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INSIDE

CHANGING THE RULES OF THE GAME:

THE COMMERCIAL AIRCRAFT INDUSTRY IN CHINA

COMAC Shanghai Facility
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ABSTRACT

The present article explores innovation and imitation in the context of the commercial aircraft industry in China as a critical case. The rise of Chinese firms has been one of the most fascinating stories in global business during the past decades. In 2012, Chinese firms have outnumbered Japanese firms in the *Fortune Global 500* ranking for the first time. Many scholars have focused on technological innovation and upgrading, or the absence thereof, as the primary explanatory variables for this phenomenal development. This study complements this perspective by examining non-technological forms of innovation such as a firm's business model. It argues that Chinese firms are innovators as much as imitators of business models and do not necessarily converge with global industry standards. Such business model innovation can occur at the "top of the pyramid" and has potentially disruptive implications for competition in global markets.

INTRODUCTION

Since the beginning of the post-Mao reforms the pace of economic change in China has been extraordinarily rapid. This phenomenal development has been one of the most fascinating stories of the global economy during the past decades. At the heart of this story has been the rise of Chinese firms that has resulted in the number of *Fortune Global 500* firms from China overtaking those from Japan for the first time in 2012.[1]

Whereas the magnitude of the growth of corporate China is largely uncontested, the mechanisms driving this shift in the global corporate landscape have given rise to considerable debate within the scholarly, journalistic, and business communities and have resulted in a rich body of

[1] Molly Gray, "China Overtakes Japan in Fortune 500 List for First Time," *CNN*, July 11, 2012, accessed July 11, 2012, http://business.blogs.cnn.com/2012/07/11/china-overtakes-japan-in-fortune-500-list-for-first-time/?hpt=hp_c2.

The author gratefully acknowledges helpful comments by Mari Sako and Dwight H. Perkins on earlier related and unpublished research projects that have informed the present study and by Eric Thun and Felix Boecking on drafts of the present article. The author would also like to thank Peter Tufano for providing inspiration for the title of the present article and GE Aviation for granting permission to use the above picture.

studies covering a broad range of analytical perspectives across different industries. In the context of these efforts to explain the rise of Chinese private and state-owned firms, many scholars have focused on technological innovation, or the absence thereof, by Chinese firms with particular reference to technological upgrading in specific product markets.

As empirically rich and as analytically insightful this body of studies has been, these studies could be grouped into two schools of thought: The first school argues that the rise of Chinese firms has been a story of imitation rather than innovation. The second school argues that the transformation of Chinese firms has been a story of true innovation rather than imitation.

Both of these perspectives share a technology-centric and product-focused view of innovation. Whereas the present article does not seek to question the relevance of either of these schools of thought, it does argue that an exclusively "technology-focused" perspective is likely to overlook other interesting loci of innovation such as a firm's business model. Hence this article seeks to complement the extant technology-focused literature on innovation in the context of Chinese firms by examining China's emerging commercial aircraft industry via an expressly "organization-focused" lens. It explores how Chinese firms seek to change the rules of the game on the basis of business model innovation.

This article seeks to make contributions in the following ways: First, as mentioned above, it seeks to add to the "technology-focused" literature on innovation in China by exploring how Chinese firms act as organizational innovators rather than imitators with particular reference to business models. Second, a large body of scholarship has focused on the disruptive power of technological innovation. In contrast, this article seeks to examine the potential disruptiveness of organizational innovation and to highlight the resulting implications for competitors of Chinese firms.

The remainder of this article is organized as follows: The second section introduces the theoretical background and develops propositions, the third section briefly summarizes research methods and data, the fourth section provides background on the global commercial aircraft industry, the fifth section examines the commercial aircraft industry in China, the sixth section discusses research findings, the seventh section addresses limitations, and the final section offers concluding remarks.

BACKGROUND

Given the richness of the literature on the development of the Chinese economy and Chinese firms in general and the role of innovation therein in particular, a detailed, comprehensive literature review would be far beyond the scope and space limitation of the present short article. For the purposes of this article only a few, selected studies shall be highlighted below.

In the interest of clarity and as the risk of doing injustice to analytical nuance and detail, extant scholarship on technological innovation in the context of Chinese firms can be grouped thematically into two different schools of thought.

The first school argues that the rise of Chinese firms has been a story of imitation rather than innovation. In this view, China's economic development has been primarily a function of labor cost advantages at the level of the firm and significant surplus labor in the Chinese economy as a whole. Genuine, indigenous technological innovation is viewed as being conspicuous by its absence and competitive strategies of Chinese firms are described as predicated on cost leadership and technological followership at best and on informal technology "borrowing" and quality short-cutting at worst.[2]

In contrast to this view of technological imitation, the second school argues that the rise of Chinese firms has been a story of innovation rather than imitation. In this view, China's economic development has been driven by continuous technological upgrading across a broad range of different industries. And it is human capital formation rather than utilization of surplus labor that has been the driving force behind the rise of Chinese firms. The capacity for genuine, indigenous technological innovation is seen as a core element of competitive strategies of many Chinese firms and as an explanatory variable for their successful entry into, or even dominance of, global markets.[3]

As different as the underlying assumptions of these two schools might be, both perspectives share, explicitly or implicitly, a focus on technology and products as the primary loci of innovation. Whereas the present article has no intention of challenging the importance of technological innovation and upgrading, or the absence thereof, as an explanatory variable for the performance of Chinese firms, it argues that an exclusively "technology-focused" perspective is likely to

[2] For a book-length, somewhat extreme version of this view, see Paul Midler, *Poorly Made in China: An Insider's Account of the Tactics Behind China's Production Game* (Hoboken: John Wiley & Sons, Inc., 2009).

[3] For recent journalistic examples that highlight technological innovation in China, see Benjamin Reuter, "Verwandlung der Nachmacher," *WirtschaftsWoche*, June 30, 2012, accessed July 10, 2012, http://www.wiwo.de/technologie/forschung/globalisierung-verwandlung-der-nachmacher-/6784692.html; and WirtschaftsWoche Global, *Der Aufstieg des Drachen: Von der Imitation zur Innovation – die chinesische Herausforderung*, 1/2012. A recent thoughtful analysis of technological upgrading in China in the context of global value chains is Loren Brandt and Eric Thun, "Going Mobile in China: Shifting Value Chains and Upgrading in the Mobile Telecom Sector," *International Journal of Technological Learning, Innovation and Development* 4 (2011): 148-180.

