都飞机工业(集团))	*Military aircraft*	*1,505 (2010)*	*15,000*	*ARJ-21 nose section; components subcontracting for Boeing/ Airbus*
Shenyang Aircraft Corp. (沈阳飞机工业(集团))	*Military aircraft*	*1,858 (2011)*	*15,000*	*ARJ-21 tail assembly; components subcontracting for Boeing/ Airbus*
AVIC Aircraft Company (中航飞机有限责任公司)	Medium/large aircraft	Unknown	Unknown	MA60 series; Y-8 series; ARJ-21 fuselage & wings; landing gears and braking systems; components subcontracting
Xi'an Aircraft Industrial Corp. (西安飞机工业(集团))	*Medium and large aircraft (civil & military)*	*1,372 (2011)*	*20,000+*	*MA60 series; Fuselage & wings for ARJ-21; Components subcontracting for Boeing/Airbus*
Shaanxi Aircraft Industrial Group (陕西飞机工业(集团))	*Military transports*	*464 (2011)*	*10,000+*	*Y-8 series (An-12 Cub derivatives)*
AVIC General Aircraft Co. (CAIGA—中航工业通用飞机公司)	General aviation	2,821 (2010)	~50,000	Starlight 100/200 Business Jets (in development); Primus 100/150 (in development); Y-5 (An-2 Colt derivative) series; LE500; H0300; Cirrus product line
CAIGA Zhuhai Co. (中航通飞珠海公司)	*General aviation*	*Unknown*	*Unknown*	*Starlight 100/200 (in development); Primus 100/150 (in development)*
Shijiazhuang Aircraft Industry Group (石家庄飞机工业有限责任公司)	*General aviation*	*Unknown*	*3,000+*	*Y-5B(An-2) series; LE500; H300*
Cirrus Aircraft Corp.	*General aviation*	*170 (2011)*	*~1,300*	*SR20/22 series, Vision SF50 jet*
AviChina Industry and Technology Co. (中国航空科技工业有限公司)	Helicopters, general aviation, commercial airliners	2,122 total, 1,184 from aviation sector (2010)	26,300+	Helicopters; Trainers; Light transports; ERJ-145 final assembly line (J.V. with Embraer); A320 final assembly line in Tianjin (20% in JV w/ Airbus); Composite Material Center in Harbin (20% in JV w/ Airbus)
Harbin Aircraft Industry Group (哈尔滨飞机工业集团)	*Helicopters, general aviation, commercial air*	*429 (2011)*	*6,000+*	*Helicopters; Y-12 Utility Transport; ERJ-145 final assembly (49% share in J.V. with Embraer); Composite Material Center (20% share in J.V. with Airbus)*

Table A.1—Continued

Company Name	Major Aviation Area	Revenues (in $millions)	Employees	Major Commercial Aviation Products
AVIC Helicopter Co. (Avicopter—中航直升机有限责任公司)	Civil helicopters	Unknown	~15,000	Civil helicopters
AVIC Commercial Aircraft Engines Co. (中航工业商用飞机发动机公司)	Commercial aircraft engines	Unknown	Unknown	C919 Engine Systems (J.V.'s with CFM International)
AVIC Engines Co. (中航工业发动机控股公司)	Military engines	Unknown	80,000+	Commercial engines repair & maintenance
AVIC Avionics Systems (中航工业航空电子系统公司)	Avionics	Unknown	Unknown	C919 Avionics Systems (J.V.'s with foreign vendors)
AVIC Electromechanical Systems Co. (中航工业机电系统公司)	Flight control systems	3,994 (2011)	~70,000	C919 Flight Control Systems (J.V.'s with foreign vendors)
AVIC International (中国航空技术国际控股公司)	Civil aviation imports/ exports	Unknown	~50,000	International Marketing of MA-60 series, ARJ-21
China National Aero-Technology Import-Export Corp. (CATIC—中航技进出口公司)	Military aviation imports/exports	Unknown	Unknown	N.A.
Most Important COMAC Subsidiary				
Shanghai Aircraft Manufacturing Co. (上海飞机制造有限公司)	Aircraft final assembly	Unknown	Unknown	ARJ-21 Final Assembly and Systems Integration

SOURCES: Compiled from various company websites, annual reports, media reports, etc.

Table A.2
International Partners in the ARJ-21 Program

Partners	Products
U.S. Partners	
Alcoa, Inc.	Advanced alloys for airframe, wing and fuselage stringers, floor beams, seat tracks, fasteners and misc. structural components
B/E Aerospace, Inc.	Oxygen equipment
Eaton Corp.	Flight deck instrument panel and lighting controls
GE	Propulsion (engines, nacelles, and accessories)
Goodrich Hella Aerospace	Lighting equipment
Hamilton Sundstrand (UTC subsidiary)	EPS/high lift/auxiliary power unit
Honeywell International	Flight control system integration and synthesis
Kidde Aerospace (Hamilton Sundstrand subsidiary)	Fire protection
MPC Products Corp	APU door system
Parker Aerospace	Fuel, hydraulic, and electrical flight controls
Rockwell Collins	Integrated avionics system
Rosemount Inc. (Emerson subsidiary)	Windshield wiper and heater
Zodiac Air Cruisers Company	Emergency evacuation system
Other International Partners	
Antonov ASTC (Ukraine)	Wing design, structural strength analysis
Avio-Diepen (Netherlands)	Material management
CAE Inc. (Canada)	Full flight simulator
Fisher Advanced Composite Components (Austria)	Cockpit, cabin interior, kitchens, restrooms
Liebherr Aerospace Toulouse	Air Management System
Liebherr Aerospace Lindenberg	Landing gear braking system
Meggitt Vibro-Meter SA (Switzerland)	Engine interface control unit, engine vibration monitoring system
Safran Sagem (France)	Flight deck control suite
Saint-Gobain Sully (France)	Windshields and opening windows
Zodiac Evac Vacuum Systems, Shanghai	Water/waste
Zodiac Sicma Aero Seats (France)	Crew seating

SOURCES: Cliff et al. 2011, Table 4.1, p. 45.

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