Catching-Up and National Environment: The Case of the Korean Aircraft Industry

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Abstracts

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Korean firms have attempted to catch up in the aircraft industry during last quarter century. Korean firms have built up their capabilities by moving from parts manufacturing through subassembly to system integration. The number of projects carried out and the intensity of technological effort undertaken by firms strongly influences market position and firm performance.

However, successful catching up is not simply dependent on capability building within the firm. The national environment (Porter, 1990) in which firms are located plays a pivotal role. The Korean government has been effective in creating a favorable environment in many areas, but has not been able to replicate this success in the aircraft industry. Opportunities for learning in the aircraft industry have been hampered by the small size of the Korean civilian aircraft market and the sophisticated requirements of military systems. A policy of domestic rivalry in airframe manufacture has created too many firms for such a small market.

The ability of Korean firms to catch up in the aircraft industry depends on both the internal capabilities of firms as well as appropriate government policies and the involvement of government research institutions and universities over an extended period of time.

There have been many studies about the catching up of developing countries in mass production (such as automobile, consumer electronics, and recently DRAM), but few in complex systems, such as aircraft.

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I. Introduction

This paper aims to examine the influence of national environment in catching-up of the Korean aircraft industry. Internationalisation is a pervasive trend in modern industrial society, especially in the aircraft industry. However, the role of the home nation is still important, as most technological activities are carried out in their home countries, even in multinational firms. This underlines the importance of the home base of firms. Firms occupy a position in their home country, and at the same time, they are embedded in a nation's system of innovation.

Firm capabilities are essential to the acquisition and assimilation of foreign technologies, and critical to the process of catching up with world frontier firms. However, I argue that catching-up in the aircraft industry should not be regarded simply as an internal matter. On the contrary, the national environment as well as the nature of the industry in which firms are located must be taken into account.

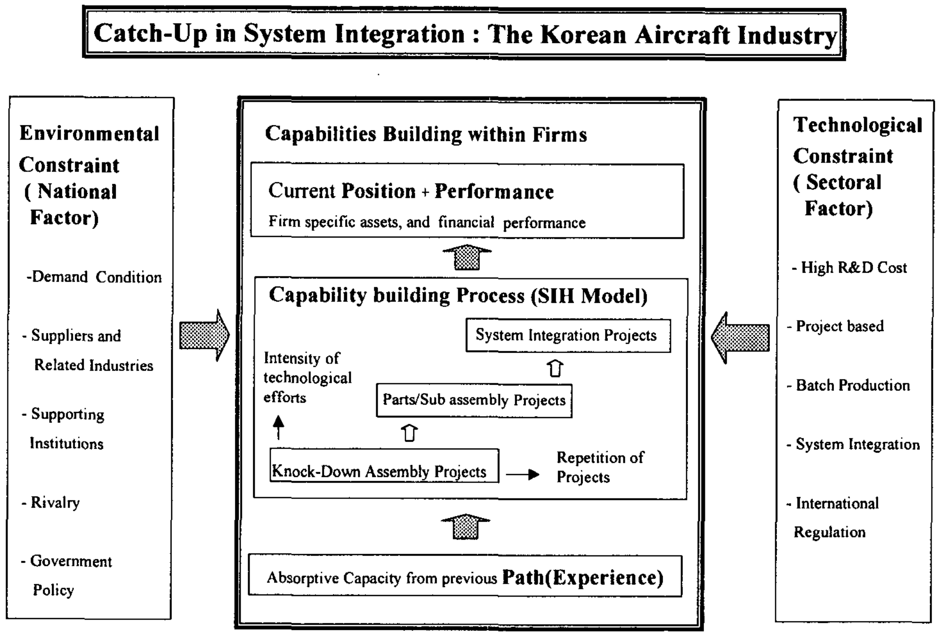
I suggest three-dimensional conceptual framework to analyse the issues of catching-up consisting of capability building within firms, national environment, and sectoral characteristics. (See Figure 1)

The first dimension is capability building within firms. In the aircraft industry, latecomer firms develop its capability from system assembly, through airframe parts manufacturing and sub-assembly, then sub-assembly development, and finally system integration. During the process, intensity of the firm efforts and the number of projects it carried out are very important.

The second dimension and main area of this presentation is national factors in catching-up, as national environment influences to local firms whether it is positive or negative..

