Technology Policy, Firm Strategy and Innovation Performance in Chinese ASM

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Abstract

Using data from Aircraft and Spacecraft Manufacturing (ASM) in China and matrix analysis model, this article examines the link between state technology policy, enterprise development strategy, and firm innovation performance and also revisits the technology policy-strategy interactive evolution from 1950s to 2010s in ASM.

Key words: technology policy, firm strategy, innovation performance

Introduction

Aircraft and spacecraft manufacturing (ASM) is one of the most important industries in the era of the knowledge economy. As a key industry for a country's state security and international status, the ASM development is of strategic significance to promote the overall strength, improve the industrial structure and upgrade the labor skills of a nation (Orsenigo, 1989).

The last 60 years have witnessed continuous progress of the ASM in China despite all the unfavorable domestic and international conditions. By the end of 2011, China had made nearly 60,000 units of engines as well as more than 20,000 military and civilian aircrafts of which over 2400 were exported to other countries (Zhang et al., 2012). The development of ASM in China in the past 60 years displayed different features at different stages. In this study, we divide China's ASM development into three stages, namely, the pre-reform (1949-1977), post-reform (1978-2005) and upgrading (2006-present) stages. Under the circumstances of lacking venture capital and equity investment, the success of China's ASM was primarily due to the support of national policies in the pre-reform period. However risks are attached to adopting the government policy, especially in the post-reform stage when the internationalization and marketization are carried out. The failure of "Y-10" and "three steps" programs led to the upgrading stage in the field of aircraft and spacecraft manufacturing. This stage had witnessed another fast development of the aerospace industry, proving particularly significant in the aircraft field. China's official statistics show that the annual growth rate of main business income in China's aviation sector reached 16% during 2006-2011 (China Statistics Yearbook on High Technology Industry, 2012). Since 2006 China has made some remarkable achievements such as the establishment of the Commercial Aircraft Corporation of China (COMAC) in 2008 and the successful launches of MA600 in 2009 and ARJ21-700 in 2013. The success of the aviation industry during the upgrading phase can be attributed to the technology policy support on the one hand. Enterprise technology strategy also played a role on the other hand. However, few studies have focused on the relationship between the technology strategy and government policy and the impact of technology policy and enterprise development strategy on innovation performance in China's aerospace industry.

This paper attempts to address the following research questions. What are the policy paradigms and development strategies driving the growth of China's ASM? What is the relationship between technology policy, technology strategy and innovation performance? The remainder of this paper is structured as follows. In Section 2, we introduces the matrix analysis model between technology policy and development strategy. Technology policy-strategy interactive evolution in aircraft manufacturing of China is reviewed in Section 3. Then the analytic methods and data are described in Section 4, which is followed by the discussion of the findings in Section 5. Finally implications and limitations of this study are discussed in Section 6.

Conceptual Issues

Theoretical concepts

State technology policy

In emerging countries like China, policy-makers need to use different policy paradigms to balance the often-intertwined relationship between state interests and business interests (Yu et al., 2012). In this study, following the classification of mission- and diffusion-oriented policies by Ergas (1987), we suggest two policy paradigms, namely, the mission-oriented policy and market-oriented policy. By definition, the mission-oriented policy is characterized by centralized decision-making at the state level and the focused support of only some state-owned enterprises. In China, the mission-oriented state policy involves strong state participation and usually encourages the participated enterprises to pursue technology breakthrough and technology leadership (Yu et al., 2012; Spencer et al., 2005).

Market-oriented technology policy reflects China's market-oriented reforms. It aims to promote technology application and to improve the country's capacity of innovation through policy supported technology infrastructure construction, technology transfer and co-operation between different actors to adjust the country's industrial structure (King et al., 1994; Spencer et al., 2005). In comparison with the mission-oriented policy, market-oriented technology policy is committed to a wider range of technical support, focuses on a more advanced technology stage, and pays attention to a broader range of technical service ability building (Cantner and Pyka, 2001). Therefore, market-oriented policy usually focuses on technology acquisition, spread and assimilation and it often attempts to add more values to the existing products by improving quality, increasing efficiency and accessing niche service markets (Yu et al., 2012).The relationship between the two technological policies is shown in Table 1.

