Entrepreneurial judgment and re-combinative innovation: the emergence of the Chinese aerospace industry

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Entrepreneurial Judgment and Re-combinative Innovation

The emergence of the Chinese aerospace industry

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***Abstract*—The many re-combinative innovations of the Chinese aerospace industry have been associated with self-sufficiency technological policy between the 1960s and the 1970s and the pro-market policy since the 1980s. In this paper, we will discuss the activities of the Chinese state and its comparative advantage in judgmental decision making during uncertainty. By exploring how the Chinese state has handled entrepreneurial events over the decades, we will gain insight into the role of entrepreneurial judgment and how it serves as the driving force of re-combinative innovation within the aerospace industry.**

Keywords-entrepreneurial events; judgmental decision; entrepreneurial opportunity; entrepreneurial crisis; re-combinative innovation; aerospace industry and the People's Republic of China

I. INTRODUCTION

Though the People's Republic of China is a later entry in the aerospace industry, it has gradually caught up with early leaders in Russia, Europe and the USA. This paper will discuss the successive judgmental decisions made by the Chinese state and its related organizations that facilitated many re-combinative innovations. According to China's "Guidelines for the Medium- and Long-Term National Science and Technology Development Program (2006–2020)", the concept of re-combinative innovation or Zizhu Chuangxin is defined as the reassembling of existing technologies in different ways as to generate innovation as well as absorbing and upgrading of imported technology. Indeed, Schumpeter famously wrote that "innovation combines components in a new way, or that it consists in carrying out new combinations" [1]. In other words, re-combinative innovation focuses on creating new and improved products by re-combining existing technologies in new ways rather than developing new-to-the-world products using new technologies. An example of re-combinative innovation is the Shenzhou spacecraft series, which has been launched successfully since 1999. Shenzhou is a re-combinative innovation as it was influenced by the Soviet design but not a copy of Soyuz [2]. In this paper, we will elaborate the entrepreneurial events since the inception of the Chinese aerospace industry; an industry comprising of aviation, space and defense. We will identify critical entrepreneurial judgment that has been taken; in particularly, we will focus on the judgmental decisions which have enabled Chinese conglomerates Aviation Industry Corporation of China (AVIC), China Aerospace Science and Technology Corporation (CASC), China Aerospace Science and Industry Corporation (CASIC) and (Commercial Aircraft Corporation of China) COMAC to accumulate technological knowledge that subsequently generated re-combinative innovation.

II. JUDGEMENT AND DECISION MAKING

Decision making has been widely studied since the publication of Herbert Simon's seminal work Administrative Behavior in 1947; social scientists in the domains of management, psychology, philosophy, politics, sociology, economics, history and neuroscience have all provided substantial inputs into the topic. Decision making has been linked to rationality, preference, utility, dilemma, risk, accountability, culture etc. One of the most well-known decision makings is associated with the bible story within the Garden of Eden, where Eve and Adam chose to eat from the tree of knowledge and were as a result expelled from the paradise. At the individual and group level, Hardin elaborated the divergent of judgment between individuals and the collective, which originated from the contradiction of self- and group-interests and resulted in The Tragedy of the Commons [3]. Among researchers that are interested in public policy, judgment and decision making are associated with relevant information that feed into the nature of problem, the available alternatives and the likely outcomes.

III. ENTREPRENEURIAL EVENTS AND JUDGMENTAL DECISIONS

Entrepreneurial events are external, historical events that take place at certain conjecture of an industry's development, and can positively or negatively influence the development of the industry. Entrepreneurial event can be classified as entrepreneurial crisis or entrepreneurial opportunity; the former is an event that could hamper industrial growth while the latter relates to an event that can enhance growth.

Organizational leadership is critical during entrepreneurial events; in particularly, core leaders make judgmental decisions that enable the organizations capitalizing on opportunities or crises. Casson discussed the importance of judgmental decision making in the context of the entrepreneurial theory of the firm [4]. Since entrepreneurship is key to the growth and survival of

organizations in external environment characterized with crises and opportunities, he argued that entrepreneurial judgment is the basis for success as those who excel in making decisions in uncertainty will generate competitive advantages for their organizations. Casson's entrepreneurial decision makers incorporated the historical themes of risk, uncertainty, innovation, perception and change and specialized in 'taking judgmental decisions about the coordination of scarce resources' [5].