The third dimension is sectoral characteristics. It influences the overall performance of the firm. The aircraft industry is a typical system integration industry. R&D investment is very high, but production volume remains small batch from several units to hundreds. The learning opportunities are very limited, whereas the learning cost is extremely high.

We maintain that technical changes take place within firm. However, the influence of external environment should not be underestimated. In this paper, the main issue will be national environment in catching up in the aircraft industry. I will briefly discuss about technological capabilities and catching-up stage models, and then move to the overview of the Korean aircraft industry. Finally, I will discuss national factors which have been influencing capability building of local firms along the System Integration Hierarchy (SIH) stages in the Korean aircraft industry.



Source: Hwang(2000)

Figure 1 Three Dimensional Framework for Catching-up in the Korean Aircraft Industry

II. The Catching-Up Stages of the Korean Aircraft Industry

Catching-up is the capability-building process of latecomer firms in an unfavourable environment in terms of technology, knowledge, skilled personnel, finance, market conditions, and infrastructure. Firms in latecomer economies, at the outset, have no capabilities to innovate, or to generate market competences. They have to acquire them from foreign firms, and internalise and develop them. In the process, learning is the key activity of capability building.

Many scholars show that the catching-up process in developing countries is a technological capability building process. They deal with technological capability as being the most important factor of catching-up, though they define it somewhat differently (Amsden 1989; Bell and Pavitt 1993; Dahlman, et al. 1987; Fransman 1984; Lall 1980, 1987, 1992; Katz, 1984; Lee, at, al. 1988; Westphal, et. al.1985; Kim 1997). They use the term 'technological capability (TC)', and demonstrate that latecomer firms in developing countries have built up their technological capability by various mechanisms.

Fransman (1984) defines technology as everything pertaining to the transformation of inputs and outputs, and technological change as involving 'changes in the way in which inputs are transformed into outputs', including a change in social organisation of the production and labour. He considers that knowledge plays a key role in technological change, and that knowledge could be embodied in hardware and software, in people and institutions.

Westphal, et al (1985) defines TC as 'the ability to make effective use of technological knowledge' (P171). They redefined the concept of TC into three areas: production, investment, and innovation.

Lall (1987, 1993) developed the concept in more detail. He assumed that 'technology means ...the application of scientific knowledge and skills to the setting up, operating, improving and expanding of productive facilities' (1987, p1), and TC is 'the general ability to undertake this broad range of tasks'. (1987, p3) To him, technological development at the firm level means increased capability, but not necessarily to the world frontier. He categorised TC into three types of activities: 1) investment, 2) production, and 3) linkage. In particular, he explicitly listed 'linkage capability' with other firms (or organisations) outside firms.

Bell and Pavitt (1993) divided capability into two stocks of 'resources': 1) Production Capacity (PC), and 2) Technological Capabilities (TC). In their definition, PC is 'the resources to produce industrial goods with given input combination', such as equipment (capital-embodied technology), labour skills (operating and managerial know-how and experience), product and input specifications, and organisational methods and systems used. On the other hand, TCs are more 'intangible resources to generate and manage technical change, including skills, knowledge and experience, and institutional structures and linkages'. (P163) The former is related to 'technology-using', and the latter is related to 'technology-changing'. They warned that many developing countries have focused on the expansion of PCs, and not TCs.

Using the definition of TC, each scholar has tried to explain the catching-up stages, which is the industrialising process of latecomer economies. These efforts have several patterns.

The first pattern is to follow the type of activity. It implies that the required TC changes along the catching-up stages. For example, Dahlman and Westphal (1981) divided the catching up stage into 1) production engineering, 2) project execution, 3) capital goods manufacturing, and 4) R&D. Katz (1984) defined it as 1) product engineering, 2) process engineering and production planning, 3) R&D. Similarly, Fransman (1985) divided it into 1) searching and adaptation, 2) improving, 3) developing, 4) basic research.