Table 1-The relationship between mission- and market-oriented policies

	Mission-oriented policy	Market-oriented policy
Strategic purpose	Technology leadership	Market capability
Technology property	Breakthrough	Value added
Interests orientation	State interest	Business interest
Participants	Large state-owned enterprises	Much wider participation
Industry type	aerospace	aviation
product sample	“Shenzhou”, “Chang’e”	MA600, ARJ21-700

Enterprise technology strategy

Technology strategy is a relatively new concept, which first appeared in R&D management strategy applied by some major companies focusing on diversification management in the 1950s (Narayanan, 2001). Our findings reveal that follow-up imitation and indigenous innovation are two major technological innovation models in the development of China's aerospace industry. We therefore propose that the leading and following strategies are the two major categories representing the technology strategy types in China (Blumenthal, 1976; Narayanan, 2001), despite the diversified classifications by different scholars (Porter, 1985; Butler, 1988; Slater and Mohr, 2006).

Technology leading strategy aims to establish and maintain the leading position in the technological competition market through technology development and utilization. Technology is the principal method for enterprises to create and maintain competitive advantage (Goodman et al., 1994; Teece, 2010). Meanwhile companies can choose the following strategy as the important component of its technology strategy, focus on using externally developed technology to avoid the risks of basic research and maintain a wide range of technical applicability. For these enterprises technology is not the main way to obtain competitive advantage (Narayanan, 2001; Slater and Mohr, 2006).

Matrix analysis model

Based on the mission- and market-oriented policy paradigms and the leading and following strategies, this paper constructs a matrix analysis model for technology policy and technology strategy, which is shown in Table 2.

Table 2-Technology Policy-Development Strategy Matrix

	Mission-oriented	Market-oriented
Leading dynamic	Government-guided indigenous innovation	Market-oriented technology leadership
Following dynamic	Government-guided technology absorption and learning	Market-oriented follow-up imitation

According to Table 2, there are four stages in the Chinese ASM technology upgrading process:

(1) Government-guided indigenous innovation (GGII) refers to the indigenous innovation supported by state technology aimed at technology breakthrough and leadership so as to establish and maintain competitive advantages or a dominant position in the field. The main participants are a few large state-owned enterprises with technical products and projects such as “Shenzhou” Moon Project and “Chang 'e” Program.

(2) Government-guided technology absorption and learning (GGTAL) means that the Chinese government or some Chinese state-owned enterprises first procure advanced technology from abroad or cooperate with foreign leading companies and then digest the introduced technology and learn from their leading international counterparts. A typical product in the category is the chujiao-5[4], based on the Yak-18 purchased from the Soviet Union in 1950s.

(3) Market-oriented technology leadership (MOTL) focuses on the indigenous innovation or cooperative development of advanced and core technology to improve the technical level and service capabilities of the enterprise. It is worth noting that the main participants are enterprises and the ultimate goal is profit. The corresponding representative technical products are the MD-82/MD–90 cooperated with McDonnell Douglas, as well as the ARJ21-700 and MA600 developed through China’s independent research.

(4) Market-oriented follow-up imitation (MOFI) refers to the technical follow-up imitations by some Chinese ASM enterprises in order to cooperate with and learn from their international leading counterparts so as to achieve their own independent R&D of their products. This includes a typical product of twin-engine propeller medium/short-range transport aircraft Y-7, made by China’s Xi 'an Aircraft Company, basically an upgraded imitation of the AN-24 airplane manufactured by the former Soviet Union.

Interactive evolution of policy and strategy in the aircraft industry

China’s aviation industry started from general maintenance business in the 1950s and gradually grew into a relatively complete industrial system. Now China has four aviation manufacturing bases in Shanghai, Shenyang, Xi'an and Chengdu respectively with the total staff beyond 300,000. We basically classify the development of China's aviation industry into three stages; pre-reform, post-reform and upgrading stages. The detailed information about the evolution process of technology policy and strategy is shown in Table 3.

Table 3- Interactive evolution of technology policy and technology strategy in China’s aviation

Time	Stage	Technical features	Innovation types	Achievement	Governmental department
1951-1978	Pre-reform	Repair and imitation manufacturing	GGTAL /MOFI	Chujiao-5, Y-8, B-6	Aviation Industry Bureau, The Third Ministry of Machinery Industry

1979-2005	Post-reform	Cooperative R&D and imitative innovation	GGII	Y-10, J-10, MD-90-30T, MA60	Aviation Ministry of Industry, Aviation Industry Corporation, AVICI and AVICII
2006-	Upgrading	Indigenous innovation	MOTL	ARJ21-700, MA600, Y-20	AVIC

Table 3 shows the reforming stage to be the watershed for China's aviation industry. Before this phase the industry is characterized by technical repair and imitation manufacturing, during which cooperative R&D and imitative innovation characterized the industry, and after which the indigenous innovations prevailed in China's aviation.

Methods and Selection of Variables

The model

In order to investigate the relationship between technology policy and strategy, and their impact on the innovation performance of China's ASM, this paper constructs a theoretical model. This model analyzes the relationship between state technology policy, enterprise technology strategy and innovation performance (Figure 1).