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overlook other interesting loci of organizational innovation such as a firm's business model. Hence this article seeks to complement the extant technology-focused and product-centric literature on Chinese innovation by examining, as a critical case study, China's commercial aircraft industry on the basis of an expressly "organization-focused" perspective that explores how Chinese firms seek to change the rules of the game in global markets via business model innovation.[4]

In the larger context of scholarship on the rise of emerging markets in general, many studies that have taken an organization-oriented perspective and that have explored business model innovation have focused on markets at the "bottom of the pyramid."[5] Many of these markets at the "bottom of the pyramid" tend to be characterized by relatively low-tech products such as fast moving consumer goods and relatively simple value chains. In contrast to these studies, the present article examines a distinctly high-tech industry characterized by highly complex value chains – i.e. commercial aircraft manufacturing – and thereby expressly focuses on business model innovation at the "top of the pyramid."

Exploratory propositions developed on the basis of this "organization-focused" perspective on innovation at the "top of the pyramid" are listed below:

- **Proposition 1**: In the realm of organizational innovation, Chinese firms are as much innovators as imitators and do not necessarily converge with global industry "standards."
- **Proposition 2**: Innovative business models pursued by Chinese firms have disruptive potential for changing the rules of the game in global markets.
- **Proposition 3**: Rivalry in global markets often is not only a story of competition between efficient Western corporations and inefficient Chinese state-owned enterprises but rather a contest between fundamentally different business models.

METHODS AND DATA

The present article examines the commercial aircraft industry in China as a single case study. Whereas the author is cognizant of the inherent disadvantages of such research design, a single case approach can be appropriate when it represents a critical case for determining whether a proposition is correct or whether alternative modes of explanation need to be pursued.[6]

The commercial aircraft industry in China represents a suitable case study for the purposes of the present article inasmuch as the global commercial aircraft industry can be characterized, as shown below, by a single, strongly dominant business model that is shared by all leading players. Hence any empirical finding that would suggest that forms of industrial organization pursued by Chinese aerospace firms, even if emergent in nature, diverge from this global industry "standard" would be of a particularly revelatory nature.

Despite the large volume of scholarly and practitioner-oriented literature on business models that has emerged in the recent past, there is surprisingly little agreement on what business models really are.[7] For the purposes of the present article, the term "business model" refers to the market segment in which the firm chooses to compete and, most importantly, the structure of the firm's vertical value chain and the firm's horizontal product range.[8]

Case study research is not limited to a single source of data.[9] In this spirit, the present article draws on and is informed by multiple data sources including, but not limited to, industry- and company-level documentation. All publications used for the purposes of the present study are of a non-classified, public domain nature. Such public domain industry-level data includes industry trade publications, trade association documents, and interviews given by industry leaders. Similarly, public domain company-level data includes, but is not limited to, company press releases, company brochures, company presentations, and published interviews with company executives. This article is also informed by the extant body of literature in the English language covering aviation in China such as related general business books and policy-oriented analyses.[10]

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4 Notable examples of the relatively small number of studies that incorporate, at least implicitly, both technology- and organization-focused perspectives on innovation in Chinese firms include Loren Brandt and Eric Thun, "The Fight for the Middle: Upgrading, Competition, and Industrial Development in China," *World Development* 38 (2010): 1555-1574; Winter Nie and William Dowell, *In the Shadow of the Dragon: The Global Expansion of Chinese Companies – And How It Will Change Business Forever* (New York: American Management Association, 2012); Yinglan Tan, *Chinnovation: How Chinese Innovators Are Changing the World* (Singapore: John Wiley & Sons (Asia) Pte. Ltd., 2011); and Ming Zeng and Peter J. Williamson, *Dragons at Your Door: How Chinese Cost Innovation is Disrupting Global Competition* (Boston: Harvard Business School Press, 2007).

5 For a seminal article that has pioneered the "bottom of the pyramid" concept, see C.K. Prahalad and Allen Hammond, "Serving the World's Poor, Profitably," *Harvard Business Review* 80 (2002): 48-57. A recent book-length study that examines entrepreneurship and new business models in India and China is Tarun Khanna, *Billions of Entrepreneurs: How China and India Are Reshaping Their Futures – and Yours* (Boston: Harvard Business School Press, 2007).

6 Robert K. Yin, *Case Study Research: Design and Methods* (4th ed) (Los Angeles: Sage Publications, Inc., 2009).

7 A helpful review of this literature can be found in Christoph Zott, Raphael Amit, and Lorenzo Massa, "The Business Model: Recent Developments and Future Research," *Journal of Management* 37 (2011): 1019-1042.

8 This definition is consistent with, but less comprehensive than, Henry Chesbrough and Richard S. Rosenbloom, "The Role of the Business Model in Capturing Value from Innovation: Evidence from Xerox Corporation's Technology Spin-off Companies," *Industrial and Corporate Change* 11 (2002): 529-555.

9 Yin, *Case Study Research: Design and Methods*.

10 For a recent, excellent example of the former that broadly addresses the development of civil aviation in China, see James Fallows, *China Airborne* (New York: Pantheon Books, 2012); of the latter, see Roger Cliff, Chad J.R. Ohlandt, and David

THE GLOBAL COMMERCIAL AIRCRAFT INDUSTRY

The global commercial aircraft industry can be characterized by prospects for long-term growth, intense yet largely duopolistic competition, and extraordinarily high barriers to entry due to high capital requirements and technological, value chain management, and global service delivery challenges. For the purposes of the present article the focus of analysis shall be what is often referred to as the "commercial aircraft" market (i.e. regional aircraft, single-aisle jets such as the Airbus A320 and Boeing B737 families, twin-aisle jets such as the Airbus A330/A340 and Boeing B777 families, and ultra-large jets such as the Airbus A380 and the Boeing B747). The markets for smaller general and corporate aviation aircraft and helicopters are not subject of analysis of the present article.

The Global Market for Commercial Aircraft[11]

Over the past three decades airline traffic has grown by a cumulative average annual rate of about 5 percent. By 2011, this growth had given rise to a global jet fleet of about 19,890 aircraft consisting of 2,780 regional, 12,610 single-aisle, 3,710 twin-aisle, and 790 ultra-large jets. Whereas in the recent past aircraft projects such as the ultra-large Airbus A380 and the new generation twin-aisle Boeing B787 have attracted major news attention, it is important to note that the current jet population for single-aisle aircraft is almost three times as large as the combined twin-aisle and ultra-large fleet.