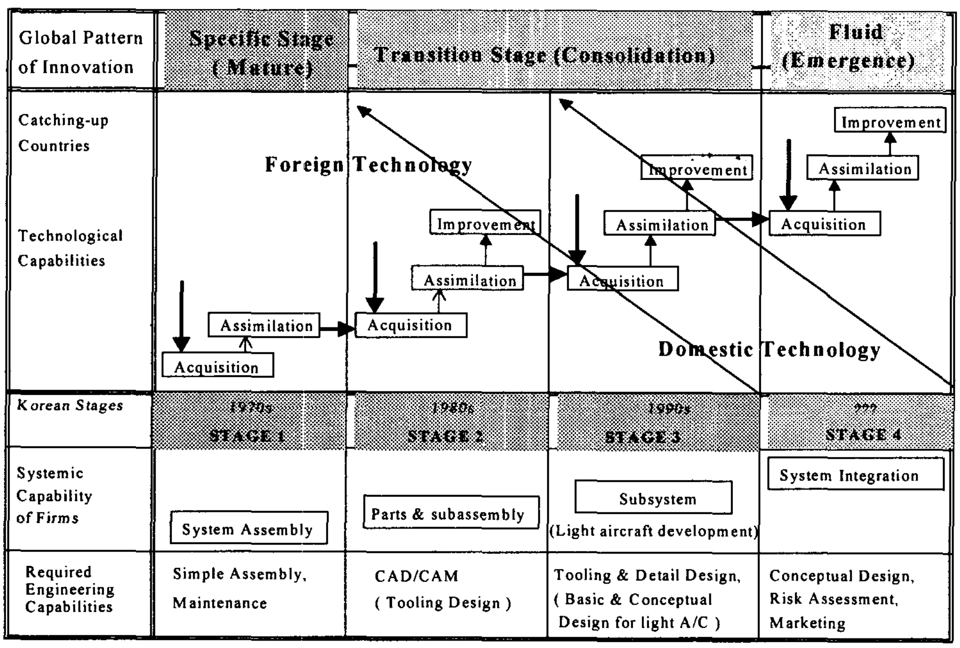
The second pattern is to separate it according to the level of overall TC. Enos (1962) classified it into two stages; 1) Alpha, 2) Beta. The Alpha stage refers to all the efforts involved in introducing a radically or relatively new technology, and the Beta stage is all the subsequent minor technological changes needed to modify and adapt it. Kim (1980, 1997) classified it into three stages; 1) acquisition (implementation), 2) assimilation, 3) improvement.

The third pattern explains TC as different types of learning. Lall (1980) divides it into elementary, intermediate, and advanced. Each stage incorporates several learning patterns; 1) Elementary stage ('learning by doing', ' learning by adaptation'), 2) Intermediate stage ('learning by design', and 'learning by improved design'), 3) Advanced stage ('learning by setting up complete production system', 'learning by innovation'). Similarly, Bell (1984) explained the TC building process by various types of 'learning': learning by operating, learning from changing, system performance feedback, learning through training, learning by hiring, learning by searching. Among them, the first two activities are 'doing-based learning'.

Fourth, Hobday (1995) classified it according to the source of technology, such as 1) OEM (Original Equipment Manufacture), 2) ODM (Own Design and Manufacture), OBM (Own-Brand Manufacture). Gereffi (1996) tried to explain TC in terms of commodity chains, such as 'producer-driven' and 'buyer-driven'.

However, in the aircraft industry, learning is somewhat different than in other mass production industries. The aircraft system is not a mass-production industry, but at best produces a volume of small batch and/or project base. This makes learning more difficult.

A strikingly different point of technological trajectory in this model is systemic capability. In a traditional standardised, mass production industry, technological capability develops from a low quality, low priced "product" to a high quality, high priced "product" However, in the aircraft industry, technology trajectory develops along a system hierarchy like 1) System assembly, 2) Airframe parts manufacturing and subassembly, 3) Subassembly development (and Low-level system development), and 4) System integration. (See Figure 2) Of course, the path from parts to system development will be shortened if the complexity of the aircraft is low, for instance, propeller-driven low speed, light aircraft.



Source: Hwang (2000)

Note: The upper part was modified from Linsu Kim (1997)

Figure 2. Catching-up Stages of the Korean Aircraft Industry

The first stage in the Korean aircraft industry occurred in the 1970s and the second stage in the 1980s. From the 1990s, the Korean aircraft industry entered the risk-share subcontract market, and light aircraft development stages.

In a systemic industry, especially in the Korean aircraft industry, the technological catching-up path has developed along a system hierarchy. Because the technological gap between stages is much deeper and wider in Complex Product Systems (Hobday, 1995, 1996), it takes a longer period of time to step up to the next stage compared with other standardised products.