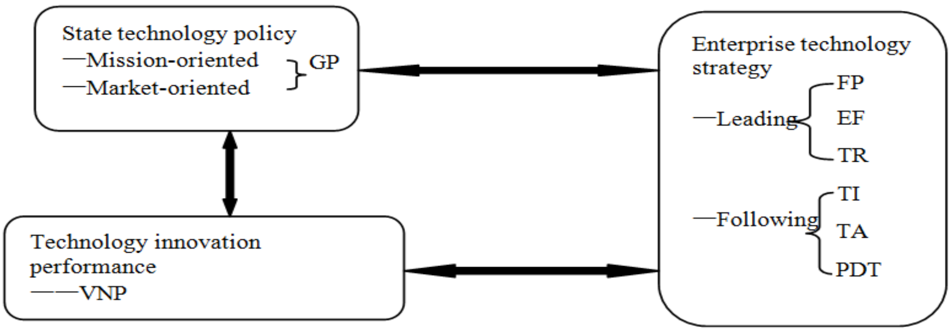

Figure 1-Theoretical model of relations

Definition of variables

The operational definitions of the variables with their abbreviations are presented in Table 5.

Table 5- Definitions of the variables and abbreviations

Variable	Classification	Definition	Abbreviation
Technology policy	Mission-oriented Market-oriented	Government Funds in the Sources of Funds for S&T Activities of ASM	GP
Technology strategy	Leading	R&D Personnel full-time equivalent of ASM	FP
		Funds Raised by Enterprises in the Sources of Funds for S&T Activities of ASM	EF
		Expenditure on Technical Renovation of ASM	TR
	Following	Expenditure on Technology Import of ASM	TI
		Expenditure on technology Absorption of ASM	TA
		Expenditure on Purchase of Domestic Technology of ASM	PDT

Innovation performance	Industrial Output Value of New Products of ASM	VNP

For enterprise technology strategy variables, leading and following strategies are the main technical innovation models in China's ASM industry. Technology breakthrough is the goal of leading strategy (Blumenthal, 1976), so we can select FP (R&D Personnel full-time equivalent of ASM), EF and TR as the three indexes indicating the leading strategy. The following strategy pays more attention to the purchase, import and absorption of existing technologies for imitative innovation, so we use TI, TA, and PDT to represent enterprise technology following strategy (Lee and Miller, 1996).

Preliminary Analysis

Descriptive statistical analysis

Figure 2 shows that the rising trends are obvious for the government fund (GP), the enterprise investment (EF), the expenditure on technical renovation (TR) and the industrial production value of new products (VNP) during 1995-2008. It is worth noting that the obvious declining trends from 1997 to 1998 are observed for indicators such as FP, TR and TI. We hold the opinion that the emergence of the decline correlated with the failures of "Y-10", and the "three-step" programs. The two failures casted a deep impact upon the development and internationalization of China's aviation industry, resulting in a significant reduction of spending on China's ASM technology import and renovation. The "Three-step" program however, was not a complete failure. Though the cooperation was terminated, China still obtained a wealth of cutting edge knowledge and technologies, which can be verified by the significant growth in the expenditure on technology absorption of ASM in 1998, even laying a good foundation for the subsequent "large aircraft" project in 2008.

