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The Role of the Government in the Development of the Aircraft Manufacturing Industry in Korea: Implications for Developing Countries

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ABSTRACT

The aircraft manufacturing industry is critical to national defense and linked to various other industries. This paper explains the development of Korea's aircraft manufacturing industry and the role of the government. Despite late entrance to the industry, Korea has developed and produced basic and jet trainers since the 1990s. In the meantime, the government has pursued technology sharing, integrated large companies, and provided financial incentives to manufacturers. It has also supported the strengthening of human capital and established a government research institute devoted to the aircraft manufacturing industry. In the early 2020s, Korea began to produce advanced fighter jets using its technologies. Based on Korea's experience, this research presents policy implications for developing countries. The government must play a critical role in the aircraft manufacturing industry, which is an example of the infant industry argument. In the early stages of development, a developing country may learn advanced technologies through licensed production contracts and by requesting technology transfer when purchasing aircraft. It is necessary for the government to provide appropriate incentives, particularly for R&D activities, human capital development, and a dedicated government research institute in aircraft manufacturing. Moreover, regulating the number of domestic aircraft manufacturers may lead to greater efficiency.

Keywords: Government; Aircraft; Fighter; Korea; Developing nations.

INTRODUCTION

South Korea (Korea hereafter) has recorded rapid economic growth alongside changes in its industrial structure since the early 1960s. For example, the textile and garment industry, which is a typical labor-intensive domain, dominated the manufacturing sector and led exportation until the mid-1980s. The increase in wage levels drove the emergence of more value-added, technology-intensive industries, which began to assume a primary position in the Korean economy in the late 1980s. These industries, such as the electronics and automobile fields, have prevailed in Korea's manufacturing sector since the early 2020s. This development can be partly attributed to active industrial policy implementation in the country. That is, the Korean government had pursued a policy of promoting heavy and chemical industries (HCIs) since the mid-1970s before actively enforcing a policy on research and development (R&D) in technology-intensive sectors in the mid-1980s (Mah 2007).

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Korea's entry into the aircraft manufacturing industry was half a century behind that of nations that have developed their industries since the early 1900s. It was not until the 1970s that Korea debuted its manufacture of aircraft components during its active promotion of HCIs. Reflecting the rapid development of the aircraft manufacturing industry over the past several decades, the production value of Korean-made aircraft and aircraft components amounted to US$ 6.0 billion, and its exports reached a value of US$ 2.8 billion in 2019 (Ministry of Trade, Industry, and Energy [MOTIE] 2021a).

In the development described above, a critical player was the government, with the public sector negotiating international agreements on licensed production and ensuring efficiency by selecting capable companies to fulfill the contracts. The government's involvement was natural, as the typical first stage of entry into the aircraft manufacturing industry revolves around national defense. The negotiated contracts were thus primarily aimed at manufacturing military aircraft, as self-sufficiency in supplying such vehicles was the government's initial goal for the advancement of the industry. The extensive preliminary cost of manufacturing aircraft made sizable investments essential, driving the government to provide substantial subsidies to entities processing aircraft projects (Jeon *et al.* 2020). The government's involvement was also motivated by the fact that aircraft manufacturing is a high-value-added industry with a crucial role in defense and positive spillover effects on the national economy and other allied sectors.

Korea's late entrance into the aircraft manufacturing industry and the high barriers to entry are explained by the complicated characteristics of this industry. This research aims to explain the evolution of Korea's aircraft manufacturing sector and the significant role of the government in this process. This paper is unique, as there is limited comprehensive research examining the development of the aircraft manufacturing industry in countries that have experienced rapid development, such as Korea, while focusing on the role of government policies during its progression. This paper also presents policy implications for developing countries that endeavor to develop their aircraft manufacturing industries.

Evolution of Korea's aircraft manufacturing industry

Korea's aircraft manufacturing industry was founded in the 1950s amid the Korean War. At the time, the industry was limited to the basic maintenance, repair, and operation (MRO) of military aircraft produced in the United States. Korea continued to cultivate its ability to maintain its importation of military aircraft and expand its repair facilities, thus beginning to gain recognition in these respects (Choi 2011). However, the nation's range of aircraft manufacturing capabilities did not extend beyond the maintenance of military aircraft. The industry lacked experience in the MRO of civil aircraft and skills in the domestic manufacturing of aircraft components. This situation persisted for the next 2 decades.

The 1970s, during Korea's efforts to promote HCIs, saw a shift from aircraft maintenance to aircraft manufacture. The HCI drive since 1973, led by President Park Chung Hee, specifically targeted six industries for development (Oh 1996; Mah 2007), one of which was the machinery sector, which encompassed the production of aircraft components. During the period of HCI promotion, the government issued a production license to Korean Air to manufacture the 500MD, a helicopter for military use developed by the Hughes Aircraft Company in 1976 (Choi 2011).