In the aircraft industry, critical cost-saving economies stem from repetitions of production in small to large batches providing economies of scale (Wright, 1936; Arrow 1962 etc.). Increases in the volume of productions allow benefits from the learning curve effect as well as the spread of costs involved in the learning process.

Table 1. The development Path of the Korean Aircraft Industry

Year	1976-1983	1984-1991	Early 1990s	Later 1990s
Technology stage	Overhaul + System Assembly	Airframe Parts manufacturing & Subassemblies	Risk-share subassembly development	Low level Aircraft Development
Major Project	Overhaul: F-4/F-5 Knockdown assembly: 500MD, A225 Engine	System Assembly: F-5E/F, J85 Jet-engine Parts and subassemblies: MD-11 spoiler, MD-80 fuselage structure, B747 wingtip extension, B767 Stringer etc.	System assembly + parts + subassemblies:F-16, UH-60, BO-105 Risk-share subassembly: Do-328, PW4000 Turbofan engine Light Aircraft Development: Chang Gong-91	Risk-share subassembly development: B717 main wing + Nose cone Low & Medium Level A/C Development: KTX-1 Basic Trainer, KTX-2 Jet Trainer

At the same time, repetitions of similar projects are very important for learning. The accumulation of international airframe subcontract projects lets latecomer firms experience a wide range of technologies within a limited scope, and makes it easier to step up to the next stage in the system ladder. If learning by production (learning curve effects) is based on production/assembly skill improvement, learning by projects allows more engineering based learning (capabilities).

In the complex product systems like the aircraft industry, core competence lies in system integration, not in individual sub-divisional competencies. System integration capabilities in the aircraft industry cannot be acquired when a firm's experience is confined to only a few projects. From this point of view, 'repetition of projects' (Davies and Brady, 1999) is crucial in building the organisational capabilities necessary for catching-up.

Korean firms are just beginning to understand the aircraft system integration 25 years after their first entry into the sector. The current stage may lie within the first part of the transition stage in Linsu Kim's framework.

In summary, the Korean aircraft industry is in the second stage of the global standard and it means catching-up in the aircraft industry has not been successful. From the next session, we will discuss the reasons, particularly in terms of national environment, why Korean firms have been so difficult to catch up in the aircraft industry.

III. Determinants of National Competitiveness

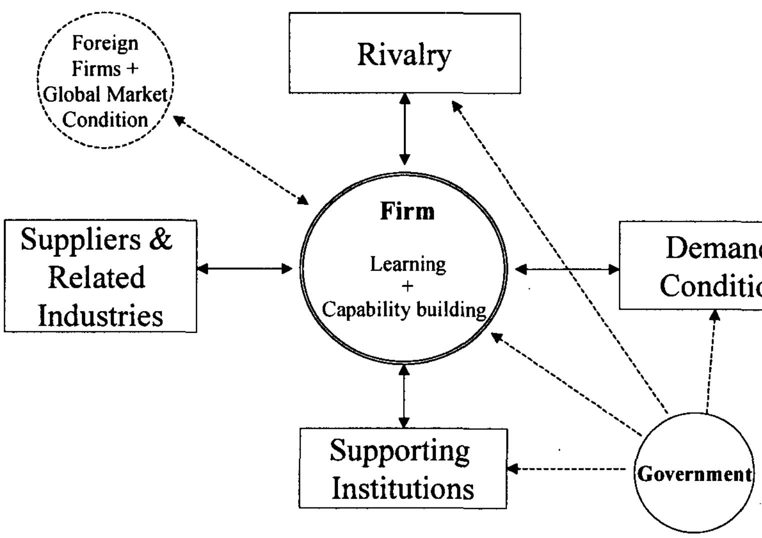
Michel Porter (1990) presents a framework to explain national competitiveness in a particular industry. He argues that this lies in four dimensions: 1) factor conditions, 2) demand conditions, 3) related and supporting industries, and 4) firm strategy, structure, and rivalry. He calls it a 'diamond', and argues that national competitiveness is dependent on whether or not the national diamond is favourable. He adds that favourable factors have to be created and continuously upgraded for sustainable competitiveness.

