2003

The Impact of Government Policy on Technology Transfer: An Aircraft Industry Case Study

David King
Marquette University

Mark L. Nowack

Available online at www.sciencedirect.com
SCIENCE DIRECT®

ELSEVIER

J. Eng. Technol. Manage. 20 (2003) 303–318

Journal of
ENGINEERING AND
TECHNOLOGY
MANAGEMENT
JET-M

www.elsevier.com/locate/jengtecman

The impact of government policy on technology transfer: an aircraft industry case study

David R. King[a,*], Mark L. Nowack[b,1]

[a] 1060 Air Force Pentagon (SAF/AQP), Washington DC, 20330-1060, USA
[b] 1180 Air Force Pentagon (AF/SB), Washington DC, 20330-1060, USA

Abstract

This case study explores the interaction between domestic and foreign governmental policy on technology transfer with the goal of exploring the long-term impacts of technology transfer. Specifically, the impact of successive licensing of fighter aircraft manufacturing and design to Japan in the development of Japan's aircraft industry is reviewed. Results indicate Japan has built a domestic aircraft industry through sequential learning with foreign technology transfers from the United States, and design and production on domestic fighter aircraft. This process was facilitated by governmental policies in both Japan and the United States.
Published by Elsevier B.V.

JEL classification: F13; F14; L16; L52; L93; L98; O38

Keywords: Aircraft industry; Government policy; Technology transfer

1. Introduction

The creation of the National Economic Council by President Clinton during his first term recognized the increased importance of economic issues. The importance of national economic policies is brought about by increased global competition and pace of technological change. The focus on economic issues has spillover implications for national security. For example, the US ambassador to Malaysia intervened to help save a sale of F/A-18 aircraft that includes meeting Malaysia demands for "offsets" or technology transfer of advanced manufacturing skills (Cole and Lubman, 1994; Mecham, 1998). This provides evidence that nations are increasingly concerned with their economic competitive advantage, and knowledge may be the only lasting source of competitive advantage (Hitt et al., 1998). In

* Corresponding author. Tel.: +1-703-588-7170; fax: +1-703-588-6196.
E-mail addresses: david.king@pentagon.af.mil (D.R. King), mark.nowack@pentagon.af.mil (M.L. Nowack).
[1] Tel.: +1-703-697-4811; fax: +1-703-693-6262.

0923-4748/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.jengtecman.2003.08.007

this environment, technology transfer, or the exchange of knowledge, between nations has strategic implications for national competitiveness and security.

The rise of multinational corporations demand more sophisticated government policies, because these policies can have a wide-ranging impact on competitiveness. As a result, several studies have called for a greater understanding of government policy on economic competitiveness (Ham and Mowery, 1995; Nelson, 1995; Vogel, 1996). These papers focus largely on better understanding "US" government policy. However, multinational corporations are impacted by policies in multiple nations. A complete paradigm for understanding the impact of government policy on technology transfer requires balancing competing domestic and international political–economic interests. In other words, what are the long-term impacts, if any, of an increased economic focus in the United States on technology transfer?

Accepting that governments play a role in international competition, home nations and their firms may inadvertently accept greater risk when objectives motivating host and home nation government policy are not considered together, or are assumed to be the same. When arms sales involve offsets worth 60–100% of weapon purchases (Cole and Lubman, 1994), government policies represent an important environmental factor that needs considered by corporate managers and government policy makers. The present study contributes to the process of better understanding the impact of government policy by studying the case of US aircraft technology transfers to Japan after World War II (WWII). We compare national policies of the United States and Japan, and the impact of each nation's policy on technology transfer in building an aircraft industry in Japan. The aircraft industry and its associated technology concern governments, because it can act as a catalyst for new technologies or have significant spillover effects (Turnipseed and Rassuli, 1999).

2. Dynamics of technology transfer

Although any technology transfer and the principals of any agreement have complex motives, technology transfer can be viewed along a continuum framed by event or learning perspectives. The event perspective views technology transfer primarily as an economic transaction where one party provides technology in return for some form of payment. In general, the United States tends to view technology transfer as an event (Olk and Xin, 1997). For example, US defense exports are motivated, in part, toward reducing the cost of weapon system programs through extra sales (Economist, 1998). Other motivations include maintaining common equipment with allies, and facilitating joint operations and interchangeability of parts. A key implication of an event perspective is that it is less likely to consider long-term implications of a transaction, and view a technology transfer as an end in of itself.

Organizational learning provides an alternate perspective of technology transfer where technology transfer is not an event but a process. Levitt and March (1988) stress the importance of learning by doing and suggest trial and error is how organizations develop routines and procedures. These routines and procedures are necessary to address the large gap that exists between obtaining knowledge and subsequently using that knowledge to create a product. This distinction can be better understood by considering the difference between "explicit" and "tacit" knowledge (Polanyi, 1958). Explicit knowledge can be transmitted in formal, systematic language. Meanwhile, tacit knowledge is harder to communicate and is rooted in action or a specific context of a person's experience. Japan tends to view technology transfer from a learning perspective (Hamel et al., 1998), and the aircraft industry requires large amounts of tacit knowledge. For example, Boeing is not concerned with patent expirations because of the high costs of reverse engineering that result from a lack of common experience (Katz, 1998).

Although economic considerations remain, viewing technology transfer from a learning perspective translates into Japan viewing technology transfer as a process (Olk and Xin, 1997), or a means. Japan's process perspective contributed to its achieving industrialization and rapid economic growth after WWII (Katz, 1998). Kim (1997, pp. 230–231) called the learning approach exhibited by Japan "creative imitation," or a three-step process of knowledge acquisition, assimilation, and improvement. Japan has distinguished itself from other nations in its openness to foreign knowledge acquisition, or technology transfer (Pack, 2000). Nonaka (1994) identifies Japan as valuing the importance of experience in achieving understanding, or knowledge assimilation. The final step in learning from technology transfer is to improve the knowledge gained. Consistent with a process perspective is Japan's tendency to improve knowledge in part by acquiring new technology in a building block approach. This is supported in part by Chang (1995) who found that Japanese firms follow an expansion strategy of sequential entry.

