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A comparative study of technological learning and organizational capability development in complex products systems: Distinctive paths of three latecomers in military aircraft industry

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ABSTRACT

This paper identifies different patterns of latecomers' technological learning in developing complex products systems (CoPS). The experiences of South Korea, China, and Brazil in military aircraft development are compared to explain the learning process in attaining indigenous technological capability. The military aircraft development programs involving international technology transfer agreements have been documented to investigate the technological learning patterns. We find different technology acquisition modes determined by latecomers' focus of knowledge-base: technological for "make" and production for "buy". We also find that these modes may influence the process of learning-by-doing. In addition, we find how the role of foreign partners influences technology acquisition mode. Whereas an active role results in co-production or co-development arrangement, a passive role leads to the vitalization of reverse engineering. We also shed light on the role of government policy initiatives that facilitate technological learning. Lastly, this paper extensively documented the successful technological learning in South Korea's T-50 and Brazil's AMX joint venture projects.

1. Introduction

Complex products systems (CoPS) are systems, networks, infrastructure and engineering constructs, and services that are highly costly and technology-intensive. They shape and enable modern industrial and economic progress with the introduction of new technology to the economic system (Hobday et al., 2005). Most CoPS research has until recently focused on developed countries, as latecomers have shown their intrinsic weaknesses stemming from the high entry barriers (Park, 2012). In order to fill in this gap, we document the cases of KAI (Korea Aerospace Industries) for South Korea, Embraer for Brazil, and AVIC (Aviation Industry Corporation of China) for China that have successfully acquired indigenous technological capability to develop their own military aircraft (Goldstein, 2002a,b; Vertesy and Szirmai, 2010). Although these three countries are generally considered as latecomers owing to their late-industrialization, Brazil and China have entered the aircraft industry quite early. In order to avoid the confusion on the extent of a latecomer, we define latecomers as firms who have been recipient of technology transfer whether through a formal or informal mechanism from the beginning of their aircraft industry.

For latecomers, this industry presents special challenges, as it is one of the most technologically intensive and complex industries with a steep learning curve for new entrants (Frischtak, 1994; Smith and Tranfield, 2005). This is the reason why cross-border technological alliance in aerospace and defense sector is a common behavior and constitutes a significant portion of the partnerships set up in manufacturing industries (Hergert and Morris, 1988; Dussauge and Garrette, 1995; Garrette et al., 2009). Regardless of the challenges and difficulties, latecomers recognize its importance and pursue technological breakthrough with the support of foreign partners. Since the industry involves a wide range of technology, it has a large ripple effect across all industries. In fact, military aircraft industry requires state-of-the-art technology not only confined to aviation engineering, but also across all high-tech disciplines such as mechanical, electronic, computer science, materials, systems engineering, etc. Despite its importance, very little is known about how cross-border technology transfer contributes to success-

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ful technological learning in latecomers' military aircraft industry (Hobday et al., 2000).

Most of the time, latecomer's initial learning is limited to performing production work as a subcontractor to major foreign integrators. Later, this is extended into absorption of design and system integration experiences through co-development schemes such as joint venture (Hobday et al., 2000). However, our strand of literature suggests that this typical pattern of latecomers' technological learning may differ contingent on the context of countries and industries (Gerschenkron, 1962; Pavitt, 1984; Nelson, 1993; Teece et al., 1997; Kim, 1998). First, the difference is derived from the focus of their knowledge-base influenced by industrial policy prior to the formal embarkation of the industry. Secondly, security-sensitive nature of military aircraft industry influences latecomers' accessibility to external resources which is reflected in the extent of foreign partners' role whether it is active or passive (Cho and Lee, 2003; Li, 2010). Thus, we posit that these factors may shape the patterns of technological learning in acquiring indigenous technological capability.