Historic growth patterns are estimated to continue for the next two decades resulting in a cumulative average growth rate of the global aircraft fleet of 3.5 percent. This growth is forecasted to result in a combined global fleet of about 34,000 aircraft (after replacements) by the year 2031. Once again, single-aisle jets are forecasted to account for the majority of all aircraft deliveries.

This forecast of sustained, long-term growth in aircraft deliveries is particularly applicable to the commercial aircraft market in China. Boeing forecasts China to become its second largest national market (only second to the United States) with a demand of 5,000 new aircraft of all types for the period 2011-2030 resulting in a growth of the aircraft fleet in China from 1,750 aircraft of all types in 2010 to 5,930 in 2030. Of this tremendous volume of 5,000 new aircraft deliveries, 71% are expected to be in the single-aisle category.

In short, both the global and the domestic Chinese markets for commercial aircraft are attractive inasmuch as both are expected to maintain continuous and significant growth rates over the next two decades. As a sub-segment of this market, the market for single-aisle, short-to-medium range aircraft appears to be most promising due to its disproportionately large share in expected aircraft deliveries.

Industry Structure and Dominant Business Model

Until the late 1970s and early 1980s three American companies and one European company divided the market for commercial jet aircraft.[12] Even then Boeing was the dominant player among the three American jet makers. Lockheed Aircraft Corporation and McDonnell Douglas were driven out of business or forced to merge with Boeing due to the emergence of Airbus and due to their inability to develop competitive products. By the mid-1990s, a virtual duopoly between Boeing and Airbus had emerged in the market of single-aisle and larger jets and by the 2000s Airbus pulled equal with Boeing in terms of new aircraft orders and deliveries.[13]

Similar duopolistic structures developed in the markets for turboprop- and jet-powered regional aircraft. After the demise of a number of other players the turboprop market is virtually dominated by Bombardier, a Canadian company, and ATR, a joint venture between EADS and Alenia Aermacchi of Italy. Currently, the market for jet-powered regional jets is a virtual duopoly shared between Bombardier and Embraer of Brazil after other aircraft manufacturers exited or failed to enter the regional jet market.[14]

In addition to this duopolistic industry structure, the global commercial aircraft industry can probably be best characterized by a single, dominant business model that has emerged over the past decades and that is shared by the two remaining major commercial aircraft manufacturers. This dominant business model is comprised of two key structural features:

First, historically – especially since the rise of jet-powered aircraft in the 1960s – the business model of major aircraft makers has been characterized by horizontal separation of product ranges between the makers of aircraft such as Airbus or Boeing on the one hand and makers of major aircraft components on the other. Traditionally, aircraft makers have neither designed nor manufactured major components in-house but have sourced those from independent, third-party firms. These major component makers tend to supply different aircraft makers on a non-exclusive basis and have become major drivers of technological innovation and efficiency gains in aviation in their own right. Such third party-sourced major

Yang, *Ready for Takeoff: China's Advancing Aerospace Industry* (Santa Monica: RAND Corporation, 2011).

[11] Market data is derived from The Boeing Company, *Current Market Outlook 2011-2030*, 2011, and The Boeing Company, *Current Market Outlook 2012-2031*, 2012. This data is largely consistent with similar forecasts by Airbus.

[12] Earlier competitors such as de Havilland had already fallen by the wayside with the coming of the jet age. See Sam Howe Verhovek, *Jet Age: The Comet, the 707, and the Race to Shrink the World* (New York: Avery, 2010).

[13] For a good account of the rivalry between Airbus and Boeing, see John Newhouse, *Boeing versus Airbus: The Inside Story of the Greatest International Competition in Business* (New York: Vintage Books, 2007).

[14] Current non-Chinese regional aircraft that are in process of development for this market include the Mitsubishi Regional Jet and the Sukhoi Superjet 100.

components (and exemplary component makers) include, but are not limited to, engines (General Electric, Pratt & Whitney, Rolls-Royce), auxiliary power units (Hamilton Sundstrand, Honeywell), landing gears (Goodrich, Liebherr), electrical systems (Crane Aerospace, Hamilton Sundstrand), cockpit avionics (General Electric, Rockwell Collins), etc.

Second, the business model of major aircraft makers has come to be increasingly characterized by significant vertical disaggregation. Whereas historically aircraft makers had sourced major components from external suppliers, they had performed on an in-house basis design engineering and manufacturing of aircraft structures and overall systems integration. Over the past two or three decades, however, aircraft makers have undergone several phases of increasing vertical disaggregation of their value chains for structural aircraft parts and entire sub-assemblies. Most recently, aircraft makers have even spun off significant parts of their remaining in-house structural manufacturing facilities. For example, in 2005, Boeing sold its entire Wichita Division to Onex, a North American private equity firm, that subsequently has been rebranded as Spirit AeroSystems. Similarly, in 2008, Airbus sold its Filton-based wing manufacturing operation to GKN, a UK engineering group.[15]

As a result of this increasing disaggregation of their vertical value chains, Airbus and Boeing have converged on a common business model in which aircraft makers function as overall systems integrators and value chain managers with relatively shallow vertical integration. Previously core activities such as design engineering and manufacturing of structures and integration of entire sub-modules have moved outside the legal boundaries of commercial aircraft makers.

In sum, the dominant business model of commercial aircraft makers such as Airbus and Boeing can be characterized by horizontal separation between aircraft makers on the one hand and aircraft component suppliers on the other and vertically highly disaggregated value chains. This industry "standard" is shown in **Figure 1** below:

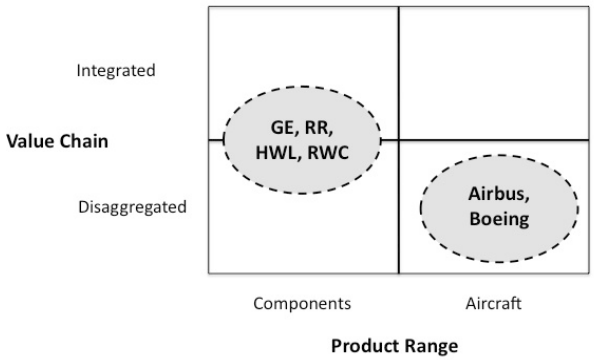

Figure 1: Global Commercial Aircraft Industry "Standard" Business Model

[15] For exemplary supplier information for two of the currently most high-profile aircraft programs, the Airbus A380 and Boeing B787, see http://events.airbus.com/a380/navigator/industrial_adventure.html and http://www.boeing.com/commercial/787family/dev_team.html, both accessed July 18, 2012.