In 1980, the Korean and U.S. governments signed a memorandum of understanding for the licensed production of the Northrop F-5 light fighter, which also cleared the way for a sales and production license agreement between Northrop and the Korean government (Cho 2003). For these initiatives, Korean Air was again designated production responsibilities, and the company assembled and produced 68 units of F-5 E/F fighters from 1982 to 1986 (Cho 2000). This contract was an opportunity for Korean Air to learn and develop its technology, as well as improve its ability to domestically produce and assemble fighter components. Nevertheless, although it manufactured 3,348 aircraft components, these accounted for only 22% of the value (Cho 2003). Meanwhile, Samsung acquired a license from General Electric to produce and assemble F-5 E/F engines for domestic fighter jets (Lee 1996). Through this experience, the company succeeded in localizing the production of components of the engine, allowing it to secure a monopoly in jet engine production in the country. The first fighter jets domestically produced and assembled in Korea by Korean Air and Samsung were known as the KF-5 aircraft.

Since the late 1970s, the Korean Air Force and the government had been planning the first Korean Fighter Program (KFP), which was intended to develop the aircraft manufacturing industry in the country (Cho 2000). The U.S. F-16 developed by General Dynamics was the model chosen for licensed production, and Samsung was selected as the main contractor for the project (Cho 2003). At the time, the KFP was Korea's most extensive endeavor to expand the aircraft manufacturing industry. The total project

size was estimated at US$ 5 billion, of which US$ 1.3 billion (or 1 trillion Korean won as per the exchange rate in the late 1980s) was invested in facilities and equipment (KDIA 2000). It also involved 120 companies and employed 4,000 individuals (KDIA 2000). A total of 120 KF-16 fighters, the domestically produced F-16 model, were delivered to the Korean Air Force by 2000 (KDIA 2004).

The KFP was considered a meaningful step in Korea's development of the aircraft manufacturing industry, as the project enabled the country to adopt advanced production technology that was essential to developing an advanced fighter jet. During the initial KFP, national defense regulations mandated that the purchase of a military weapon be accompanied by a trade offset of 30% of the purchase price. The Korean government ensured the trade offset for the F-16 to be the transfer of technologies necessary for developing the advanced jet trainer called KTX-2 (Jeon 2011). In doing so, it laid a strong foundation and the technological capability for Korea to produce advanced jet trainers and fighter jets. The KFP also accelerated integration between companies manufacturing finished products and components and those specializing in materials (Cho 2000).

Toward the end of the first KFP and after the 1998 economic crisis, in the process of restructuring large conglomerates known as *chaebol*s, the Korean government sanctioned the integration of three *chaebol*s – Hyundai, Daewoo Heavy Industries, and Samsung (Jeon 2011) – into the specialized company Korea Aerospace Industry (KAI), which was dedicated to aircraft manufacturing beginning in 1999. The company subsequently moved on to the second KFP, producing 20 more KF-16 fighter jets for the Korean Air Force. The first and second KFPs enabled a 78% localization rate for aircraft component production and resulted in an additional US$ 1.5 billion in value per year in the early 2000s (KDIA 2004). Thus, the KFP was a significant step toward a self-reliant aircraft manufacturing industry in Korea.

Korea's aircraft industry began to pursue a shift from licensed production to independent development and production in the 1980s. In 1983, the government research institute devoted to defense, the Agency for Defense Development (ADD) commenced assessing the manufacture of the basic trainer KTX-1, later known as the KT-1, with an initial budget of 70 million Korean won (US$ 88,000) (Gang 2003). The first Korean trainer development project was implemented to replace the imported basic trainers used by the air force at the time, which were the T-41B and the T-37 (Cho 2003). Daewoo Heavy Industries, in collaboration with the ADD, was the main contractor for the KTX-1 project. The initial R&D project to develop the basic trainer was designated a national initiative by the Korean government in 1990 (Cho 2003).

In 1997, the KT-1 completed a 1,000-hour test flight, and in 1998, it was approved for combat use by the U.S. Department of Defense. Over 11 years, approximately 110 billion Korean won (about US$ 150 million as per the exchange rate in 1991) was invested in the development of the aircraft (Park 2001). In 1999, a mass production contract was signed with Korea's Defense Acquisition Headquarters, currently known as the Defense Acquisition Program Administration (Park 2001). The development and production of the KT-1 basic trainer was a momentous stage in Korea's aircraft manufacturing industry, as it was the first military aircraft to be developed independently by the country using domestic technology. The KT-1 development program enabled Korea to achieve proficiency in armament system integration, key aircraft component design and development, software development, and evaluation (Cho 2003). In addition, the KT-1 was the first Korean-developed aircraft exported in 2001 (Choi 2011).