Sequential entry into a market allows Japan to acquire knowledge and build a base of experience that allows it to progress to improving the knowledge gained. There is evidence that Japan's aircraft industry followed such an approach between WWI and WWII. At the end of WWI, Japan recognized that it needed to modernize its arms (Pelvin, 2000). The Japanese companies of Mitsubishi, Nakajima, and Kawasaki turned to foreign assistance to develop an aircraft industry and each developed close links with European firms to obtain the latest technology (Pelvin, 2000).

From this inauspicious beginning, Japan by WWII was building bombers that set transoceanic distance records and the "Zero" a fighter that flew farther and faster than any plane in the US arsenal at the beginning of WWII (Shear, 1994). Although the United States invented the first aircraft, it had lost its lead by WWII (McLarren, 1949). For our purposes, we use a four-part framework beginning with having the skills to operate and maintain a technology as a yardstick for measuring technological capability of an industry (see Fig. 1). Technological capability then expands to include the sequential skills of reproducing parts, adapting designs, and, finally, creating new technology and designs. The question motivating

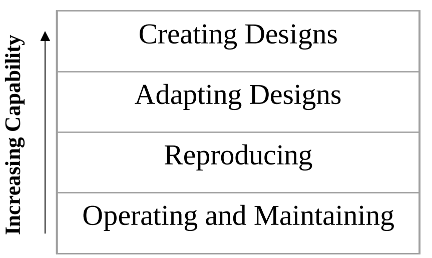

Fig. 1. Technological capability framework.

this research is: has Japan followed steps consistent with a learning perspective to build its post-WWII aircraft industry through technology transfer, and has US policy facilitated this process?

3. Government involvement

Japan was barred from having an aircraft industry from the end of WWII until 9 April 1952, by which time Japan had virtually no aircraft industry capability (Hall and Johnson, 1968). However, Japan quickly began re-building its aircraft industry as evidenced by Mitsubishi breaking ground on an aircraft production facility in December 1952 (Jane's, 1976). Primarily through the importation of technology, Japan re-acquired a capable aircraft industry. A key element in that effort was government sponsorship of military aircraft co-production programs (Hall and Johnson, 1968). The Japanese government Ministry of International Trade and Industry (MITI) under the 1954 Arms Manufacturing Law was given authority to regulate "weapons procurement in the nation's industrial structure", and Mitsubishi Heavy Industries (MHI) remains the sole fighter aircraft prime contractor (Alexander, 1993). Japan's government first declared aviation a "key technology" in 1954 (Alexander, 1993). Between 1952 and 1964, Japan's government directly supported the creation of an aircraft industry and supplied US$ 14.68 million in the financing of aircraft industry equipment and US$ 5.23 million in R&D subsidies (Hall and Johnson, 1968). In 1958, MITI wrote the Aircraft Industrial Promotion Law that sought the successful development of a defense aircraft industry as a means of developing a commercial aviation industry (Shear, 1994). It is the success of this effort that is the subject of this paper.

Japanese government support for the domestic aircraft industry has remained strong over time. In 1970, the MITI re-identified aviation as a key technology (Shear, 1994). During the 1980s, MITI reiterated its goal of penetrating the commercial aircraft industry (Turnipseed and Rassuli, 1999). Japanese government support included policies requiring licensing of technology from foreign firms. The impact of regulated and forced licensing includes shifting the distribution of innovation from foreign to domestic firms by limiting ownership of specialized assets (Teece, 1986). This makes licensing appear profitable to firms, because other avenues are blocked by the host government (Teece, 1986). The expectation, in these circumstances, is that licensed products will cost more than direct purchases, because a premium will be built into the price of the license. However, analysis of early aircraft licenses to Japan show no premium was paid (Hall and Johnson, 1968). Essentially, Japan obtained the aircraft, related technology, and manufacturing experience at a lower price than just buying the aircraft directly from US manufacturers.

4. Aircraft programs

We use a case study following Eisenhardt's (1989) methodology to examine whether a process, or learning, perspective describes technology transfers between the United States and Japan over time. Specifically, we focus on the transfer of fighter aircraft technology since WWII. Data on post-WWII fighter programs were collected from relevant literature from the 1950's to present. Our focus on fighter aircraft technology transfers from the end of WWII is deliberate. First, significant changes in aircraft technology after WWII and the ensuing ban that kept Japan from having an aircraft industry presented Japan with a situation where it was faced with re-building an aircraft industry from the ground up. Second, Japan focused on re-building fighter aircraft industrial capability for economic and national prestige concerns. Third, Japan's government targeted technology transfer as a means of re-building industrial capability in general, and fighter aircraft specifically. Fourth, fighter aircraft represent systems that have been developed more or less continuously by the United States for the given time period with each generation representing an advance in technology, and often subsequent licensing of that technology to Japan and MHI (Hall and Johnson, 1968; Lorell, 1995). Finally, fighter aircraft represent a demanding type of aircraft based on an industrial capability in which critical knowledge is tacit in nature.

Evidence to support a learning perspective by Japan toward technology transfer requires identifying the changing level of Japan's domestic aircraft industry capability, and changes in the diffusion rate of technology from the United States to Japan over time. We attempt to support such a conclusion by looking at several characteristics of aircraft technology transfers. First, Japan's domestic capability is measured as the number of aircraft initially assembled in Japan from parts produced in the United States. The fewer aircraft merely assembled in Japan should indicate an increased capability to operate, maintain, and reproduce related technology. These skills relate to the first two levels of our technological capability framework that involve the ability to operate and maintain technology and then the ability to reproduce parts.