Porter's diamond is very useful to assess firms' positions in terms of national resources. The nature of the home market, market size, and rate of growth are very important factors to nurture local firms. However, we need to include the concept of systems of innovation (Freeman, 1988; Nelson, 1993, 1994, 1998; Edquist, 1997; Patel and Pavitt, 1994) to address the importance of interactive learning processes. Learning and capability building should be at the centre of a latecomer economy. Furthermore the catching up process is a co-evolutionary process of firm capability and developing institutional system. Firm capability is built up through interactions between private and public organisations and is based on the firm's own efforts.

The concept of a system of innovation originates with Freeman (1987). He defines the national systems of innovation (NSI) as 'the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies' (1987, p1). In this framework, user-producer interactions, government, company R&D, education, training, and related social innovations, the industry structure is all included in this framework.

In a new diamond, firms are at the centre of the diagram and four elements are included to analyse firm's competitiveness, such as 1) demand condition, 2) suppliers and related industries, 3) supporting institutions, and 4) rivalry. In addition to those four elements, government and foreign firms as well as global market condition have to be discussed.

We will review these four main elements of national environmental factors and the role of government in promoting competitiveness.



Source: Hwang (2000)

Figure 3. Modified Determinants of National Competitive Advantage

Demand Conditions

The first element influencing firm capability building is the demand condition. The size of the home market is important to achieve economies of scale and learning. At the same time, the nature of home demand is also critical. Airbus Industries' entry was possible, as there was a niche market for a relatively large capacity plane for short hauls in European countries. In addition, sophisticated and demanding buyers are an important source of innovation. They put pressure on local firms to meet their high standards.

Suppliers and Related Industries

The second dimension is suppliers and related industries as learning and capability building can take place through their interactive relationships. Home-based suppliers are very important, as they deliver low-cost intermediates - materials, parts and components - efficiently, early, and rapidly. The existence of related industries affects international competitiveness, as they can provide information flows and technical interchange of knowledge more easily. Firms in related industries can share complementary technology development activities. Computers and applications software are a good example of this.

Supporting Institutions

The third dimension is supporting institutions. The interaction between public institutions and the private sector is very important. In particular, collaborative research by universities, government research institutes (GRIs), and industries provides very important sources of learning.

The existence of highly educated personnel, and university research institutes are very important for competitive advantages in higher productivity industries. These cannot be easily acquired, and require substantial investment and conscious effort. Furthermore specialised infrastructure, such as 'narrowly skilled personnel, infrastructure with specific properties, knowledge bases in particular fields, and other factors with relevance to a limited range or even to just a single industry', are more important factors for sustainable competitive advantages.

Beyond the existence of those factor conditions, the interactions between universities, research institutes, and between firms, final product manufacturers and suppliers are the most important factors to create competitive advantages in particular industries.

The management systems of countries vary widely. Although there is no universally accepted managerial system, certain types of management practice and modes of organisation can affect firms' success in a particular industry. The differences in managerial patterns, attitude of workers, etc., can be embedded in cultural differences.

Rivalry

The fourth factor is rivalry. Porter (1990) argues that strong domestic rivalry is 'a final, and powerful', stimulus to the creation and persistence of competitive advantage, as competition between domestic firms is an important motivation for innovation. He points out that most national champions are uncompetitive. However, it can erode the competitive advantage of latecomer firms.

The Role of Government

In developing countries, government plays a critical role. Government influences industry structure, and regulates market mechanisms. The investment in supporting institutions and infrastructures is the responsibility of government. In particular, the Korean government has driven firms towards new sectors through various policy measures such as preferential interest rates for loans, subsidies, import restrictions, etc. The Korean government has created a competitive base for local firms.

Government policy also shapes national competitiveness. Porter divides the stages of competitive development into 1) the factor- and investment-driven stage, 2) the innovation-driven stage. In the first stage, government has the greater direct influence, but in the latter stage, firms play a major role in creating competitiveness.

Foreign Firms

Foreign firms are the main source of technology. In the first stage of catching-up, Korean latecomer firms acquire foreign technologies in various ways, such as licensing, technology consultation, recruitment of foreign expertise, etc. At the next stage, after assimilation of imported production technologies, Korean aircraft firms exported commercial aircraft parts and subassemblies to foreign firms. Following that, Korean firms participated in international aircraft development programmes as risk share sub-partners. If Korean firms can reach the system development stage, they will confront foreign firms as competitors. The relationship between foreign firms and latecomer firms changes stage by stage. Global market conditions also influence latecomer firms' competitiveness.