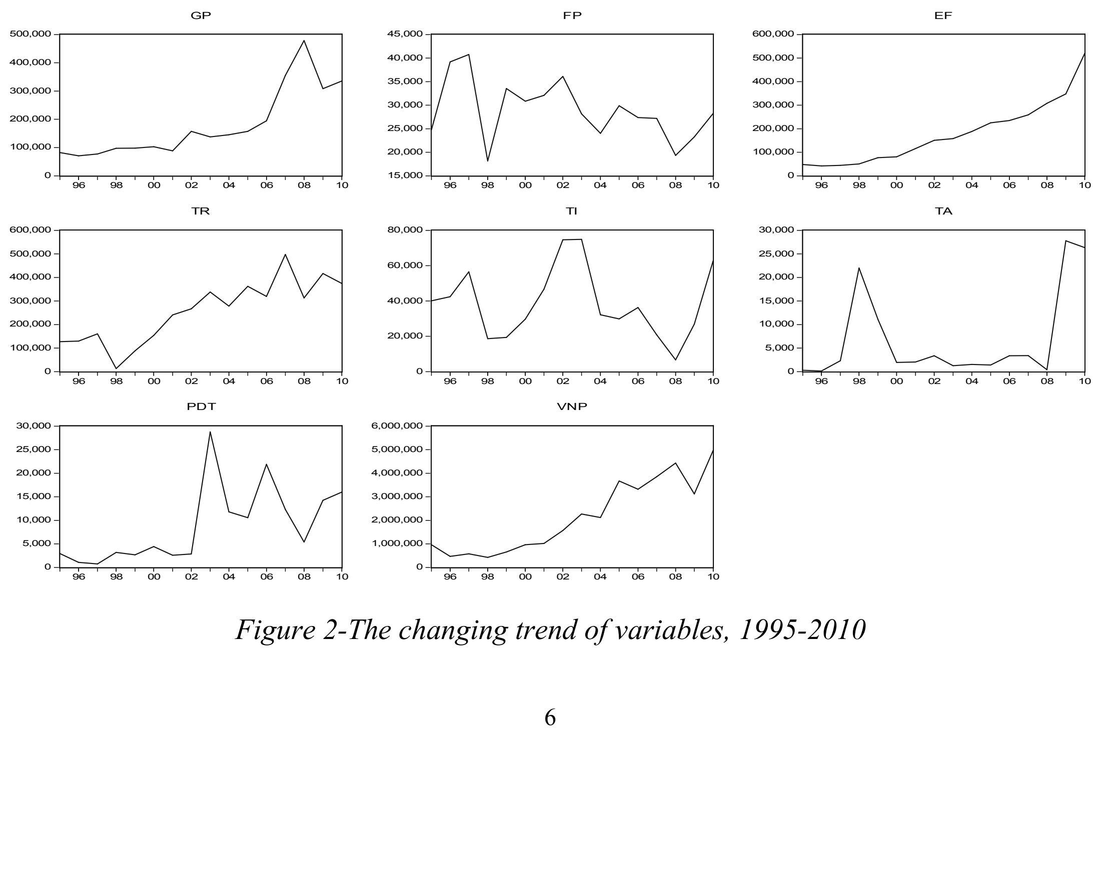

Figure 2-The changing trend of variables, 1995-2010

All indicators display an increasing trend after 2008, except government investment (GP). This phenomenon could possibly be explained by *National Program for Medium-to-Long-Term Scientific and Technological Development (2006-2020)* in 2006, the support for *Large Aircraft Project* in 2007 and the establishment of *Commercial Aircraft* Corporation *of China, Ltd.* in 2008. Obviously since 2008 the pursuit of leading technology and indigenous innovation has become the dominating policies in China, so all investments but the investment in the following strategy did increase.

Granger causality tests

Granger causality tests are useful to analyse the causality between variables when the causal relationship is not clear (Granger, 1969; Engle and Granger, 1987). In this section, we conduct Granger causality tests to examine the relationship between state technology policy, enterprise technology strategy and the innovation performance in China's ASM. Based on the results of Granger causality tests, we draw the influence diagram shown in Figure 3 to better understand the causal relationships between the variables.

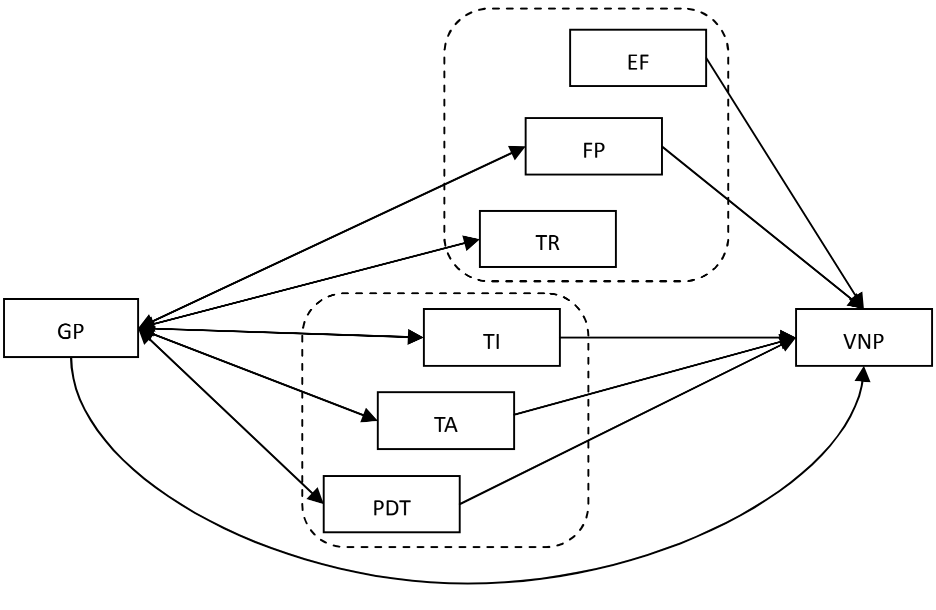

Figure 3-The relationship between technology policy, technology strategy and innovation performance

According to Figure 3, state technology policy and enterprise technology strategy have significant positive effects on innovation performance in ASM. Both the leading and following strategies have significant positive influences on the output of innovation. Furthermore, there is a mutual influence between state technology policy and enterprise technology strategy.