Korea's ability to independently develop aircraft progressed with its accumulated experience in aircraft assembly production through international licensing and technology introduction. The KTX-2 aircraft, now known as the T-50, was a significant peak achieved by the industry based on the nation's previous efforts and experiences. The KTX-2 is a jet aircraft capable of traveling at a speed of over Mach 1.5 (i.e., 1,852 km per hour) (KAI 2023) – a considerable advancement from the propeller-driven KTX-1, which can travel only up to 648 km per hour (KAI 2023). In 1990, the ADD supervised the KTX-2 project, for which Samsung, Korean Air, Daewoo Heavy Industries, LG, other smaller entities, and a U.S. defense company, Lockheed Martin, collaborated (Lee 1996). Thanks to the KFP, Korea cultivated the ability and technology to develop the KTX-2. Nevertheless, investment was limited. Although expenses related to military equipment are typically covered by the public sector, the Korean government provided an insufficient budget for the systems development phase of the KTX-2 (Jeon 2003).

Consequently, the KTX-2 scheme became the first private sector-led military development program in Korea's defense industry (Jeon 2003). The Korean government was determined to achieve self-reliance in military defense and the development and production of advanced military aircraft systems. The integration of Samsung, Daewoo, and Hyundai into KAI led to the development of the KTX-2 aircraft in 1999. The KTX-2 project commenced the systems development phase, and in 2001, the advanced supersonic

jet trainer T-50 was exhibited to the public. In August 2002, the T-50 completed its first flight (Jeon 2011) – yet another mark of advancement that made Korea the 12th country in the world to domestically produce a supersonic aircraft (MOTIE 2021a).

For the project to achieve the ultimate goal of independent production, it was imperative to localize the manufacture of its components because this would enable the country to attain the positive spillover effects of having a self-sufficient aircraft manufacturing industry. Sixty percent component localization was achieved for the T-50 by 2021 (MOTIE 2021a). After the development of the T-50, KAI continued its efforts to develop advanced fighter jets for the Korean Air Force, including the FA-50, a light combat aircraft operating since 2013, and the TA-50, a lead-in jet trainer (KAI 2021a).

Korea's determination to progress in aircraft manufacturing persisted throughout the 2000s. In 2001, the president at the time, Kim Dae-Jung, announced his plans to develop a domestic state-of-the-art fighter jet by 2015. This would later be announced as the Korean Fighter Experimental (KF-X), which was aimed at replacing the outdated F-4 and F-5 fighter jets with fighters classed at KF-16 or above. These fighters, which were deemed appropriate for the nation's future military operations, were developed through domestic R&D. However, the program was met with controversy and delays, as it was considered highly risky (Hyeong and Kim 2015). Despite this risk, the government expected significant economic benefits, including the employment of 70,000 workers, the stimulation of local economies through newly established infrastructure, and the creation of considerable additional value from the development of core technologies in the aircraft manufacturing industry (Hyeong and Kim 2015).

The Korean government estimated the total cost of the project to be 8.8 trillion Korean won (i.e., about US$ 8.6 billion based on the 2014 exchange rate), of which the Ministry of National Defense would pay 60%, domestic and foreign companies would shoulder 20%, and Indonesia, via a joint development agreement, would pay 20% (Hyeong and Kim 2015). The KF-21, which succeeded in its first flight in 2022, was the first indigenously developed and produced frontline fighter developed with minimal dependence on U.S. technology. Its production was also highly localized at approximately 65% (Ji 2022).

The Korean government's focus on developing and producing military aircraft was an obvious step to advance the aircraft manufacturing industry given the definite demand for military aircraft from the nation's air force for defense. Unfortunately, the same could not be said about civil airplanes, for which the global market is generally characterized as a duopoly (i.e., Airbus and Boeing), making it near impossible to enter. Nonetheless, Korea has progressed in producing civil aircraft components through joint international development. In 1999, for example, KAI produced components for Boeing's B777-9 and established a lifetime contract, in 2005, to produce components for the B787 (KAI 2021a). Contracts for international joint ventures have continued to serve Korea in increasing its production and export of aircraft components. Over the past 4 decades, the country has gradually progressed in manufacturing aircraft components, helicopters, and military aircraft despite the late establishment of its industry.

Government policy on promoting the aircraft manufacturing industry

Regulations

When aircraft were introduced to Korea in the 1950s, the nation lacked information, technology, and experience in this respect, thereby restricting its aircraft manufacturing industry to MRO. The government attempted to develop the sector by providing and modifying regulations to suit the needs of the industry. Changes in the industry began to occur in the 1970s when the government actively pursued its HCI promotion policy. In 1978, the Aircraft Manufacturing Business Act of 1962 was replaced by the Aviation Industry Promotion Act, whose purpose was the development of the national economy through the efficient promotion of the aviation industry. It stipulated the advancement of military aircraft production – a provision missing from its predecessor. Under the Aviation Industry Promotion Act, the MOTIE can identify aircraft or aircraft components deemed necessary for the development of the industry and authorize a given enterprise to produce these technologies to avoid excessive competition among entities.