Judgmental decisions are a synergy of judgments and decisions and occurred when 'different individuals, sharing the same objectives and acting under similar circumstances, would make different decisions' [6]. Different decisions were results of different access to information or different interpretations of the same information. Casson elaborated on the importance of possessing complementary information among entrepreneurial decision makers as not about 'possess any single item of information that no one else does', but 'his advantage lies in the fact that some items of information are complementary, and that his combination of complementary items of information is different from everyone else's'; Casson also suggested that entrepreneurial decision makers needed 'to be in contact with primary sources wherever possible' in order to ensure that the information was up to date and accurate [7]. A useful feature of the primary source is that the information has not been distorted by the providers with selective mechanism or personal attitudes and beliefs. Figure 1 implements Casson's framework for judgmental decision making within entrepreneurial events. The process of judgmental decision making involves decision problem structuring, information gathering, interpretation of information and then applying the relevant data to the decision criteria.

Within the domain of public policy research, the complexity of information is acknowledged during its transformation throughout the inquiry, making and communication stages. In the analysis of policy, elements of judgmental decision could be seen in the use of delphi technique, cross-impact analysis and feasibility assessment. For instance, the feasibility assessment in relation to tax increase to cover a targeted expenditure project will focus on the issue position (the degree of support among stakeholders), available resources (the resource available to stakeholders in pursing their positions) and relative resource rank (the relative rank of each stakeholder with respect to its resources). Decision makers are required to use explicit subjective judgment accordingly; nevertheless, the process is mechanical and the role of entrepreneurship is not emphasized. We will, for the first time, synthesize existing literature concerning entrepreneurship, judgment, decision making and organization-environment interface to present a framework that enable us to explain technological accumulation and the growth of an industry. The framework is of particular importance to understand the emergence of the knowledge-intensive aerospace industry, which shapes China's industrial innovation and technological trajectory.

		Entre-preneurial Events
FORMULAT-ION OF THE DECISION PROBLEM	Specification of the objective Alternative Option Specification of the constraints Derivation of the decision rule	
DATA GENERAT-ION	Data Collection Data Estimation	
EXECUTION OF THE DECISION	Application of data to the decision rule Initiation of the implementation process	

Figure 1. Judgmental decisions

IV. METHODS

Based on the interpretive research paradigm proposed by Yanow and Schwartz-Shea, this paper adopted the qualitative methodology focusing on the case study of the Chinese aerospace industry. The qualitative nature of the research provides thick description of entrepreneurial events and their subsequent implications, and is appropriate in understanding judgmental decision and the subsequent technological significance [8]. A case study can be seen as an empirical inquiry that investigates a phenomenon within a specific context; the use of case study in this paper allows an explicit understanding of judgment, decision making and their interaction within historical entrepreneurial events that have led to accumulation of re-combinative innovation in the Chinese aerospace industry. Primary data was obtained from industry participants within China; the respondents, aged between 25 and 45 and who were in research-intensive career, took part in 7 semi-structured interviews that explored the growth of aerospace industry. These interviews were conducted between 2015 and 2016 and lasted for one to two hours. The topics revolved around the management, technology and the growth of the industry. The interviews were transcribed by a native speaker. Additionally, firm publication and reports were also used. Secondary data included books, archival information and industry reports. Consequently, a large volume of textual materials were generated in both Chinese and English. Analytical techniques were used to generate insights from the data collected. First, we complied the entrepreneurial events that were critical for the Chinese aerospace industry. Then, we generated the issues in relation to the decision problem and the relevant judgmental decisions associated with them. Finally, we explored the implications of the judgmental decisions upon re-combinative innovation.