Discussion

The empirical results indicate that the state technology policy and enterprise strategy have a significant positive effect on innovation performance in ASM. It can be seen from the table that the VNP is positively related to GP, EF, FP, TR and PDT. The results confirm the traditional wisdom that technology innovation performance is affected by the state technology policy and technology strategy (Fan and Watanabe, 2006; Kangand Park, 2012). The selection of specific strategy is needed to meet their particular social and economic conditions (Fan and Watanabe, 2006). Niosi (2012) suggests that government policy and some indirect support are important factors for the strategy formation, innovation promotion and performance enhancement in ASM industry. Affected by its own specific political and economic context, China's state mission-oriented policy had been dominating before both the mission-oriented and market-oriented policies began to influence enterprise strategies and the innovation performance as well. The model is useful for the development of Chinese ASM. The success of the new regional aircraft ARJ21-700 is based on technology policy and enterprise strategy.

Moreover innovation performance of China's ASM is more dependent on the proficiency of Chinese domestic technology. It can be seen in Table 8 that VNP is significantly positively related to PDT and TR. But does not have any obvious correlation with TI and TA. Thus we conclude that the domestic technology has significant positive effects on the innovation performance in ASM in China. Scholars point out that technical enhancement and path dependence are two main development ways of the aerospace industry (Goldstein, 2002). In the development process, to promote their technology capacity and performance in ASM, Chinese policy makers attempted through cooperation with large foreign companies like McDonnell Douglas and the Boeing Company. They finally realized that they must rely on their own technical strength to achieve the development of ASM industry. We find that FP is closely related to the PDT and TR. Many researchers argue that the FP, to a large extent, reflects the enterprise technology strategy. To sum up, both the state technology policy and the enterprise technology strategy pay more attention to the domestic technology improvement and achieve better innovation performances based on the advanced domestic technology.

In addition, government policy has a greater influence on the leading strategy than the following strategy. The result shows that GP has a significant impact on EF, FP and TR representing the leading technology strategy. However GP doesn't have a positive effect on TI, TA and PDT reflecting the following strategy. Creating and maintaining the competitive advantage (Narayanan, 2001) has always been a main purpose of Chinese technology strategies in the aerospace industry since the 1980s. Determination on technology priority as the main strategy was affected by Chinese historical contexts. On the one hand due to the political and economic blockade against China during the Cold War, it was very difficult for China to bring in advanced aerospace technologies from the western countries. On the other hand, the withdrawal of the Soviet Union experts in the 1960s meant that the Chinese aerospace industry had to rely on its own ability to realize technology advancement and breakthrough. China has therefore adopted the mission-oriented and leading policy and strategy in developing its ASM.

Conclusion

The purpose of this study is to analyze the policy paradigms, strategic choices and the relationship between technology policy, technology strategy and innovation performance in China's ASM. This paper puts forward four types of the technology upgrading processes in Chinese ASM industry, namely, government-guided indigenous innovation, government-guided technology absorption and learning, market-oriented technology leadership and market-oriented imitative innovation. Furthermore the study reviews the evolution of the aviation and aerospace industry respectively. Finally an analytic model is constructed to analyze the relationship of the technology policy, strategy and performance. The main conclusions are summarized below.

Firstly, government policy support, the enterprise investment and the innovation performance in China's ASM all showed a rising trends in the past 60 years despite some fluctuations. The failures of "Y-10" and the "three steps" strategy as well as the restart of the "large aircraft" project are the main events in the ASM sector during the period of 1998-2008.

Secondly，the study reveals that the government technology policy and enterprise strategy have significant positive effects on innovation performance in ASM. In addition, the combination of mission policy and market strategy has become the dominant factor affecting China's ASM development. In other words in addition to the building of technology leadership following the mission-oriented policy, the Chinese government and enterprises also tend to foster a high rate of market services which are dependent on the market-oriented policy.

Thirdly, the empirical results show that domestic technical progress is the main catalyst for the improvement of the ASM technical ability and the innovation performance. Decades of explorations and experience show that the industrial development and performance improvement can't be dependent on the foreign technology and cooperation but are reliant on the domestic technology and indigenous innovation. Only in this way can China's ASM industry keep on the rising track.

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