Specifically, in the 1980s, the government appointed Korean Air, which had experience with the licensed production of helicopters, and Samsung, which had experience maintaining the engines of 500MD helicopters, to produce the KF-5 light fighter under license. Per the Aviation Industry Promotion Act, Korean Air and Samsung began to monopolize the aircraft and jet engine

assembly markets, respectively. This law also required the MOTIE to establish a basic plan for promoting aircraft production, with provisions to address matters concerning the localization of aircraft component production, technology development, and government support. The implementation of the act signified the beginning of the government's determination to advance Korea's lagging aircraft manufacturing industry. This was also reflected by the government's direct involvement in acquiring aircraft production licenses for issuance to capable Korean companies. Note, however, that the government did not endorse the sector as aggressively as others did, such as the automobile industry, during the 1970s and 1980s, given the complex process of aircraft manufacturing (Hwang 2000).

In 1987, the Aviation Industry Promotion Act was replaced by the Aerospace Industry Development Promotion Act, which enabled the government to assign items to be developed to the entities that it selected. It mandated the establishment of a basic plan for the development of the aerospace industry and covered matters concerning the implementation of a comprehensive R&D system, participation in international joint development projects, and the introduction of technologies. Table 1 summarizes the vision, basic goals, and major strategies of the basic plan for the development of the aerospace industry since the late 1990s. As shown in the Table 1 , the government began to actively promote the aircraft manufacturing industry through planning. The act likewise stipulated the establishment of research institutes for the continuous and efficient development of aerospace science and technology. By the 1990s, the government realized the importance of R&D in further developing the aerospace industry. The Aerospace Industry Development Promotion Act of 1987 paved the way for the implementation of costly R&D programs, including the development of the basic trainer KT-1, the jet trainer T-50, the light combat aircraft FA-50, and the advanced fighter jet KF-21.

Table 1. Korea's basic plans for development of the aerospace industry.

	First Basic Plan (1999-2009)	Second Basic Plan (2010-2020)	Third Basic Plan (2021-2030)
Vision	Becoming a country finished aircraft	Producing finished aircraft and having core technologies	Becoming a G7 country in the aviation industry
Goals	Production base for major parts of medium/large aircraft Becoming a country producing small/medium-sized aircraft Establishing independent development capabilities of fighter jets and helicopters	Becoming a country exporting finished aircraft Having 300 aviation for the future aircraft 70,000 employees	Developing new markets by upgrading the aircraft manufacturing industry Building the foundation manufacturing industry by advancing R&D
Major Strategies	Manufacturing components for civil aircraft Independently develop military aircraft and localize their parts Expanding market for civil and military aircraft Securing core core technology improving infra.	Developing and exporting finished aircraft Producing core components and expanding maintenance, repair, and operation (MRO) Securing R&D for core technology Advancing infra.	Strengthening infra Strengthening market competitiveness and upgrading parts industry Creating urban air mobility (UAM)/ advanced air mobility (AAM) ecosystem Developing advanced technology and technology contributing to the industry

Source: MOTIE (2021a).

Financial and fiscal incentives

The Korean government provided financial incentives for the promotion of the aircraft manufacturing industry in accordance with the Aviation Industry Promotion Act of 1978, which stipulated that the government might subsidize all, or part, of the technical development expenses of a designated entity and provide long-term funds at low interest rates. This financial incentivization continued under the Aerospace Industry Development Promotion Act of 1987 and its revisions, which stipulated that the government could lend low-interest funds and shoulder R&D project-related expenses. Subsidies were essential for entities participating in aircraft manufacturing given the exceptionally high cost of developing an aircraft. The total amount of R&D expenditure borne by the

government increased from 184 billion Korean won (US$ 279 million) in 1980 to 2.4 trillion Korean won (US$ 1.9 billion) in 2000 and then to 24.2 trillion Korean won (US$ 22.3 billion) in 2020 (Han and Kim 2021). Such a budget allocation by the government was partly directed to the subsidization of R&D activities related to the aircraft manufacturing industry.

Recent years have seen increased government R&D investment targeting the aircraft manufacturing industry. As indicated in Table 2, the annual average growth rate of the government's budget for R&D expenditure in space, aviation, and maritime technology reached about 7% during 2012-2020. The government's budget for R&D expenditure in space, aviation, and maritime technology increased from 1.6 trillion Korean won, accounting for 10.1% of the government R&D expenditure as a whole, in 2012 to 2.9 trillion Korean won, accounting for 11.9% of the government R&D expenditure, in 2020. This increased investment enabled Korea to successfully develop complex aircraft, such as the KF-21, of which 60% was funded by the Ministry of Defense (Hyeong and Kim 2015). The government's increased willingness to provide subsidies for R&D programs and enlarge the R&D budget since the 1990s has stimulated innovation in aircraft development and manufacturing.