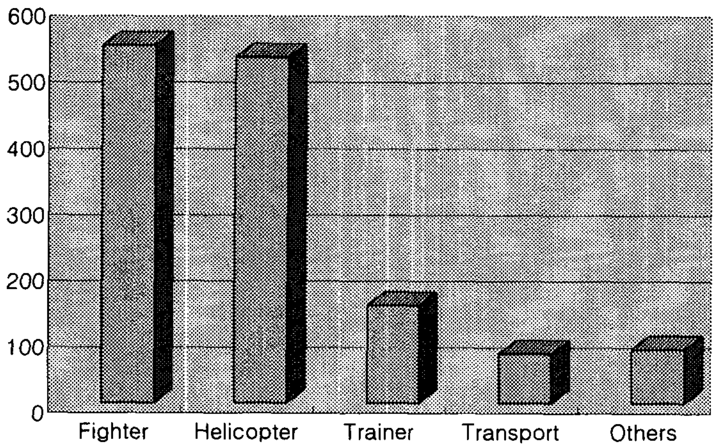
IV. National Environment and the Korean aircraft industry

In the Korean aircraft industry, both diversification path and technological capability building process have been constrained by the national environment. Table 2 shows the external environment in the Korean aircraft industry. In most factors, Korea has no advantages compared with foreign countries. Even the poor performance and weak position of the Korean firms may originate outside the firm.

Demand Condition

There are two aspects to domestic demand conditions. First, the demand in Korea is concentrated on large commercial aircraft, jet fighters, and military helicopters. The first two categories require extremely advanced technologies, and are the world standard products. Second, in the military market, demand for the high performance jet fighter is relatively large, and regular replacement demand exists, even though the demand is cyclic. However, the big gap between the high quality and performance required by military aircraft and the technological capabilities of domestic suppliers forced Korean firms into joint development or simple licence production of foreign aircraft.

In the civil market, there is some demand for different types of commercial aircraft, but most of the demand is for large commercial transport, like Boeing or Airbus series, rather than general aviation. Furthermore, domestic demand is far below the break-even point to develop, and the technological requirement of those categories is also far beyond the capabilities of the Korean firms.



Source: Aviation Week and Space Technology (2000)

Figure 4 The Number of Military Aircraft in Korea

These factors have led Korean firms to expand into the export market. However, unlike traditional mass production industries, the only opportunities to penetrate in the world market have been confined to the airframe subcontract market, not aircraft as a final product. In the aircraft industry, the aircraft produced under licence agreement has not been allowed to be exported to other countries. Without system integration capabilities, market entry in the global aircraft market is impossible and the size of the market is neither large enough to gain economies of scale, nor profitable enough. Korean firms have therefore concentrated on domestic military programmes, which guarantee production costs and profits.

The small domestic market hampers both the benefit of economies of scale, and learning opportunities.[2] It is one of the main reasons why catching-up in the Korean aircraft industry has been so slow, because latecomer firms build up their technological capabilities through repetition of projects. The measure of the extent of the market is the number of projects as well as the value of production.

Related and Supporting industries

Related and supporting industries are poorly developed in Korea. There are no machinery producers supplying the aircraft industry. Capital goods are imported mainly from the US and Japan. There are very few small and medium sized domestic suppliers for airframe parts, and equipment. The weakness of related and supporting industries has not been a particular phenomenon in the aircraft industry in the Chaebol oriented Korean economy.

However, an aircraft consists of lots of materials, parts, component and subsystems including hydraulics, equipments, instruments, avionics, and aero-engines. In the short term, lack of related and supporting industries hinders progress in stepping up to system integration.

Rivalry

Industry structure and rivalry in Korea is another problem area. Though four Chaebols participated in the aircraft industry, their business area overlapped in airframe and system assembly. This has resulted in fierce competition between Chaebols. Strong rivalry in the Korean aircraft industry works unfavourably in a limited domestic market and provides a poor platform for entry into the global market.

By contrast, fierce competition in the small market for mass production industries induced an export oriented strategy. However, the entry barrier in the aircraft industry is too high simply to change the target market. Rivalry in latecomer countries with small domestic market does not help to build their competences.