THE CHINESE COMMERCIAL AIRCRAFT INDUSTRY

The present section offers a brief overview of Aviation Industry Corporation of China, the Chinese state-owned enterprise in which China's aviation activities are bundled, outlines the historical background of civil aircraft manufacturing in China, introduces the current major, indigenous commercial aircraft programs, and discusses the resulting business model of commercial aircraft making in China.

Aviation Industry Corporation of China[16]

As suggested above, China's civil and military aviation activities are consolidated within a single, state-owned corporate group, Aviation Industry Corporation of China (henceforth "AVIC"), and its subsidiaries.

AVIC is one of China's largest state-owned enterprises and is comprised of approximately 200 subsidiaries of which 20 are publicly listed, including a broad range of aerospace R&D institutes and joint ventures with non-Chinese aerospace firms. AVIC is a highly diversified aviation group that consists of ten strategic business units: commercial aircraft, military aircraft, helicopters, general aviation aircraft, engines, avionics and components, aviation R&D, flight test, trade and logistics, and asset management. Historically, like many other Chinese state-owned enterprises, AVIC has also pursued a broad range of non-core activities.[17]

AVIC has a much broader aviation-related core product range than EADS, the European Aeronautic Defence and Space Company N.V. to which Airbus belongs, and Boeing as neither of these two Western aerospace giants is active in general aviation aircraft, engines, and avionics and components.[18] An AVIC subsidiary also owns a significant shareholding in Chengdu Airlines.[19]

AVIC was originally founded in 1951 as the

[16] Data for AVIC is primarily derived from http://www.avic.com.cn/cn/wzsy/index.shtml, accessed June 1, 2012.

[17] For example, in 1997, various constituent companies of the predecessor group of AVIC reportedly manufactured more than 5,000 non-aviation products. See Peter Nolan and Jin Zhang, "Globalization Challenge for Large Firms from Developing Countries: China's Oil and Aerospace Industries," *European Management Journal* 21 (2003): 295.

[18] EADS was formed via merger of the major French, German, and Spanish aerospace and defense companies in 2000. Its major operating divisions are Airbus primarily for commercial aircraft, Astrium for space systems, Cassidian for defense technology, and Eurocopter for helicopters. See http://www.eads.com/eads/int/en.html, accessed July 10, 2012, for further details. In the interest of readability, EADS and Airbus are collectively referred to as "Airbus" throughout most of the remainder of the present article.

[19] There are some product categories, primarily in space and military technology, in which Boeing and/or EADS are more broadly positioned than AVIC. For example, AVIC – in contrast to Airbus or Boeing – is not active in the satellite and space launch systems business. Such space-related activities fall under the purview of other Chinese state-owned enterprises.

Aviation Industry Administration Commission and has undergone multiple rounds of comprehensive organizational restructurings since its founding. In 1999, the China Aviation Industry Corporation, which had combined all Chinese civil and military aviation activities, was split into two entities, AVIC I and AVIC II. AVIC I was focused on military aircraft and larger civil aircraft whereas AVIC II was focused on smaller civil aircraft and helicopters. In 2008, however, AVIC I and AVIC II were formally recombined due to the organizational inefficiencies and resource redundancies of the previously split organization, and the merged entity was designated Aviation Industry Corporation of China.[20]

In 2010, AVIC had over 400,000 employees and estimated total group revenues of approximately US$ 31 billion. In the same year, Boeing had a workforce of just over 160,000 and revenues of over US$ 64 billion and EADS, including Airbus, about 121,000 employees and revenues of well over EUR 45 billion.[21] AVIC ranked 311th amongst the *Fortune Global 500* corporations in 2011.[22] It is headquartered in Beijing and has major R&D and manufacturing facilities in Chengdu, Harbin, Nanchang, Shanghai, Shenyang, Tianjin, and Xian.

A Short History of Civil Aircraft Making in China[23]

China's current commercial aircraft programs can be best understood in their historical context. China has tried to build up civil aircraft design and manufacturing capabilities since the 1950s. The history of civil aircraft manufacturing in China is shown in stylized form in **Figure 2** below:

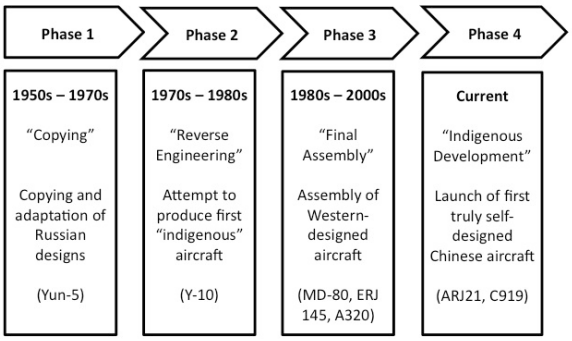

Figure 2: History of Civil Aircraft Manufacturing in China

Phase 1: From the 1950s until the middle of the 1970s almost all aircraft produced in China were copies or technological derivations of Russian designs. The most commonly produced of these airplanes was the Yun-5, a copy of the Antonov An-2 propeller-powered biplane.

Phase 2: The most ambitious aircraft development project launched prior to the post-Mao reforms was the Y-10, a passenger aircraft powered by jet engines. After President Nixon's historic visit to China in 1972, China had agreed to purchase Boeing B707 aircraft and the Shanghai Aircraft Research Institute was tasked to develop the first "indigenous" Chinese four-engine long-range commercial aircraft.[24] The Y-10 saw its maiden flight in 1980 but did not enter commercial operation due to insufficient performance.

Phase 3: China adopted a revised Three-Step Plan in the mid-1980s that was intended to de-risk China's acquisition of commercial aircraft design and manufacturing capabilities. After a drawn out contest between Boeing and McDonnell Douglas, the latter won a joint venture agreement in 1984 to assemble its MD-80, a DC-9 derivative, in Shanghai on the basis of complete knock-down kits. In 1992 the cooperation between McDonnell Douglas and Shanghai Aviation Industry Corporation was extended to include production of the MD-90 as well.