Additionally, changes in the domestic content of fighter aircraft produced in Japan, when available, are reported. Second, the rate technology diffuses is measured as the time between a fighter aircraft achieves initial operational capability (IOC), in the United States, to when Japan first produces the same fighter aircraft domestically as measured in years. A faster diffusion of technology from the United States to Japan would indicate a narrowing gap in industrial capability. Finally, Japan's domestic capability in supporting industrial base is measured by identifying capabilities for fighter aircraft subsystems.

To develop the background needed to evaluate these characteristics, the Japanese fighter aircraft programs, including US licensed production and domestic development, are described in the following sections. Considering only fighter aircraft production of US licensed designs would distort the picture of Japan's evolving aircraft industry capability, so indigenous Japanese fighter programs are also reviewed. Japan has domestically designed and produced two fighter aircraft, since WWII, the Mitsubishi F-1 and F-2. The domestic fighter aircraft programs also help demonstrate the last levels of industry capability in our framework adapting and creating technology. A montage of the fighter aircraft reviewed in the following subparagraphs is shown in Fig. 2.

4.1. North American F-86 Sabre

Japan's involvement with the F-86 aircraft is one of evolution, and it began at the level of operating and maintaining technology. Between 1952 and 1954, Japanese industry focused on repair and overhaul work on the F-86 aircraft for the Japanese Air Self-Defense Force (JASDF) and the US Air Force (Hall and Johnson, 1968). Then, in June 1955, MHI

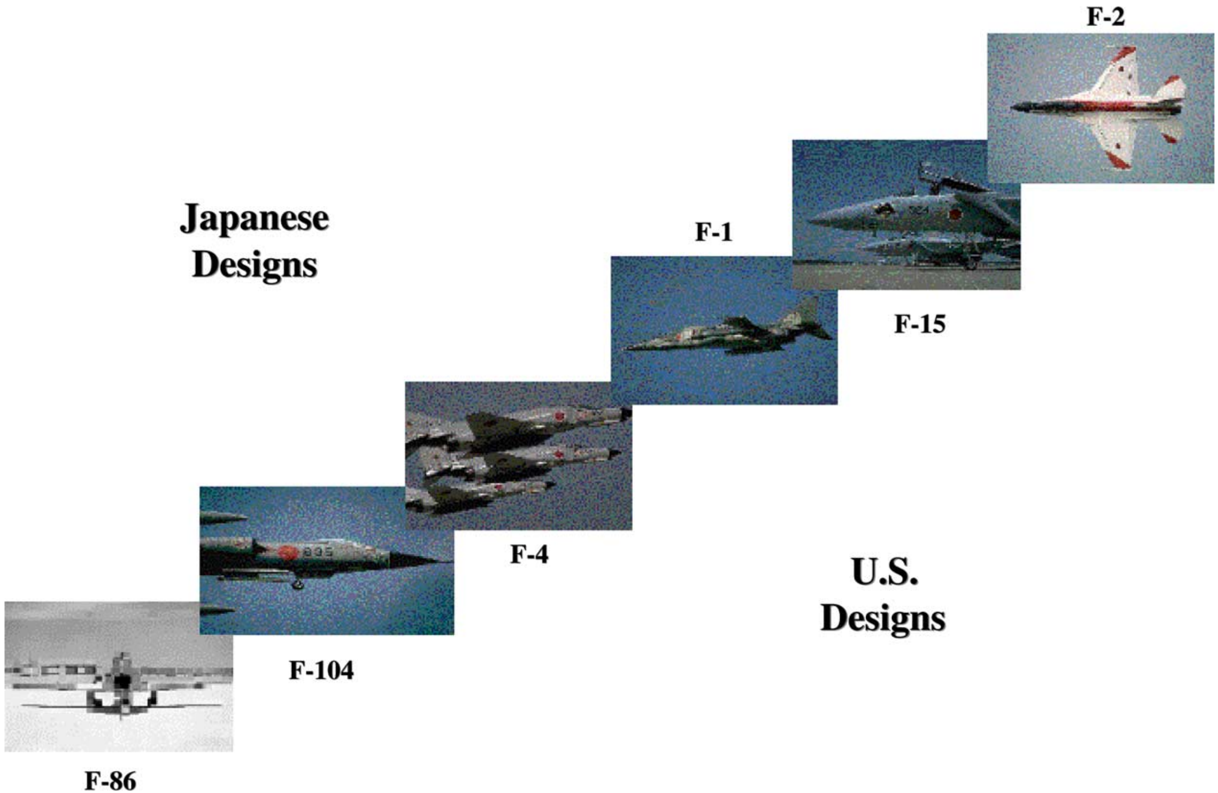

Fig. 2. Montage of fighter aircraft programs reviewed.

was selected for licensed production of the F-86 aircraft (Jane's, 1968). By 1956, Japan produced its first domestically assembled F-86 (Jane's, 1957). By 1969, Japan's Mitsubishi had delivered 300 F-86 aircraft to its armed forces with 77% domestic content (Todd and Simpson, 1986). However, the first 70 F-86 aircraft were essentially produced in the United States and assembled in Japan (Hall and Johnson, 1967). Still F-86 licensed production extended Japan's aircraft industry to at least the level of reproducing parts.