Table 2. R&D expenditure for space, aviation, and maritime technology (unit: billion Korean won).

R&D investment	Year				
	2012	2015	2018	2020	2022
Total R&D expenditure [a]	16,024	18,923	19,668	24,220	n.a.
Space, aviation, and maritime Technology expenditure [b]	1,624	1,889	2,129	2,882	n.a.
KARI's government funds[c]	n.a.	113	110	104	124

Source: a: Han and Kim (2021); b: Ahn and Kim (2016) for 2012; KISTEP (2020) for 2015-2020; c: KARI (2023).

Education and research institutes

Investing in education for skilled human capital was equally essential to innovation in the aircraft manufacturing industry. In Korea's attempt toward industrialization and economic development, it realized its lack of human capital with expertise in science, technology, and engineering, driving the government to reform the education system as part of the 1973 HCI promotion policy. A critical requirement, therefore, was to provide specialized education to produce skilled workers and successfully develop HCIs. For this reason, the government focused on expanding the HCI-related departments of vocational schools, technical high schools, engineering colleges, and graduate schools. By 1974, the number of individuals studying machinery in technical high schools increased by 53% compared with 1973 levels (Jung and Mah 2014; Park 2011). The reform to offer better education for the development of HCIs during the 1970s and 1980s fulfilled the demand for competent workers, thus providing the human capital necessary to evolve the aircraft manufacturing industry.

In the process of supporting HCI-related education, the government has offered, since 1973, special military service exemptions to young male researchers and industrial engineers to motivate students and workers to contribute to national development through research. Such benefits continue under the Military Service Act. The government supports entities selected by Korea's Military Manpower Administration (MMA), such as research institutes, graduate schools, and private companies, to enhance the competitiveness of the industry and national economy (MMA 2023). As a government research institute, the Korean Aerospace Research Institute (KARI) provides its young male researchers with the privileges of military service exemptions. Such benefits have also been provided by KAI to qualified researchers since 1994 (MMA 2021). Exemption from military service obligations for talented graduate students and researchers enabled them to contribute to the development of technology-intensive industries, such as aircraft manufacturing (Mah 2007).

The government established the KARI in 1989 with the aim of facilitating economic development through technological progress in the aerospace domain. The KARI has helped companies in the industry through technology transfer. Since its establishment, it has had a spillover effect on the national economy by producing as much as 4.5 trillion Korean won (US$ 4.1 billion based on

the 2020 exchange rate). It has also contributed to the aircraft manufacturing industry by reinvesting its R&D budget in external companies to produce prototypes and technologies as well as conduct joint research (KARI 2023).

KARI's research activities are funded by the government each year. The annual average growth rate of R&D expenditure of all industries in Korea reached 5.3% from 2012 to 2020. It increased from 16.0 trillion Korean won (US$ 14.9 billion) in 2012 to 24.2 trillion Korean won (US$ 22.3 billion) in 2020. During the same period, the annual average growth rate of R&D expenditure devoted to space, aviation, and maritime technology amounted to 7.4% – a figure substantially higher than the growth rate of the national economy as a whole (Han and Kim 2021).

Performance of Korea's aircraft manufacturing industry since the 2000s

The aircraft manufacturing industry has grown significantly since the 1990s when Korea started domestically developing and manufacturing aircraft and aircraft components. Table 3 shows production capacity by item from 2013 to 2021, indicating Korea's steady production of over US$ 1 billion worth of aircraft yearly. The annual average growth rates of aircraft and engine production equaled 4.1 and 17% from 2013 to 2019, respectively. Aircraft production value as a whole rose from US$ 3.5 billion in 2013 to US$ 5.7 billion in 2019. These figures fell somewhat to US$ 4.6 billion in 2021 because of the coronavirus disease 2019 (COVID-19) pandemic and the consequent worldwide recession. Overall, the annual average growth rate of the values produced in the aircraft manufacturing industry reached 8.5% from 2013 to 2019. In addition, integrated aircraft companies, including KAI, Korean Air, and Hanwha Aerospace, and aircraft component companies experienced increases of 263 and 333% in exports from 2009 to 2019 (MOTIE 2021a).

Table 3. Korea's aircraft production by item (unit: US$ million, %).

Year	Finished airframe engine avionics				Others	Total
2013	1,368	1,269	528	132	215	3,512
2016	1,738	2,307	745	244	214	5,247
2019	1,738	2,111	1,357	214	307	5,727
2020	1,825	1,770	555	267	141	4,558
2021	1,688	1,425	936	429	129	4,607
Annual average growth rate (2013-2019)	4.1	8.8	17.0	8.4	13.7	8.5
Annual average growth rate (2013-2021)	2.7	1.5	7.4	15.9	2.4	3.5

Source: KAIA (2022).