In addition, China was able to acquire significant final assembly best practices know-how by virtue of partnerships with other aircraft makers throughout the 2000s: For example, in 2003, Embraer, one of the two dominant regional jet manufacturers, launched a joint venture with an AVIC subsidiary to assemble its ERJ-145 regional jet. Most importantly, the first Airbus final assembly line outside Europe opened formally in Tianjin in September 2008 as a joint venture between Airbus, AVIC, and the Tianjin Free Trade Zone. This facility is dedicated to assembly of the Airbus A320 single-aisle family and, as it General Manager states, "is not only as good as Airbus' plants in Toulouse and Hamburg – it is an improvement. 'It is better … we had a chance to start from a green field, the production flow is perfect.'"[25] All Airbus aircraft assembled in Tianjin are of comparable quality to those assembled at Airbus home base facilities in Hamburg and in Toulouse.[26]

In short, AVIC has been able to acquire significant experience running final assembly lines for modern aircraft. AVIC has also accumulated extensive experience manufacturing a broad range of aircraft parts, including structural sub-assemblies and other key components, for most of the currently active commercial aircraft programs at

[20] For a good account of the historical background of AVIC, see Mark Dougan, *A Political Economy Analysis of China's Civil Aviation Industry* (New York: Routledge, 2002).

[21] The Boeing Company, *Annual Report 2011*, 2011; EADS, *Annual Report 2011 – At a Glance*, 2011.

[22] http://money.cnn.com/magazines/fortune/global500/2011/snapshots/11566.html, accessed June 1, 2012.

[23] Data is primarily derived from http://www.avic.com.cn/cn/wzsy/index.shtml, accessed June 1, 2012, and Dougan, *A Political Economy Analysis of China's Civil Aviation Industry*.

[24] There still is popular debate in the aviation community on whether the Y-10 project was a reverse-engineering exercise or whether this constitutes a genuine Chinese indigenous effort; see, for example, http://www.airliners.net/aviation-forums/general_aviation/read.main/3745561/, accessed July 17, 2012.

[25] Francis Leithen, "Improving the Best," *Flight International*, September 1-7, 2009, 43.

[26] Ghim-Lay Yeo, "China Special: Airbus Builds Bridges," *Flight International*, November 5, 2010, accessed July 10, 2012, http://www.flightglobal.com/news/articles/china-special-airbus-builds-bridges-349324/.

Airbus, Boeing, Bombardier, and Embraer.[27]

Phase 4: Aerospace has been defined as a priority industry in China's current Twelfth Five-Year Plan. This push to develop a truly indigenously designed commercial aircraft dates back to the Tenth Five-Year Plan and has resulted in the current ARJ21 and C919 programs.

The ARJ21 Program[28]

The ARJ21 is a twin-engine regional aircraft with tail-mounted engines. Its baseline version, the ARJ21-700, is designed to have a capacity of 78 to 90 passengers, a standard range of 2,225 kilometers and a maximum take-off weight of just over forty metric tons.

The ARJ21 program was originally launched in 2002 by the formation of a consortium comprised of several of AVIC's aircraft design institutes and aircraft manufacturing subsidiaries. For example, Chengdu Aircraft Industry Group is responsible for manufacturing of the nose, Xian Aircraft Corporation for production of the wings and fuselage, and Shenyang Aircraft Corporation for construction of the tail section. Although the ARJ21 is reportedly designed by use of Chinese indigenous technical know-how, its basic configuration – tail-mounted engines, T-tail – bears resemblance to the MD-80 and MD-90 that, as mentioned above, were previously assembled in Shanghai.

In other ways, however, the ARJ21 is a technologically new aircraft. First, aerodynamic performance is likely to have been improved significantly by means of a new supercritical wing with winglets. Second, the ARJ21 is powered by modern General Electric CF34 engines. Other variants of this engine are used for competing regional jets such as Bombardier's CRJ family and Embraer's E-Jet family. Third, the flight deck features a modern glass cockpit primarily consisting of avionics systems provided by Rockwell Collins. Also, key components and systems are state-of-the-art and are sourced from international component suppliers. For example, Hamilton Sundstrand supplies the auxiliary power unit, Liebherr the landing gears, and Parker the hydraulic system.

AVIC has announced that it has secured more than 300 orders for the ARJ21, including orders from GECAS, a General Electric subsidiary and one of the world's largest aircraft leasing companies, and from Lao Airlines, the ARJ21's export launch customer.[29] A relatively large share of orders seems to have been placed by smaller Chinese operators, including Chengdu Airlines in which AVIC is a major indirect shareholder.[30]

Although the ARJ21 maiden flight was planned originally for 2005, first flight only took place in November 2008 due to delays caused by significant technical challenges. Regulatory certification and first delivery are unlikely to occur prior to 2013.[31]

In sum, the ARJ21 program appears to be characterized by a very steep learning curve. In effect, the ARJ21 is as much a learning and technical and procedural proof-of-concept opportunity as it is a commercial endeavor in its own right, and it serves as an, albeit somewhat unintended and costly, preparatory exercise for the more important C919 program.

The C919 Program[32]

The C919 is a twin-engine, single-aisle, medium range aircraft. Its baseline version is designed for a capacity of 168 passengers in an all-economy configuration or 156 passengers in a standard mixed configuration and a standard range of 4,075 kilometers with a cruise speed around Mach 0.785. Additional variants, including stretched and shrunk passenger versions, a freighter, and a business or VIP jet version, are planned as well.

The C919 is the first clean-sheet, indigenous commercial aircraft design in China since the aforementioned Y-10 program. In contrast to the ARJ21 that is a nominal competitor to Bombardier and Embraer regional jets, the C919 is expressly designed to challenge the Airbus A320 family and Boeing B737 family duopoly for single-aisle, medium range commercial aircraft, the largest global market segment by number of aircraft deliveries.

Commercial Aircraft Corporation of China (henceforth "COMAC"), the Shanghai-headquartered AVIC subsidiary charged with lead responsibility for the C919 program, was positioned from its start to achieve competitiveness in international markets, and the C919 has the potential to become a game changer not only for the Chinese market but also for the global commercial aircraft industry.

The C919 program was launched in 2007 when China's State Council approved the foundation of COMAC as a joint subsidiary of AVIC, a number of China's largest state-owned enterprises such as Baosteel, Chinalco, and Sinochem, the municipal government of Shanghai, and China's central government. In 2008 COMAC received an initial paid-in capital of RMB 19 billion including RMB 5 billion from AVIC, RMB 1 billion from each of the aforementioned state-owned enterprises, RMB 5 billion from

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27 Francis Leithen, "Modern and Ancient," *Flight International*, September 1-7, 2009, 40-41.

28 Data for the ARJ21 program is primarily derived from http://www.comac.cc/, accessed June 1, 2012, and from http://www.airframer.com/aircraft_detail.html?model=ARJ21, accessed July 10, 2012.