The progression in Japan's capability resulted largely from imitation. During 1956, a group of MHI officials spent several months at North American's Los Angeles plant, and the group later reproduced everything down to the color of paint in tool rooms in Japan (Hall and Johnson, 1968). Japan also used what it had learned to innovate. For example, MHI developed a new and ingenious way to produce Monahan hinges, a portion of the airframe that posed problems for North American (Hall and Johnson, 1968). Further, Japanese experience with co-production on the F-86's air brakes had a powerful residual effect on the civilian economy, when that technology was applied to Japan's revolutionary bullet train (Shear, 1994). This provides examples of Japan progressing, at a minimum, to adapting technology. Japanese learning also increased their absorptive capacity for future technology transfers. For example, during the initial stages of the F-86 program, MHI's design group spent 70% of their time converting drawings and specifications into Japanese and the metric system, but this experience allowed MHI to use drawings for the F-104J program without translation (Hall and Johnson, 1968).

4.2. Lockheed F-104 Starfighter

On 7 November 1959, MHI was notified it would be the prime contractor for Japanese production of the F-104J aircraft (Hall and Johnson, 1968). MHI was given exclusive rights to sell the F-104J, but only to the Japanese government (Hall and Johnson, 1968). A significant design effort was carried out in both the United States and Japan to modify the F-104C into the F-104J (Hall and Johnson, 1968). Examples of F-104 technology gained under license production include chemical milling, a spray mat process to control icing, and improved techniques for the high-heat treatment of steel (Todd and Simpson, 1986). MHI produced a total of 203 F-104J aircraft with the first domestically produced F-104J being completed in January 1960 (Jane's, 1976). However, the first seven aircraft were again largely produced in the United States and assembled in Japan (Hall and Johnson, 1968).

A significant amount of learning was transferred to Japan on the F-104J program with the first MHI produced F-104J taking 25% less man-hours than the first Lockheed F-104 (Hall and Johnson, 1968). Additionally, Japan paid no premium for licensed production with the F-104J having a lower cost than if they had been made in the United States even though the F-104J represented a more sophisticated design than the US F-104C (Hall and Johnson, 1968). The increasing capability of the Japanese aircraft industry can also be seen by comparing the percentage of value added by MHI on the F-104J program. MHI achieved an added value of 44.6% compared to an average added value for the leading five US aircraft firms from 1961 to 1964 of 45.8% (Hall and Johnson, 1968).

This means by the end of the F-104J program Japanese aircraft manufacturing efficiency was similar to US firms. Additionally, the F-104J program developed supporting industries, including: Ishikawajima-Harima Heavy Industries (IHI) for engines, Mitsubishi Electronics

Company (Melco) for air-to-air missiles, and Kawasaki Heavy Industries (KHI) as an airframe subcontractor (Alexander, 1993). In total, the F-104J program used over 21 Japanese suppliers of components and elements that were also under licensed production with various US manufacturers (Hall and Johnson, 1968).

4.3. McDonnell F-4 Phantom II

The F-4 was the next US military fighter co-produced in Japan. In November 1968, Mitsubishi was selected as the contractor for the F-4E (Jane's, 1976). The F-4 presented new manufacturing challenges, since it was the first fighter aircraft to make extensive use of titanium (Boeing, 2000). Japan's F-4 aircraft co-production agreements included producing almost 100% of the F-4 airframe, avionics, and engine components in Japan (Todd and Simpson, 1986). In all, Japan manufactured a total of 138 F-4 aircraft (Jane's, 1980). The first two F-4 aircraft were completed in July 1971 and were only assembled in Japan with production complete in July 1971; the first F-4 produced from parts manufactured in Japan was completed in May 1972 (Jane's, 1976). Although the high domestic content of the F-4 produced in Japan shows an aircraft industry with a widespread capability to reproduce designs, Japan lacked the ability to higher technological capabilities. By the late 1970's, the Japanese were aware of their shortcomings and took steps to remedy deficiencies to include co-production of the F-15 (Lorell, 1995).

4.4. Mitsubishi F-1

The F-1 was Japan's first attempt at a domestically developed fighter aircraft. In September 1967, the Japanese Defense Agency (JDA) selected MHI as the prime contractor for the XT-2 supersonic trainer that was Japan's first domestically produced supersonic fighter (Jane's, 1971). The first flight of the T-2 occurred in July 1971 (Jane's, 1976). The T-2 was re-designated the F-1 in November 1976 (Jane's, 1980), and the first flight for a production F-1 aircraft was made in June 1977 (Jane's, 1985). The F-1 program was not considered a success and although it was developed as an all-weather fighter it was restricted to daylight due to safety and operational concerns resulting in the production run being cut short with only 80 aircraft produced (Shear, 1994).

4.5. McDonnell Douglas F-15 Eagle

The most recent US fighter "co-produced" in Japan was the F-15 aircraft. The first Japanese produced F-15 rolled off the Mitsubishi assembly line in August 1981—3 months after the delivery of last F-4 from the same assembly line (Todd and Simpson, 1986). Japan was the second foreign nation to receive the F-15 aircraft, after Israel, but the only country to co-produce the F-15 (Sullivan, 1991). Japan bought 209 F-15 aircraft with the last Japanese produced F-15 rolling off the production line in 1996 (Sekigawa, 2000). The first fourteen F-15 aircraft were largely assembled from parts shipped from the United States (Sullivan, 1991; Jane's, 1991).

Chinworth (1992) described US motivations for co-producing the F-15 with Japan as focusing on security concerns, but, whether intended or not, it also helped boost Japan's industrial capabilities. The potential for technology transfer exceeded the F-86, F-104, and F-4 programs even though a number of F-15 components were delivered as “black boxes” (Chinworth, 1992). Interestingly, it was not until December 1984 that the Memorandum of Understanding was revised for the United States to receive “flowback” technology from Japan where the US government would be entitled to improvements made to the aircraft or individual components (Chinworth, 1992). Even though the potential for “flowback” was recognized it often was not actively sought. Lorell (1995) and Chang (1995) identify a deficiency of knowledge on the US side about Japanese technology developments and military R&D that results in part from a lack of apparent interest from the United States. Additionally, a reluctance by Japan to allow military technology to be exported further discourages flowback.