Based on these contextual factors, we identify patterns of technology acquisition mode and major technological advancement made through the cross-border technological alliance that facilitates knowledge and technology transfer in their respective military aircraft industry (Mowery, 1987; Hergert and Morris, 1988; Dussauge and Garrette, 1995). We also document milestone projects "AMX for Brazil" and "T-50 for South Korea" to shed light on key technological asset and skillset acquired throughout the development stages which has not been addressed in previous studies on latecomers' technological catch-up in CoPS (Choung and Hwang, 2007; Jun, 2011; Park, 2012). Lastly, we also identify the role of organizational capabilities in orchestrating latecomers' technological learning in CoPS. Previous literature on CoPS mainly emphasized the role of organizational capabilities in creating similar projects at minimum cost which may not be applicable to latecomers' cases (Davies and Brady, 2000). In fact, this conventional approach in CoPS with its emphasis on cost-minimization hinders us to address latecomers' main concern raised by technological barriers throughout the lifecycle of CoPS (Hobday, 1995a,b). Thus, this paper mainly focuses on the technological learning outcomes instead of focusing on economic outcomes of aircraft development programs involving foreign partners. In addition, existing literature on organizational capabilities have been applied at firm-level. However, it is important to note that latecomers' military aircraft industry involves active participation of government policy makers (King and Nowack, 2003; Cho 2003). In other words, existing organizational capabilities should be applied at government-level. In fact, three companies including Embraer, KAI, and AVIC for our study are state-owned companies in our analysis time frame. Thus, we find how latecomer government policy initiatives successfully facilitate technological learning.

Our study intends to contribute to the literature in three important aspects. First, while the conventional studies of latecomers' technological learning in aircraft industry claim that technological capability is obtained after practicing some production activities, we move beyond this sequence by identifying its determinants. Specifically, we ask how the focus of knowledge-base affects technology acquisition mode and learning by doing process. For this purpose, we compare the cases of Brazil with South Korea and China. Second, we find how the role of foreign partner influences latecomer's technology acquisition mode by comparing the cases of China with South Korea and Brazil. Third, we attempt to make a contribution to the literature by documenting the joint venture project "T-50" of South Korea and "AMX" of Brazil. With these projects, South Korea and Brazil gained global recognition for their aerospace technologies. The cases offer practical methods and detailed process of project-based technological learning. Lastly, we clarify the role of the government policy initiatives for CoPS in orchestrating latecomers' technological learning. We further advance the current operationalization of each capability by applying the recent stream of research in latecomers' CoPS (Lee et al., 2009; Park, 2012; Choung et al., 2012). By doing so, we find the key success factors of each case from strategic, functional, and project capability-building perspectives.

The remainder of this study is organized as follows. Section 2 begins with the theoretical background by reviewing the streams of literature in latecomers' technology acquisition strategies and organizational capabilities for CoPS. With the theoretical foundation, an analytical framework is built to examine the technological learning. Section 3 entails methodological approach and process along with brief background information on our cases. Section 4 compares the technology acquisition mode determined according to the focus of knowledge-base and the role of foreign partners. We also document the technological advancement and learning outcome of the three latecomers and the summary of T-50 and AMX joint venture projects. Section 5 provides a summary of the latecomer government policy initiatives to discuss implications, followed by concluding remarks on our theoretical and practical contributions.

2. Theoretical background

2.1. Major determinants of latecomers' technology acquisition strategy

In the past, literature on latecomers' technology acquisition strategy focused on cross-border knowledge transfer mechanism. In order to imitate, improve existing technologies, and create new products, latecomers absorb information and know-how by collaborating with foreign partners from advanced countries (Pack and Westphal, 1986; Lall, 1993; Kim, 1999; Ahuja, 2000; Powell et al., 2005). Kim (1997) developed a framework "knowledge transfer mechanisms" which consisted of formal and informal mechanisms and commodity trade to explain latecomers' learning with foreign support. Based on this theoretical establishment, scholars in latecomers' technology acquisition and learning highlight the success of East Asian economies with their active learning strategies (Viotti, 2002). In a similar manner, Etzkowitz and Brisolla (1999) investigated the reasons why Brazil of Latin America had fallen behind South Korea of East Asia after an apparent head start. Whereas the former concentrated its resources on indigenous basic research to be thoroughly convinced of technological superiority, the latter focused on reinforcing its production capacities to replicate foreign partners' manufacturing techniques. In spite of such evidences, the existing studies on latecomers seem to have accomplished little. The main reason is that most of the studies have conducted national-level analysis which hinders us from considering industry or firm-specific success. In addition, the limitation of the previous literature lies in mainly considering commodities or mass-produced goods. Although CoPS industry requires foreign partners' assistance just as in commodity and mass-produced goods industries, there are some differences in the extent of higher technological barriers and strategic uncertainties (Cho and Lee, 2003; Li, 2010).

In order to overcome the limitations, we refer to technology acquisition strategies for latecomers' military aircraft industry identified by Institute for National Strategic Studies (see Saunders and Wiseman, 2011). Acquisition strategies consist of purchase (buy), indigenous development (build), espionage (steal), reverse engineering, co-production, and co-development. For the sake of theoretical clarity and unbiased analysis, we exclude the option of espionage (steal). Given these information sources, we can distin-