29 Kate Cantle, "ARJ21 Wins 100 Orders from AVIC International," *Air Transport World Online*, November 19, 2010, accessed July 10, 2012, http://atwonline.com/aircraft-engines-components/news/arj21-wins-100-orders-avic-international-1118.

30 Francis Leithen, "Taking on the Giants," *Flight International*, September 1-7, 2009, 37-38.

31 "Wing Cracks, Other Flaws Delay China Jet Manufacture," *Reuters*, June 8, 2012, accessed June 8, 2012, http://in.reuters.com/article/2012/06/08/uk-airlines-china-comac-idINLNE85700Z20120608.

32 Data for the C919 program is primarily derived from http://www.comac.cc/, accessed June 1, 2012, and from http://www.airframer.com/aircraft_detail.html?model=C919, accessed July 10, 2012.

the Shanghai municipal government, and RMB 6 billion from China's central government. In addition, China's Bank of Communications made available a credit line of RMB 30 billion.[33]

As mentioned above, in effect, the ARJ21 program can be viewed as a technical and procedural proof-of-concept for the C919 program. Technological choices for the C919 program appear to be characterized by continuity with the ARJ21 program.

First, experience gained from structural work on the ARJ21 seems to feed into the C919 program: AVIC subsidiary Chengdu Aircraft Industry Corporation is responsible for production of the C919 nose section as well, Xian Aircraft Corporation for production of the wings and the fuselage mid-section, and Shenyang Aircraft Corporation for production of the tail section. A new supplier of major structural elements appears to be AVIC subsidiary Hongdu Aviation Industry Corporation for the production of forward and aft sections of the main fuselage. The C919 is to be assembled at COMAC's facility in Shanghai.

Second, similar to the ARJ21, the C919 incorporates engines and key state-of-the-art components originally developed by leading international suppliers: The C919 will be powered by the new generation LEAP-1C engine supplied by CFM, the largest supplier of engines for the Boeing B737 family and Airbus A320 family. The line-up of component suppliers reads like a who-is-who of the global aerospace industry; for example, the auxiliary power unit is sourced from Honeywell, the landing gears from Liebherr, the hydraulic system from Parker, the electrical system from Hamilton Sundstrand, and key avionics components from General Electric.

Recently, AVIC announced that it had reached 280 orders for the C919 from twelve different customers.[34] These customers include the three major Chinese state-owned carriers and GECAS. And although the C919 has apparently not been sold to a major international airline so far, a number of high profile carriers have expressed interest in the C919.[35] Most recently, IAG, the parent company of British Airways and Iberia, announced that it is planning to cooperate with COMAC on development of the C919 and that it would carefully examine the C919.[36] Whether such support will result in firm orders remains to be seen.

Given that first flight of the C919 is expected to occur in 2014 and entry-into-service in 2016, it is far too early to arrive at definitive judgments regarding the eventual operational performance of the C919.[37] Significant technical and non-technical challenges remain to be resolved in order to deliver the first C919 on time and to make the C919 into the game changer that it could well become.[38] In spring of 2012, COMAC and Bombardier signed an agreement covering collaboration in the areas of cockpit design, electrical systems, advanced materials, and customer service. The extension of this collaboration to encompass support for winning international regulatory approvals for the C919 seems to be indicative of the range and magnitude of these remaining challenges.[39]

AVIC Business Model

Given the dominance of a single type of business model in the global commercial aircraft industry, one might expect that AVIC's effort at entering the world market for commercial aircraft would be predicated upon imitating this organizational industry standard. In contrast to this expectation, however, the AVIC business model that has emerged – in some ways by design and in others inadvertently – in process of executing the ARJ21 and C919 programs diverges significantly from the aforementioned global industry "standard."

First, Airbus' and Boeing's vertically strongly disaggregated value chain model relies heavily on sourcing engineering and manufacturing of aircraft structural parts and sub-assemblies from independent, third party suppliers. In contrast, as suggested above, the majority of structural engineering and manufacturing work for the ARJ21 and the C919 is performed within the boundaries of AVIC by a number of different AVIC subsidiaries. In other words,

[33] Anil Gupta and Haiyan Wang, "Comac: China's Challenge to Airbus and Boeing," *Bloomberg Businessweek,* June 30, 2010, accessed June 10, 2012, http://www.businessweek.com/stories/2010-06-30/comac-chinas-challenge-to-airbus-and-boeingbusinessweek-business-news-stock-market-and-financial-advice.

[34] "ABC Leasing Signs Agreement of 45 C919 Orders with COMAC – COMAC secured a total of 280 C919 orders," Commercial Aircraft Corporation of China, accessed July 10, 2012, http://english.comac.cc/home/photo/201207/09/t20120709_564466.shtml.

[35] See, for example, Ryanair, one of the most high-profile low cost carriers globally, and its interest in the C919 as reported in James T. Areddy and Andrew Galbraith, "Ryanair Trumpets Planes from China," *Wall Street Journal*, November 30, 2011, accessed July 17, 2012, http://online.wsj.com/article/SB10001424052970204262304577067951924584354.html.

[36] David Kaminski-Morrow, "Farnborough: IAG to Co-operate with Comac on C919," *Flight International*, July 9, 2012, accessed July 10, 2012, http://www.flightglobal.com/news/articles/farnborough-iag-to-co-operate-with-comac-on-c919-374014/.

[37] "Comac C919 Plane Program On Schedule, Engine Supplier Cfm Says," *Bloomberg News*, June 13, 2012, accessed June 14, 2012, http://www.bloomberg.com/news/2012-06-13/comac-c919-plane-program-on-schedule-engine-supplier-cfm-says.html.

[38] Some analysts have also pointed out the high probability of C919 program delays analogous to or caused by the ARJ21 program. See, for example, Leithen Francis and Bradley Perrett, "ARJ21 Delays Threaten C919 Schedule," *Aviation Week*, September 12, 2011, accessed July 10, 2012, http://www.aviationweek.com/Article.aspx?id=/article-xml/AW_09_12_2011_p24-366882.xml.

[39] "Bombardier to Help China's First Jetliner Win Overseas Approvals," *Bloomberg News*, June 11, 2012, accessed July 17, 2012, http://www.bloomberg.com/news/2012-06-11/bombardier-to-help-china-s-first-jetliner-win-overseas-approvals.html.

AVIC's value chain is vertically deeply integrated.