4.6. Mitsubishi F-2

The second domestically designed and produced Japanese fighter was the Fighter Support-Experimental (FS-X). The FS-X represents the first co-development program between the United States and another nation (Wegg, 1990). After a Congressional battle over transferring US technology to Japan, approval was given in May 1989 for Mitsubishi to produce an F-16 derivative aircraft (Wegg, 1990). The FS-X is giving the Japanese extensive experience in the R&D and systems integration process for developing modern fighters (Lorell, 1995). Design capabilities and managing the transition from design to manufacturing are key determinants of success in the aircraft industry (Turnipseed and Rassuli, 1999), and represents the last level in our technological capability framework.

The FS-X is demonstrating Japan’s capability to develop advanced fighter weapon systems with changes to over 95% of the F-16 engineering drawings (Lorell, 1995). This makes the FS-X program a lower risk and less costly means of learning design and integration skills, while providing further development of its domestic technology and subsystems (Lorell, 1995). The FS-X was renamed the F-2 by Japan and the first delivery from Mitsubishi occurred on 12 January 1995 (Jane’s, 1998), and the JDA plans to procure 143 F-2 aircraft through 2003 (Sekigawa, 2000).

5. Case summary

It appears Japan has built a domestic aircraft industry through sequential learning from foreign technology transfers from the United States, and trial and error design and production on domestic fighter aircraft. At the same time that it was seeking external knowledge, Japan’s government deliberately curtailed foreign firm ownership of technology markets to promote domestic capability (Song et al., 1999). Japan demonstrates significant learning about fighter aircraft manufacturing with the large decline in the number of aircraft that it assembled from parts sent from the United States, see Fig. 3. Additionally, the larger production runs of early licensed production projects indicate an increased opportunity for process refinement.

Fig. 3 shows a declining trend in the number of aircraft Japan merely assembled from parts shipped from US manufacturers. The significant decline between the F-86 to the

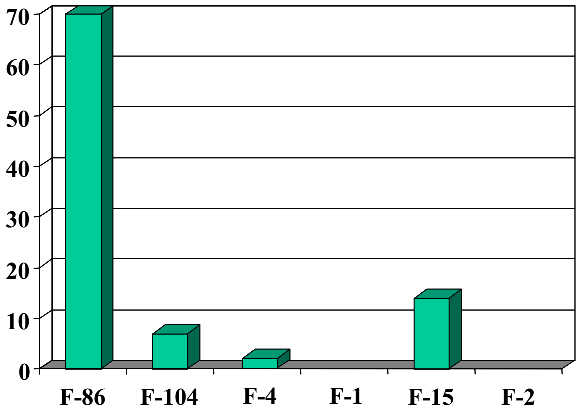

Fig. 3. Japanese fighter aircraft programs: assembly only aircraft.

F-104 aircraft shows the F-86 helped establish a general aircraft manufacturing capability. Subsequent assembly appears to be mainly driven by learning specific demands of individual aircraft designs.

Additionally, the number of years from an aircraft's IOC in the United States to the first Japanese production aircraft shows increasing Japanese capability (see Fig. 4). Again the figure shows Japan is producing the most capable aircraft fielded by the United States only a few years after they are fielded. This is significant, because most knowledge transferred in licensed production occurs before production of a first article and takes place in the exchange of drawings and tooling. The shorter the time between transfers indicates an increased ability by Japan to absorb more advanced technology.

Additionally, the fighter aircraft technology transfers to Japan occurred faster on average than similar technology transfers involving intra-firm transfers of US multination-

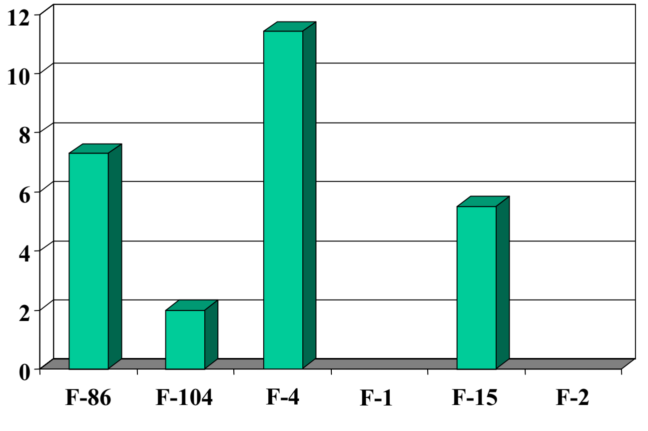

Fig. 4. Japanese fighter aircraft programs: years from US initial operational capability to first production in Japan.

Table 1
Growth in Japanese aircraft industry technological capability

Aircraft model	F-86F	F-104J	F-4EJ	F-1	F-15J	F-2
Years produced	1956–1961	1961–1965	1971–1981	1977–1987	1981–1996	1998–??
Subsystem						
Airframe	License	License	License	Domestic	License	Domestic and license
Engine	Foreign	License	License	License	License	License
Radar	N/A	Foreign	License	License	License	Domestic
Armament	Foreign and domestic	Foreign and domestic	License	Domestic	License	Domestic

Multiple sources.

als from domestic to foreign operating locations (Mowerly and Oxley, 1995). The only increase in diffusion time occurred with the F-4 can be partially attributed to Japan designing its first domestically produced fighter aircraft, the Mitsubishi F-1. Producing a domestic aircraft clearly demonstrates an increase in domestic capability; however, the curtailing of F-1 production indicates Japan recognized it had more to learn.