The onset of exporting domestically developed and produced aircraft in 2001 was a notable advancement in the industry because it was the first time that Korea supplied an aircraft to overseas buyers independently of U.S. technologies. Table 4 summarizes the volumes of aircraft exported to other countries by aircraft type. The KT-1, Korea's first independently developed trainer, was the first aircraft exported to Indonesia. By 2021, Korea had secured contracts to export the KT-1 to Indonesia, Turkey, Peru, and Senegal and delivered an accumulated total of 84 aircraft. For the T-50 jet trainer series, a significant achievement for this aircraft as the first domestically developed supersonic jet was Korea's acquisition of export contracts with Indonesia, Iraq, the Philippines, Thailand, and Poland. By 2022, Korea had delivered an accumulated total of the 141 T-50 series aircraft.

For the export of aircraft components, Korea's leading aircraft manufacturing company, KAI, has maintained a close relationship with Airbus and Boeing since the early 2000s. For instance, it secured a contract with Boeing in 2021, allowing it to produce and deliver the B787 Dreamliner's nacelle to Boeing for the period 2023 to 2027 – a project expected to be worth 120 billion Korean won (i.e., about US$ 90 million) (KAI 2021b).

Table 4. Accumulated exports of finished aircraft as of 2022.

Aircraft type		Destination	Number
KT-1 (Basic trainer)		Indonesia	20
		Turkey	40
		Peru	20
		Senegal	4
T-50 series (Advanced trainer)	T-50	Indonesia	22
		Iraq	24
		Thailand	24
	FA-50	Philippines	23
		Poland	48

Source: MOTIE (2021a).

Korea's export values for airplane and helicopter components equaled US$ 123 million in 2002 and rose to US$ 1.1 billion in 2010 and then to US$ 1.8 billion in 2019. They shrank to US$ 0.9 billion in 2021 because of the global recession. The share of Korea in global aircraft component exports rose from less than 0.5% in 2002 to over 1.8% in 2021 – a considerable growth rate compared with those of aircraft manufacturing industries in leading countries. For instance, the annual average growth rates of exports from Germany and France were 3.3 and 2.1%, respectively, whereas the export values of the United Kingdom and the United States have decreased over the past 2 decades. These nations have been operating in the aircraft manufacturing industry long before Korea's entry and have had the opportunity to rapidly expand given participation in the World Wars, for instance. Nonetheless, the United States, France, the United Kingdom, and Germany shared 45% of the world's aircraft component exports as of 2021 (ITC 2022a), positioning Korea behind these nations.

Table 5 lists the total export values of manufactured aircraft and aircraft components, which nearly doubled from US$ 119 billion in 2002 to US$ 223 billion in 2021. Korea's exports of aircraft and aircraft components rose from US$ 252 million in 2002 to US$ 1.1 billion in 2021. The annual average growth rate of Korean exports reached 7.9%, whereas the four leading nations have recorded growth rates of 2 to 3% since 2002. Korea's share increased from a mere 0.2% in 2002 to about 0.5% of the total global export values in 2021, while the United States accounted for 40%.

Table 5. Export values of aircraft, spacecraft, and their parts (unit: US billion; %).

Year	World	USA	France	Germany	UK	Korea
2002	118.6	43.9	17.2	16.8	8.8	0.3
2010	223.0	79.6	46.4	31.0	13.8	1.2
2015	330.1	131.7	54.2	43.9	19.0	1.9
2019	336.7	136.5	53.6	43.2	18.4	2.4
2020	218.7	81.3	29.1	28.9	13.0	1.6
2021	222.8	89.1	31.0	27.6	13.6	1.1
Share (2021)	100.0	40.0	13.9	12.4	6.1	0.5

Source: ITC (2022a).

Aircraft production in Korea has increased rapidly. For instance, up until the end of 2022, KAI has produced more than 600 aircraft, including basic trainers, advanced jet trainers, and their derivatives. It has also produced more than 200 helicopters (KAI

2021a). Table 6 illustrates Korea's production and importation of aircraft and aircraft components from 2002 to 2021. Its production values increased from US$ 1.4 billion in 2002 to US$ 5 billion in 2021, and its import values tripled from US$ 730 million in 2000 to US$ 2.2 billion in 2021. From 2002 to 2021, the annual average growth rates of production and importation equaled 7.1 and 5.9%, respectively. Because Korea increased its capacity to produce and export aircraft and aircraft components, it also needed to expand its importation. A comparison of performance between 2002 and 2021 showed that Korea's aircraft imports exceeded its exports each year, except for 2017.

Table 6. Korea's production and imports of aircraft, spacecraft, and their parts (unit: US million; %).