Second, in contrast to Airbus and Boeing that purchase aircraft components from external component makers, AVIC is leveraging its current aircraft programs to enter the aircraft component market in its own right as well.[40] Whereas both programs source state-of-the-art technology originally developed by international component makers, selection as supplier for the aforementioned AVIC aircraft programs tends to be contingent upon setting up joint ventures with appropriate AVIC subsidiaries.[41] For example, the electrical system for the C919 will be developed and manufactured by a Hamilton Sundstrand joint venture with AVIC Electromechanical Systems Company in Xian and the landing gears for the C919 by a Liebherr joint venture with AVIC Landing Gear Advanced Manufacturing Company in Changsha.[42] While these joint ventures are initially intended to be dedicated to the ARJ21 and the C919 programs, in the medium- to long-run AVIC aims to become a major component supplier in its own right. This strategic intent to become a tier-one component supplier is reflected in the potentially transformational 50/50 partnership in which AVIC has entered with General Electric to create a new business that will design and market integrated avionics systems to other aircraft makers such as Airbus, Boeing, Bombardier, and Embraer in addition to its launch customer COMAC.[43]

Among all major components, the development of aircraft engines is often considered the most technologically and commercially challenging endeavor.[44] AVIC has entered into partnerships to develop indigenous engine technology for future replacement of the LEAP-1C engine that will initially power the C919 and for potential future marketing of such engines to other aircraft manufacturers.[45]

In sum, AVIC is in the process of creating a business model that is predicated upon a vertical value chain that is deeply integrated and a horizontal product range that combines both aircraft and stand-alone component businesses within the boundaries of AVIC. The resulting, emergent AVIC business model that differs significantly from the global industry "standard" is shown in **Figure 3** below:

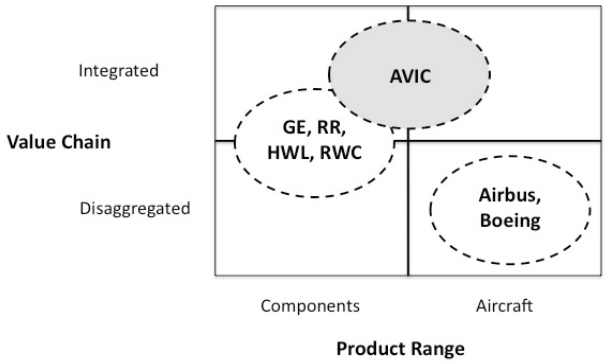

Figure 3: AVIC versus Global Commercial Aircraft Industry "Standard" Business Model

DISCUSSION

A significant part of the literature on the development of the Chinese economy in general and the transformation of Chinese firms in particular has taken a technology-focused perspective and has tried to assess whether Chinese firms are technological innovators or imitators. The present article suggests that this predominantly technology-focused perspective might fail to adequately capture other loci of innovation and thereby tend to underestimate the innovative capacity of Chinese firms.

In this context of pursuing an "organization-focused" perspective it might be worthwhile to revisit the propositions stated at the outset of the present article.

- **Proposition 1**: In the realm of organizational innovation, Chinese firms are as much innovators as imitators and do not necessarily converge with global industry "standards."

In the case of AVIC and commercial aircraft making in China, long-term market success will clearly be contingent upon AVIC's ability to design, manufacture, and support on global basis aircraft that are technologically and operationally on par with Airbus and Boeing products. This will entail a significant technological step-up to achieve and then

[40] AVIC has also acquired foreign aircraft component makers such as FACC, an Austrian composite technology and cabin parts specialist firm.

[41] Linday Blachly, "COMAC Says JVs will Develop, Produce C919 Systems," *Air Transport World Online*, July 13, 2010, accessed June 1, 2012, http://atwonline.com/aircraft-engines-components/news/comac-says-jvs-will-develop-produce-c919-systems-0712.

[42] "Hamilton Sundstrand, AVIC EM lay cornerstone to mark start of production for C919 electric system," Hamilton Sundstrand, July 31, 2011, accessed July 10, 2012, http://www.hamiltonsundstrand.com/vgn-ext-templating/v/index.jsp?vgnextoid=16eaaec96b991110VgnVCM1000007301000aRCRD&hsct=hs_news&ciid=43ddcc4247771310VgnVCM1000004f62529fRCRD; "Liebherr-Aerospace and COMAC Sign Master Contract for Chinese Aircraft C919," Liebherr, March 2, 2012, accessed July 10, 2012, http://www.liebherr.com/en-GB/134629.wfw/print-True.

[43] "GE's China Avionics Deal: A Q&A with Lorraine Bolsinger," GE, January 19, 2011, accessed July 10, 2012, http://www.gereports.com/ges-china-avionics-deal-a-qa-with-lorraine-bolsinger/.

[44] For an interesting analysis of some of the related technological and commercial challenges, see Gabe Collins and Andrew Erickson, "A Chinese "Heart" for Large Civilian and Military Aircraft: Strategic and commercial implications of China's campaign to develop high-bypass turbofan jet engines," *China SignPost*, September 19, 2011, accessed July 8, 2012, http://www.chinasignpost.com/2011/09/a-chinese-"heart"-for-large-civilian-and-military-aircraft-strategic-and-commercial-implications-of-china's-campaign-to-develop-high-bypass-turbofan-jet-engines/.

[45] See, for example, Michael Gubisch, "MTU to Work with AVIC on Possible Alternative Engine for C919," *Flight International*, September 21, 2011, accessed July 10, 2012, http://www.flightglobal.com/news/articles/mtu-to-work-with-avic-on-possible-alternative-engine-for-c919-362359/.

maintain technological parity with Airbus and Boeing. Successful execution of this game plan will be an impressive achievement for AVIC in its own right. However, it is in the realm of organizational innovation that AVIC is clearly an innovator rather than imitator. The vertically deeply integrated and horizontally broadly diversified nature of its emergent business model sets AVIC apart from incumbent players in the world of commercial aircraft making. This clearly is not a story of convergence to a global organizational industry "standard."[46]

- **Proposition 2**: Innovative business models pursued by Chinese firms have disruptive potential for changing the rules of the game in global markets.

Whether AVIC will be able to bring to market aircraft that will be truly competitive with Airbus and Boeing products remains to be seen. Interestingly, Boeing seems to consider the C919 program the biggest threat to the established Airbus-Boeing duopoly in the global commercial aircraft industry and believes that AVIC will most likely succeed in developing an aircraft comparable to Airbus and Boeing models.[47] Hence, AVIC's entry into the global market for single-aisle aircraft has potentially game-changing implications on the account of endangering a long-standing duopoly alone. Moreover, its business model perhaps offers an alternative trajectory for change at the industry level that, during the past decades, has been characterized by consolidation among aircraft makers and within the group of component makers, but not across the traditional boundaries of these two types of firms. It is in this context that AVIC's business model innovation has further potential for changing the rules of the game in the global commercial aircraft industry. It will be interesting to track whether the aforementioned alliance between AVIC and General Electric in the area of avionics components will remain an exceptional case or whether it will be emulated by other industry actors.