Up to and including the F-2, Japan has demonstrated increased defense industry capability of adapting and creating designs for aircraft subsystems (see Table 1). Mitsubishi, Fuji, and Kawasaki represent supporting industry capabilities in components, subsystems, electronics, and instrumentation (Shear, 1994). Similar to fighter aircraft, Boeing has increased Japan's role in each new commercial aircraft project (Turnipseed and Rassuli, 1999). While Japan has shown concern toward building a domestic aircraft industrial base, US prime aircraft contractors reveal few concerns about the impact of the FS-X program and increased Japanese capability on US suppliers (Lorell, 1995).

What level of technological capability does the Japanese aircraft industry possess? Though the evidence is currently unclear, the optimistic may conclude that Japan still relies on the United States for systems integration experience and engine technology. For example, the F-2 has experienced some problems during flight test, including wing flutter, wing cracks and high loads on the vertical fin, that continue to delay the program (Proctor, 2000; Sekigawa, 1998; Sekigawa, 1999). However, problems in developing a fighter aircraft are the rule and not the exception. The pessimistic may conclude that the United States has given away the keys to the kingdom (Shear, 1994). For example, Japan may have the ability to develop stealth aircraft that only the United States has currently operationally fielded (Lambeth, 1996).

Regardless of the conclusion made about the current level of technological capability by Japan's aircraft industry some things cannot be denied. Technology transfers from the United States have helped progressively build Japan's technological capability. Additionally, the lead that the United States has held in aerospace technologies is eroding. For example, between 1990 and 1994 aerospace technologies have produced large, but declining trade surpluses for the United States (National Science Foundation, 1996) as other nations including Japan become more competitive.

6. Discussion

The results of our study reinforce the findings of previous studies and provide insight into the reasons behind the findings of previous studies may relate to how individual transactions are perceived. The transaction focus of the United States does not appear to have fully appreciated the learning perspective of Japan and the progression of fighter aircraft technology transfers has had on developing Japan's aircraft industry. A learning perspective is also consistent in Japan's attitude toward licensing agreements in several areas including commercial aircraft (Turnipseed and Rassuli, 1999; Turner, 1987, p. 81), television technology and production (Radnor, 1991), and shipbuilding (Alexander, 1993). Meanwhile, US governmental policies appear to have focused on technology transfer as an event and looked at the benefits of supporting an ally, and ensuring compatibility of equipment.

The results of two related studies are worth reviewing. The first is a Government Accounting Office (GAO, 1992) study that made five key findings:

(1) the United States enters into military co-production for defense reasons,
(2) Japan enters military co-production agreements for economic reasons,
(3) the transfer of technology flows one way to Japan from the United States,
(4) military co-production agreements have helped Japan develop and expand its aircraft industry, and
(5) the United States has not considered the implications of military co-production programs.

The second study by Pack (2000) attributed the successful industrialization of Asian firms to differences in three key areas:

(1) rapid acquisition of external knowledge,
(2) ability to utilize knowledge transferred, and
(3) competitiveness of the markets in which products were sold.

Our study's findings largely agree with previous studies; however, our findings also reveal a noteworthy exception for each study.

First, in contrast to the GAO (1992) study, the United States has begun to show more interest in foreign technology and technology from Japan in particular. The United States first acted to increase the flow of technology from Japan in 1984, when the MOU on F-15 production allowed for "flowback" technology. Additionally, there are signs of progress in the United States recognizing the value of Asian technology. For example, the Asian Office of Aerospace Research and Development (AOARD) was established in Tokyo in 1992 (AOARD, 2001).

Second, in contrast to Pack's (2000) study, Japan's aircraft industry has not experienced the competitiveness that has helped its other industries become globally competitive. There are several reasons for decreased competition in Japan's aircraft industry including government intervention. Japan's government has largely regulated the aircraft industry by eliminating rivalry through work allocation on aircraft projects (Porter et al., 2000). Additionally, there is a limited market, because Japanese law currently forbids the export of military equipment (Shear, 1994; Porter et al., 2000). The implication for Japan's aerospace industry is that historically over 80% of Japanese aerospace sales were made