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[2] Mowery and Rosenberg (1984), Hochmuth (1974) pointed out similar weaknesses in the size of domestic market in the Japanese and European aircraft industries respectively compared with the United States.

It is noteworthy that most countries, including European countries, are adopting a 'national champions' policy in the aircraft industry. Furthermore, discussions for forming a single system integration company are ongoing in Europe.

Recently, Korea Aerospace Industries Ltd. was founded through merger of airframe division of SSA and DHI, and HYSA.

Supporting Institutions

Korea has relatively well trained workers and technicians. However, the technological education of university graduates is relatively poor by international standards. University facilities for experimenting are extremely poor, and university faculties are mostly engaged in teaching, not research (Kim, 1997). However, the number of aerospace graduates is growing, and gradually universities are pursuing practical engineering beyond textbooks. GRIs - KARI and ADD - are steadily accumulating their technological capabilities step-by-step. Infrastructure in the aircraft industry is very disappointing. Technology standards and safety procedures for aircraft manufacturing are not yet established. The setting up of an independent airworthiness authority is vital, if Korean firms want to develop civil aircraft. The small number of civil airports and the restricted airspace for military reasons hindered the growth of domestic market demand.

Government Policy

Historically, government policy has been a key element in the aircraft industry. In particular, long-term commitment is essential for building technological capabilities in the aircraft industry. Even the leading countries - the US and European countries - still provide formal and informal financial support for the aircraft industry.

In particular, government procurement policy is very important during the early stages of a new industry. Import protection, which the Korean government preferred to adopt to overcome the disadvantage of a small-sized domestic market, has not worked in the civil aircraft market. Airlines, the largest customer group, are already accustomed to foreign products that Korean manufacturers cannot supply. The size of civil demand never reaches economic production units for licence production.

The only way to support domestic firms is through demand for military aircraft. Government can control the number of aircraft production and its scheduling to maintain industrial manufacturing capacity through its procurement process. Deliberate government policy can protect domestic firms and nourish the latecomer firm's technological capabilities. The periods for incubation can be more than several decades in this particularly CoPS industry.

However, government policy in the Korean aircraft industry has not been effective. Military production programmes have often been discontinued. Government distributed limited military aircraft demand among too many domestic firms - all three *Chaebols* - at the expense of intensive learning opportunities.

National R&D policy is the other instrument of government policy. The Korean government established KARI (the Korea Aerospace Research Institute) in 1989. Direct subsidy to KARI has been very useful in providing R&D infrastructure, like R&D and test facilities. But there have a number of problems associated with this type of intervention. However, R&D funds for aircraft technology are too small. Most of KARI's R&D projects are space programmes. GRI used to supply experienced engineers to industry, however the Korean government could not support KARI effectively. At the same time, it is difficult to find examples of effective R&D co-operation between university and industry.

In some senses, all the institutions in the Korean aircraft industry are at the learning stage. However, co-ordination and co-operation between ministries as well as within an individual ministry is a very complex process that has to be resolved. No independent government organisation for the aircraft industry has been established to coordinate the various government ministries involved, such as the aeronautics ministry in Brazil, and CASID (Committee for Aviation and Space Industry Development) in Taiwan.

Therefore, the Korean aircraft industry is experiencing learning in its institutional system-integration, as well as in technological system integration.

Table 2 Major Factors of national environment in the Korean aircraft industry

Factors	Environment	Consequence
Demand Condition - Market size - Demand structure	 Small. Concentrated on jet fighter, military helicopter, and large commercial transport	 No economies of scale, Big gap between demand and supplying capabilities restrict learning opportunities.
Suppliers and related industries	No small & medium sized suppliers	Weak price competitiveness
Rivalry	Strong competition among four Korean Chaebols	Wasting learning opportunities and scarce resources

Supporting institutions	Not developed, but improving	Heavily reliance on foreign technologies
Government support	Too small R&D investment	Fail to compensate unfavourable environment

V. Conclusion and Policy Implications

Korea has achieved remarkable economic growth during the last 40 years. Although it has recently been experiencing some difficulties as a result of the recent Asian financial crisis, Korea is recovering rapidly. Catching up in Korea has been achieved by moving from supplier dominant industries, via scale intensive industries, to knowledge intensive industries.