Year	Production	Imports
2002	1,366	730
2005	1,398	1,365
2010	2,430	2,819
2015	4,886	3,725
2019	6,028	3,610
2020	4,903	2,203
2021	5,035	2,160
Annual average growth rate	7.1	5.9

Sources: MOTIE (2021b); ITC (2022b).

Table 7. Number of patents in aircraft, aviation, and cosmonautics.

Patent	Years						
	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	2016-2018	2019-2021
Application	223	253	409	600	1,385	2,031	2,231
Registration	75	185	119	247	481	1,184	1,456

Source: KIPO (2022).

Korea's progress in R&D is reflected by the number of patents applied and registered by the country. The Korean government began to emphasize R&D in the aircraft manufacturing industry in the 1990s with the establishment of the KARI, and it substantially increased its R&D expenditure. Table 7 presents the number of patents for which Korea applied in relation to aircraft and cosmonautics. This number increased sharply from 223 between 2001 and 2003 to 2,231 between 2019 and 2021 – a significant expansion pointing to continuous improvement in sector innovation. The number of patents registered equaled 75 between 2001 and 2003, translating to 33% of applications being accepted. This figure rose to 1,456 between 2019 and 2021, indicating an increase in acceptance rate of 65%. Thus, the establishment of the KARI drove increased R&D expenditure, and generous incentives have led to the innovation and rapid development of the aircraft manufacturing industry in Korea.

Notwithstanding Korea's success in developing and producing jet trainers and supersonic fighter jets, its aircraft manufacturing industry remains behind several leading countries in the sense that it has failed to develop the engines used in fighter jets. As of 2023, only a number of nations, including the United States, France, China, and Russia, have acquired the capability to produce their own jet airplane engines. Although Korea developed the advanced fighter jet KF-21, its engine is manufactured by General Electric. Even if it can produce the KF-21 in the coming decades, its exportation to other countries may not materialize given the conditions underlying the contract between Korea and General Electric with regard to the engine (Park 2023).

Conclusion and policy implications

Korea had lagged behind several developed countries in aircraft manufacturing, reflecting its low level of economic and technological development. The Korean government recognized the importance of such industry in both economic development

and national security. Its essentiality in the former stems from the industry's linkage to many other sectors and the characteristics of an advanced technology-intensive industry. Its significance in the latter is associated with, for example, Korea's complete reliance on the importation of military aircraft from a few developed countries, which may engender serious problems in the importation of components in succeeding years, depending on changing diplomatic situations. Such uncertainties may be reduced by the development of aircraft, such as jet trainers and fighter jets.

The Korean government has been the leading player in the development of the aircraft manufacturing industry. It negotiated numerous international agreements for licensed production and strategically selected capable companies to maximize efficiency. The aircraft manufacturing sector substantially contributes to national defense capabilities. Given the market failures observed in national defense and the government's critical role in maintaining national security, it is imperative for the government to actively foster the development of the aircraft manufacturing industry, particularly in a developing country.

The aircraft manufacturing industry in Korea can be regarded as an example of the infant industry argument on economic advancement in developing countries. That is, although Korea had no comparative advantage in producing aircraft until the 1980s, the government tried to promote it through various policy measures. In particular, the development of its aircraft manufacturing industry began in the 1990s before it evolved to include exportation starting in the 2000s. Korea's experience shows that, with government promotion backed by appropriate policy measures, the aircraft manufacturing industry of a developing country can transform into a competitive sector on the global stage.

The Korean government initiated the promotion of its industry in the mid-1970s through regulations, the provision of subsidies, and support for human resources and R&D. These efforts led to the acquisition of licensed production contracts from U.S. companies. Full-fledged expansion occurred during the 1990s, as the government actively pursued large-scale projects aimed at the indigenous development and production of military aircraft. As a result of the Korean government's intimate involvement in the progress of the aircraft manufacturing industry, the country's capability to domestically develop and produce aircraft has considerably improved.

The Korean government chose specific aircraft or aircraft components for development and prevented excessive competition among companies through the designation of competent entities to partake in the projects. This meant that the large entities already advanced in other technology-intensive industries were chosen and able to accumulate experience in aircraft manufacturing. The role of the government in guaranteeing resource allocation was essential for Korea's rapid development in this respect. As with Korea, a government's active promotion of the aircraft manufacturing industry appears to be critical in its advancement in developing countries, which lag far behind its developed counterparts given the lack of advanced technologies and experience in development and production.

International cooperation introduced Korea to the process of manufacturing an aircraft through licensed production. The role of the government in negotiating with foreign entities to acquire such contracts was vital in Korea's initial stage of aircraft manufacturing. Accordingly, a government's active pursuit of international cooperation, particularly with respect to the transfer of advanced technologies, can support the rapid development of an aircraft manufacturing industry, especially to aspiration for independent development and production.