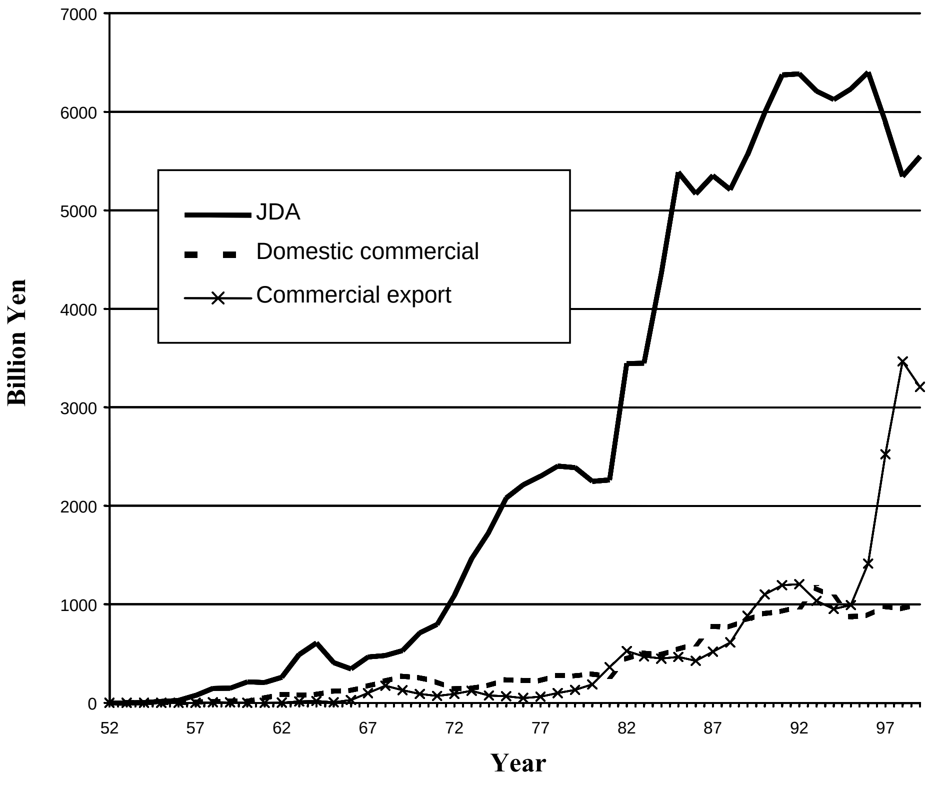

Fig. 5. Japanese aircraft industry expenditures by major category (The Aerospace Industry Yearbook, 1962, 1971, 1977, 1984, 1992, 2000; The Society of Japanese Aerospace Companies, Tokyo, in Japanese).

to Japan's military (Alexander, 1993). Although it has historically been a relatively small market, Japan's aerospace industry has shown consistent growth and the share of exports has increased significantly in the last few years, see Fig. 5.

The historically limited export market for Japan's military products and related technology represents a concern about generalizing our findings. Export of military technology is prohibited under the "three principles" originally announced by Prime Minister Sato, in 1967 (JDA, 1994). The principles forbid exports to (1) communist bloc countries, (2) countries to which the export of arms is prohibited under United Nations resolutions, and (3) countries which are actually involved or likely to become involved in international conflicts (JDA, 1994). The principles were reaffirmed in 1976, when they were extended to include arms production equipment, and they continue to guide Japanese policy (JDA, 1994). One consequence of the 'three principles' is that the concept of dual-use technology is not well established in Japan where civilian and military applications of technology are largely kept separate. Any concerns about our study's findings represent an opportunity for future research on Japan's aircraft industry or other nations where aircraft technology transfers occur, such as China, Germany, or Israel. A conservative interpretation of the present study is that technology transfers to other nations could have larger impacts on developing technological capability, and that Japan has developed the potential for a self-sustaining aerospace industry.

The amount of fighter aircraft technology transferred to Japan may not be as great as it may first appear due, in part, to special circumstances. For example, Japan's aircraft industry remains at least partially dependent on the United States for key technology, such as engines. Still there are reasons for caution. First, engine technology is available from other sources. Second, there may be a growing demand for Japan's aircraft industry in the civilian sector. For example, the Asian market is expected to represent over 40% of world aircraft sales in the coming decade (Turnipseed and Rassuli, 1999).

7. Conclusion

Technology transfer in the aircraft industry between the United States and Japan has occurred. The fundamental motivation for these transfers appears different for each nation, and is partially the result of viewing the transactions from different perspectives. Understanding the viewpoints of nations and how they differ on similar issues is important. The US perspective has been more transaction based, while Japan's perspective has been more learning based and this has implications.

The implications of different perspectives toward technology transfer for policy makers are two-fold. First, the United States was slow to learn from the Japanese, or realize that technology transfer is not inherently one-way. Indeed, every nation can gain from international interchanges of science and technology (Freeman and Soete, 1997). Policymakers in the United States also appear to ignore longer-term implications of the immediate technology transfer, and exhibit a continuing need to avoid the not-invented-here (NIH) syndrome.

Second, the Japanese have not been as successful in building an aircraft industry because it has characteristics that are different from other industries where Japan has experienced success. However, unique circumstances with Japan should not mitigate concerns about the impact of weapon licensing agreements with other nations. In conclusion, both domestic and foreign governmental policies and long-term impacts need to be considered by national policymakers in technology transfers.

Acknowledgements

We would like to thank the Institute for National Security Studies (INSS) for making this research possible. Additionally, we would like to thank Dr. Takao Miyazaki of the Asian Office of Aerospace R&D (AOARD) in Tokyo for finding and translating information used as part of this study. Further, we thank Mr. Forrest Waller of SAIC for reviewing previous drafts of this paper. Finally, we thank Mr. Norio Aoki of Aircraft of Japan for his permission to use his photographs of Japanese aircraft in this report.

References

Alexander, A.J., 1993. Of Tanks and Toyotas: An Assessment of Japan's Defense Industry, N-3542-AF. RAND, Santa Monica, CA.