With this economic growth, Korea has been facing a new paradigm (See Table 3). On the one hand, in the technological dimension, Korea has to confront the task of improving existing technology and creating new knowledge and technology through acquisition of foreign technology and by imitation. On the other hand, Korea has to build up the organisational capability to coordinate and integrate various interest groups, government ministries, public and private sectors, and upstream and downstream industries.

From the strategic dimension, its main interest should be moving from 'production efficiency' to 'engineering and R&D capabilities'. Its main competitive advantage in the 2000s should be in 'core technologies', not simple 'project management of simple product with financial capabilities' based on 'Chaebol governance'.

The Korean government must be aware that a new paradigm demands new policy measures. In particular, the understanding of sectoral differences could be the starting point of such a policy shift.

Table 3 Paradigm Changes in Korea and its new tasks for 2000s

1960 - 1970s	1980 - 1990s	2000s
Supplier Dominated Industry	Scale Intensive Industry	Knowledge Intensive Industry
Factor Driven	Investment Driven	Innovation Driven
Foreign Technology	Imitation and Reverse engineering	Improvement of existing technology & Creation of new knowledge
Strategy: Production	Production efficiency	Engineering + R&D
Capabilities: Project Management + Finance		Capabilities: Core Technologies

From this point of view, I would suggest several policy issues for the Korean aircraft industry, which the SIH model requires. First, government policy should be related to domestic market conditions. Although the Korean domestic market is not large enough to support new projects, the demand for military fighters, trainers, and helicopters is not insignificant. Government policy should focus on these demands. Government should be able to provide opportunities for the acquisition of system integration capabilities. In order to do so, deliberate long-term procurement planning is essential. The life cycle of an aircraft is more than 20 years, and the replacement demand is visible. In some areas, like jet fighters and large commercial transport, international collaboration is essential as it is difficult to achieve competitiveness in a short period.

Second, the Korean government should increase R&D investment in the aircraft industry. In particular, it is too heavy a burden for individual domestic firms to retain all the engineers to develop aircraft systems and to invest in various test facilities. One alternative is to develop government research institutes, such as KARI, and ADD. A division of research could be established. Private firms could carry out commercial development and applied research, and GRIs could perform applied research and basic research. GRIs can become involved in long-term technology demonstration projects, usually with high technological risks, or projects which are not commercially viable in the near term. Test facilities also can be invested in GRIs. In this way government research becomes an external economy enjoyed by all Korean firms.

Third, small and medium sized suppliers and related industries should be developed. The Korean government has controlled procurement costs of domestic production within 130% compared with direct purchase from abroad. This constraint has created an unbalanced industry structure. As prime contractors carry out final assembly as well as airframe production, they prefer airframe production to subsystem production. Furthermore, with the repetition of licensing production programmes, airframe firms have already invested considerably in manufacturing equipment. As a result, airframe producers have cost advantages over other subsystem manufacturers. However, the airframe sector might have reached over production capacity at the world level, and it may be more difficult to catch up. Government should pay more attention to building up subsystems and components manufacturers.

Fourth, the Korean aircraft firms (with the exception of Korean Air) have merged to form the Korea Aerospace Industries Co., Ltd. (KAI). The Korean government announced that KAI would be a prime contractor for the whole domestic production programme henceforth.[3] This represents a fundamental policy shift from domestic rivalry to a national champion. However, as Porter (1990) points out a national champion policy may also have negative effects, such as the inefficiency arising from bureaucracy and lack of competition.

Fifth, the government structure for coordinating related ministries should be reconsidered. According to 'the aerospace industry development and promotion law' announced in 1986, the Ministry of Commerce, Industry, and Energy (MOCIE) is responsible for the coordination and overall planning for the aircraft industry. However, government aircraft procurement is decided by the Ministry of Defence (MOD), and the construction and supervision of civil aviation activities, and civil aircraft infrastructure is the responsibility of the Ministry of Construction and Transportation (MOCT). Government science and technology policy is carried out by the Ministry of Science and Technology (MOST). In the case of other industries, such as consumer electronics, automobiles, and shipbuilding, etc., MOCIE has led industrial policy with measures for import restriction, export subsidies etc. However, in the aircraft industry, MOCIE has produced few policy measures. Even though there is a committee for coordination between ministries, it has been convened only twice and has not been effective in meeting its objectives. Therefore, the Korean government will need new institutions in order to support and promote its aircraft industry.

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