- **Proposition 3**: Rivalry in global markets often is not only a story of competition between efficient Western corporations and inefficient Chinese state-owned enterprises but rather a contest between fundamentally different business models.

In the case of Chinese state-owned enterprises, many analysts have highlighted the fundamental lack of efficiency due to their ownership status, governance systems, and the protracted nature of their transformation to market competitiveness.[48] Hence entry into global markets on the part of these Chinese firms is often viewed as a single-dimensional fight between efficient Western corporations and inefficient Chinese state-owned enterprises that owe their ability to enter these very global markets solely to state support. But in light of the above discussion of the case of AVIC, such a picture appears to be somewhat simplistic. At least in the case of AVIC, any future battle between AVIC and incumbent commercial aircraft makers for global market share is likely to be a contest between different business models as much as a competitive rivalry between private and state-owned firms.

LIMITATIONS

The Chinese commercial aircraft industry as a critical case has been selected deliberately for the purposes of the present article. After all, the global commercial aircraft industry can be characterized by one strongly dominant business model shared by all major incumbents. In the context of such homogeneity in terms of industry best practices, one might expect a newcomer such as AVIC to imitate this dominant business model. Should such dominance not result in imitation and followership, it appears likely that – in the case of other industries that are not as strongly dominated by a common business model as the global commercial aircraft and components industry – organizational innovation, rather than imitation, might be even more prevalent. Notwithstanding the merit of this deliberate industry selection for the purpose of the present critical case study, unconditional generalizability of the above findings would be contingent upon in-depth exploration of business model innovation, or the absence thereof, in other industries in China.

Given that the C919 is scheduled to have its maiden flight in 2014 and given that there is a non-zero probability of program slippage, it is important to point out that AVIC and its emergent business model for making commercial aircraft remain an aspirational case strongly driven by strategic intent rather than by proven technological and commercial success and on-time delivery. However, when assessing the performance of AVIC, one might be well advised to remain cognizant of significant program delays and technical challenges that have haunted the most recent major aircraft programs of Airbus and Boeing.

It is important to emphasize the emergent nature of AVIC's business model. As suggested above, for many decades it has been the Chinese state's objective to create a domestic commercial aircraft industry. Clearly, industry entry can only be explained by reference to the Chinese (developmental) state. Also, the state remains highly relevant with regards to the structure of the political economy and to many aspects of industrial organization in China.[49] At the same time, AVIC's

[46] Interestingly, as part of its recent efforts to mitigate B787 program delays, Boeing has brought in-house some work that it had previously sourced externally. See, for example, Stephen Trimble, "Boeing confirms deal for Vought's 787 role," *Flightglobal*, July 7, 2009, accessed July 10, 2012, http://www.flightglobal.com/news/articles/boieng-confirms-deal-for-voughts-787-role-329339/.

[47] See Rupa Haria, "China is Biggest Emerging Threat to Boeing And Airbus, Says Albaugh," *Aviation Week*, June 1, 2012, accessed June 10, 2012, http://www.aviationweek.com/Article.aspx?id=/article-xml/avd_ 06_01_2012_ p01-01-463868.xml.

[48] See, for example, Edward Steinfeld, *Forging Reform in China: The Fate of State-Owned Industry* (Cambridge: Cambridge University Press, 1998), and Shahid Yusuf, Dwight H. Perkins, and Kaoru Nabeshima, *Under New Ownership: Privatizing China's State-Owned Enterprises* (Stanford: Stanford University Press, 2005).

[49] See, for example, Huang Yasheng, *Capitalism with Chinese*

business model is also the outcome of managerial choices and learning. A detailed discussion of these firm-internal dynamics is far beyond the scope of the present article. AVIC's business model is emergent to the extent that it has not been the result of execution of a detailed, *ex ante* master plan but an iterative process shaped by multiple factors external and internal to AVIC.

Also, the growth of Japanese firms has given rise to a voluminous literature on Japanese management principles, styles, and practices.[50] The above discussion of business model innovation in the context of the Chinese commercial aircraft industry, however, is meant to suggest neither a generic "Chinese way of business" nor an aerospace variant of the "*shanzhai* phenomenon."[51]

Lastly, the present article is intended to be an analytical study. It is neither a normative endorsement of a particular development model nor a prediction of success or failure with regards to the ultimate performance of the ARJ21 and C919 in global markets.

CONCLUDING REMARKS

The rise of China's economy and of Chinese firms has been one of the most fascinating stories of the world economy during the past decades. This phenomenal transformation has resulted in an empirically rich and analytically insightful body of studies that has shed much light on the inner dynamics of the Chinese political economy at large and of Chinese firms individually.

At the level of the firm, the presence or absence of technological innovation and technological upgrading has often been a key explanatory variable for success. However, many of these studies appear to be somewhat single-dimensional. The present article has argued that this predominantly technology-focused perspective on innovation is likely to overlook other interesting loci of innovation such as a firm's business model. Hence this article has intended to complement the extant technology-focused literature by pursuing an expressly organization-focused perspective. The present article has also proposed that a single-dimensional and oversimplified categorization of Chinese firms as "innovators" or "imitators" with reference to their technological innovative capacity alone runs the risk of failing to capture the potentially game-changing impact of the entry of Chinese firms into global markets.

The case of the commercial aircraft industry in China suggests that Chinese firms can be innovators, rather than imitators, on the basis of business model innovation, that such business model innovation can occur not only at the "bottom of the pyramid" but also at the very "top of the pyramid," and that organizational innovation on the part of Chinese firms has disruptive potential to change the rules of the game in global markets.

Characteristics: Entrepreneurship and the State (Cambridge: Cambridge University Press, 2008).

50 For example, Jeffrey Liker, *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer* (New York: McGraw-Hill, 2004).

51 For a recent exploration of the *Shanzhai* phenomenon, see Sheng Zhu and Yongjiang Shi, "Shanzhai (山寨) Manufacturing – an Alternative Innovation Phenomenon in China – Its Value Chain and Implications for Chinese Science and Technology Policies," *Journal of Science and Technology Policy in China* 1 (2010): 29-49.