Asian Office of Aerospace Research and Development (AOARD), 30 January 2001 (http://www.nmjc.org/aoard/).
Boeing, 30 January 2000 (http://www.boeing.com/defense-space/military/f4/firsts.htm).
Chang, S.J., 1995. International expansion strategy of Japanese firms: capability building through sequential entry. Academy of Management Journal 38 (2), 383–407.
Chinworth, M., 1992. Inside Japan's Defense: Technology, Economics and Strategy. Brassey's, New York.
Cole, J., Lubman, S., 1994. Global Arms Market—Bombs Away: Weapons Merchants are Going Great Guns in Post-Cold War Era—US Becomes Pushy Seller, Competing with Russia by Targeting Third World—Worries Over Proliferation. Wall Street Journal 28 January, p. A1.
Economist, 1998. Platform envy: 12 December, p. 23.
Eisenhardt, K.M., 1989. Building theories from case study research. Academy of Management Review 14 (4), 532–550.
Freeman, C., Soete, L., 1997. The Economics of Industrial Innovation. MIT Press, Cambridge, MA.
Government Accounting Office (GAO), 1992. US Military Co-production Programs Assist Japan in Developing Its Civil Aircraft Industry. Washington, DC, 18 March.
Hall, G.R., Johnson, R.E., 1967. Aircraft Co-Production and Procurement Strategy, R-450-PR. RAND, Santa Monica, CA.
Hall, G.R., Johnson, J.E., 1968. Transfers of United States Aerospace Technology to Japan, P-3875. RAND, Santa Monica, CA.
Ham, R.M., Mowery, D.C., 1995. Enduring dilemmas in US technology policy. California Management Review 37 (4), 89–107.
Hamel, G., Doz, Y.L., Prahalad, C.K., 1998. Collaborate with your competitors—and win. Harvard Business Review 61 (1), 133–140.
Hitt, M.A., Keats, B.W., DeMarie, S.M., 1998. Navigating in the new competitive landscape: building strategic flexibility and competitive advantage in the 21st Century. Academy of Management Executive 12 (4), 22–43.
Jane's all the World's Aircraft, 1956–1957, 1957. McGraw-Hill, New York.
Jane's all the World's Aircraft, 1967–1968, 1968. McGraw-Hill, New York.
Jane's all the World's Aircraft, 1970–1971, 1971. McGraw-Hill, New York.
Jane's all the World's Aircraft, 1975–1976, 1976. McGraw-Hill, New York.
Jane's all the World's Aircraft, 1979–1980, 1980. McGraw-Hill, New York.
Jane's all the World's Aircraft, 1984–1985, 1985. McGraw-Hill, New York.
Jane's all the World's Aircraft, 1990–1991, 1991. McGraw-Hill, New York.
Jane's all the World's Aircraft, 1997–1998, 1998. McGraw-Hill, New York.
Japan Defense Agency, 1994. Defense of Japan, p. 245
Katz, R., 1998. Japan the System that Soured: The Rise and Fall of the Japanese Economic Miracle. Eastgate Books, Armonk, NY.
Kim, L., 1997. Imitation to Innovation: The Dynamics of Korea's Technological Learning. Harvard Business School Press, Boston, MA.
Lambeth, B.S., 1996. Technology Trends in Air Warfare. RAND, Santa Monica, CA.
Levitt, B., March, J.G., 1988. Organizational learning. Annual Review of Sociology 14, 319–340.
Lorell, M., 1995. Troubled partnership: an assessment of US–Japan collaboration on the FS-X Fighter, MR-612/1-AF. RAND, Santa Monica, CA.
McLarren, R., 1949. Air power strength starts in the laboratory. Aviation Week 28 February, 39.
Mecham, M., 1998. Malaysia expands F/A-18 offsets across its manufacturing sector. Aviation Week & Space Technology 5 January, 60.
Mowerly, D.C., Oxley, J.E., 1995. Inward technology transfer and competitiveness: the role of national innovation systems. Cambridge Journal of Economics 19, 67–93.
National Science Foundation, 1996. Science and Engineering Indicators: 1996. National Science Board, Washington, DC (http://www.nsf.gov/sbe/srs/seind96/startse.htm).
Nelson, R.R., 1995. Why should managers be thinking about technology policy? Strategic Management Journal 16, 581–588.
Nonaka, I., 1994. A dynamic theory of organizational knowledge creation. Organization Science 5 (1), 14–37.
Olk, P., Xin, K., 1997. Changing the policy on government-industry cooperative R&D arrangements: lessons from the US effort. International Journal of Technology Management 13 (7–8), 711–728.

Pack, H., 2000. Research and development in the industrial development process. In: Kim, L., Nelson, R.R. (Eds.), Technology, Learning, and Innovation: Experiences of Newly Industrializing Economies. Cambridge University Press, Cambridge, UK.

Pelvin, R., 2000. In: Sansouci, M. (Ed.), Japanese Airpower 1919–1945: A Case Study in Military Dysfunction, in Military Studies, Version 3.0. Air Command and Staff College, Maxwell AFB, AL.

Polanyi, M., 1958. Personal Knowledge. The University of Chicago Press, Chicago, IL.

Porter, M.E., Takeuchi, H., Sakakibara, M., 2000. Can Japan Compete? MacMillan, London.

Proctor, P., 2000. F Is for Forever? Aviation Week & Space Technology, 17 January, 399.

Radnor, M., 1991. Technology acquisition strategies and processes: a reconsideration of the ‘make versus buy’ decision. International Journal of Technology Management, 113–135.

Sekigawa, E., 1998. F-2 tests delayed for wing repairs. Aviation Week & Space Technology, 12 October, 31.

Sekigawa, E. 1999. F-2 wing cracks lead ministry to study deployment delay. Aviation Week & Space Technology 16 August, 32.

Sekigawa, E., 2000. F-2 dominates Japan’s budget, but tanker sought. Aviation Week & Space Technology 25 April, 81.

Shear, J., 1994. The Keys to The Kingdom: The FS-X Deal and The Selling of America’s Future to Japan. Doubleday, New York.

Song, S.M., DiBenedetto, C.A., Zhao, Y.L., 1999. Pioneering advantages in manufacturing and service industries: empirical evidence from nine countries. Strategic Management Journal 20, 811–836.

Sullivan, G., 1991. Modern Fighter Planes. Facts on File, New York.

Todd, D., Simpson, J., 1986. The World Aircraft Industry. Croom Helm, London, UK.

Teece, D.J., 1986. Profiting form technological innovation: implications for integration, collaboration, licensing and public policy. Research Policy 15, 285–305.

Turner, L., 1987. Industrial Collaboration with Japan. Royal Institute of International Affairs, London.

Turnipseed, D., Rassuli, A., 1999. A history and evaluation of Boeing’s coalition strategy with Japan in aircraft development and production. International Journal of Commerce & Management 9 (1–2), 59–83.

Vogel, D.J., 1996. The study of business and politics. California Management Review 38 (3), 146–165.

Wegg, J., 1990. General Dynamics Aircraft. Naval Institute Press, Annapolis, MD.