The Korean government also encouraged the integration of three leading companies in aerospace – Samsung, Daewoo Heavy Industries, and Hyundai – into the sole producer in the industry, that is, KAI. This integration enabled the skills, experiences, and technologies of each company to be shared. KAI has led Korea's aircraft manufacturing industry since the 2000s and has succeeded in developing, producing, and exporting both aircraft and aircraft components. These findings indicate that encouraging dominant companies to share their knowledge and skills may accelerate development in an aircraft manufacturing industry, which requires the accumulation of advanced technologies and scientific knowledge. As with Korea, a government's inducement or enforcement of integration among large private companies is likely to lead to improved efficiency in light of the economies of scale in the aircraft manufacturing industry.

Given the lack of technologies and knowledge, Korean companies were compelled to produce helicopters and fighter jets through licensed production contracts in the 1970s and 1980s. During licensed production, however, they were able to learn advanced technologies to a certain extent. The Korean government worked diligently to introduce the sophisticated

technologies needed to develop and produce aircraft. For instance, it requested technology transfer when purchasing weapons from developed countries and guaranteed the transfer of advanced foreign technologies occur during its development of the jet trainer. The same strategies would be helpful in the early stage of development in the aircraft manufacturing industries of developing nations.

In addition to introducing advanced technologies from developed countries, the Korean government endeavored to create its own technologies for aircraft development and production. It allocated substantial subsidies to the R&D activities essential to developing military aircraft, thereby enabling the independent development and manufacture of a supersonic jet trainer in the early 2000s and a state-of-the-art fighter jet in the early 2020s. These experiences demonstrate that since aircraft development is highly risky and necessitates extensive R&D investment, governmental support of R&D activities would be critical to progress in the aircraft manufacturing industries of developing countries.

In Korea, the government began to promote the aircraft manufacturing industry as part of the HCI drive in the late 1970s. Given that the aircraft manufacturing industry is linked to various other industries, its development is likely to benefit from advancements in the other HCI sectors directly linked to aircraft production. Therefore, when designing plans to promote the aircraft manufacturing industry, developing countries should consider it a part of their overall economic development plan, particularly within the framework of the HCI development plan.

Import protection and promotion policies in Korea were not exclusive to the aircraft manufacturing industry. Since the mid-1970s, the Korean government has targeted several sectors within the HCIs. For instance, it made concerted efforts to protect and promote the automotive and shipbuilding industries. The government sought to expand the production capacities of a selected number of automobile producers and shipbuilders, leveraging the economies of scale properties characterizing these industries (Cho 2021; Lee and Mah 2017). Additionally, the government continued to lead the semiconductor industry until the first half of the 1980s (Amsden 1989). Although regulation, protection, and subsidization of these industries began to weaken substantially by the late 1980s, in light of the advanced technologies required to develop aircraft, the Korean government persisted in regulating the number of producers and providing incentives to the aircraft manufacturing industry even under the World Trade Organization (WTO) system, which demands cautious use of government policy. This indicates the importance of the aircraft manufacturing industry.

In Korea, the reform of the education sector to offer the training necessary for the development of HCIs during the 1970s and 1980s fulfilled the demand for competent workers. The Korean government strengthened the system overseeing education in technical high schools, natural science and engineering colleges, and graduate institutions, offering programs in science and engineering beginning in the 1970s. This provided a source of the human capital needed for the development of the aircraft manufacturing industry. Together with financial incentives, such as scholarships, nonfinancial rewards may also effectively motivate young and bright students to choose jobs in research in value-added, technology-intensive industries, such as the aircraft manufacturing sector.

Realizing the importance of developing advanced technologies in the aircraft manufacturing industry, the Korean government established a government research institute fully devoted to the aircraft manufacturing industry in 1989. This institute has successfully provided appropriate information and technologies needed for industry development. In developing countries lacking capital, technologies, and human resources, the establishment of such research entities can contribute to advancement in producing technology-intensive products, such as aircraft.

Given that Korea strived to independently develop and produce military trainers, its aircraft manufacturing industry developed rapidly, enabling it to export its aircraft. Despite the lack of technology in the early stages of development, the Korean government envisioned the aircraft manufacturing industry as a potential export industry in the long run. This plan contributed to improvements in production technologies and product quality, while reducing the average cost of production. Korea's experience illustrates that a latecomer in the aircraft manufacturing market may succeed with a well-designed, active plan for support from the government. Despite Korea's success in the aircraft manufacturing industry thus far, the development of its own jet engines would be critical in its further development, but this step may take a few more decades.

CONFLICT OF INTEREST

Nothing to declare.

AUTHORS'CONTRIBUTION

Conceptualization: Yim J, Mah JS; **Formal analysis:** Yim J; **Research:** Yim J; **Methodology:** Yim J; **Supervision:** Mah JS; **Writing – Preparation of original draft:** Yim J; **Writing – Proofreading and editing:** Yim J, Mah JS; **Final approval:** Mas JS.

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