V. EMERGENCE OF CHINESE AEROSPACE

Though there are divergent views on the achievement of the Chinese aerospace industry, observers such as Laurence Young, Apollo program Professor of Astronautics at the Massachusetts Institute of Technology commented that China's re-combinative innovation had taken the best of what it imported from the Russians as well as what it learned from America and the European Space Agency [9]. The new Chinese government established the Chinese Academy of Sciences in 1949, but it only pursued a formal initiative to take part in research projects in 1956. The beginning of the aerospace industry in China was linked to a generation of scientists returning from the USA and Europe. For example, a fifth of the 5,000 graduates in the USA chose to go back to China [10]. Various institutions in different names had evolved from the Chinese aerospace industry since its inception, and they could be traced to the Fifth Research Academy that was established under the Ministry of Defence in 1956. The Fifth Research Academy restructured and rebranded itself during politico-economic changes and was the Seventh Academy of Machine Building (1964), the Ministry of Astronautics Industry (1982) and the Chinese Aerospace Corporation (1993). In 1999, the Chinese Aerospace Corporation was re-organized into the administrative function as headed by China National Space Administration whereas the research, design and production functions were grouped under CASC and CASIC. Both CASC and CASIC are independent entities, with some 300,000 employees. Similarly, AVIC which acquired its current name in 2008, was within the Mechanical Industry Department prior to the 1980s. It became the Ministry of Aviation Industry and the Ministry of Aviation and Aerospace Industry during the 1980s. It was transformed into the China Aviation Industry Corporation in 1993. AVIC is a leading shareholder of the large passenger aircraft manufacturer COMAC, which was established in 2008. The total number of employees in AVIC and COMAC are over 70,000. In this section, we will discuss the technological impact of entrepreneurial crises and opportunities that emerged since the industry's inception.

A. Entrerpreneurial Opportunity of the 1950s

The foundation of China's aerospace industry was, to a great extent, linked to a generation of foreign educated and trained scientists, and in particularly Qian Xuesen. Qian was educated in the Massachusetts Institute of Technology during the 1930s; he further gained experience in CalTec's Jet Propulsion Laboratory and the US Air Force and became an expert in propulsion and aerodynamics [11]. Nevertheless, Qian was accused of being a sympathizer of the Chinese Communist Party and his career abruptly came to an end. He was eventually allowed to leave the USA at the diplomatic request of the new Chinese government in 1955 [12]. Shortly after his arrival in China, Qian formally proposed plans to embark on space and defense research in a new nation with little financial resources as the Nationalists left China in 1949 with all its gold reserve. The Chinese state faced the choice of continuing prioritizing and channeling resource into the less risky aviation or embarking on a completely new project of space and defense. The space and defense sector was selected as the first choice, which leveraged Qian's expertise in rockets and enabled China to initiative its first move into a global industry.

B. Entrepreneurial Crises between the 1960s and the 1970s

Entrepreneurial crises in this period are two folds, covering external political isolation and internal political turmoil. We will first look at the geopolitical development that led to China's relatively isolated position. Though the Chinese aerospace industry had been able to absorb knowledge from the USSR in the 1950s with licensing and co-production, these activities came to a halt across the following two decades due to a shift of geopolitical balance of power. The USSR suspended technological transfer to China after the successful missile programme DF-1. This was accompanied by Western governments banning high technology export and key high technology knowledge exchange to the communist regime [13]. Decision makers in the early 1960s were encountered with an economy in crisis as a result of the failure in Great Leap Forward and natural disaster. Yet they continued to support the aerospace industry against all odds, which allowed the technological accumulation necessary for re-combinative innovation within the indigenous industry.

Another entrepreneurial crisis facing the aerospace industry between 1966-76 was the Cultural Revolution, where research and development was severely disrupted. The career of aerospace professionals including Zhao Jiuzhang and Yao Tongbin were terminated in series of tragic incidents. A key judgmental decision was made to shelter the aerospace units under the People's Liberation Army Air Force (PLAAF). It was reported that Zhou Enlai had prepared a list of core scientific personnel and instructed the military to protect their personal safety during the peak of the Cultural Revolution; this was corroborated with Qian Xuesen's comment that he owed his life to Zhou during the chaos [14]. The preservation of key personnel was a judgment that enabled the continuity of the significant re-combinative innovation after the end of the Cultural Revolution.

C. Entrepreneurial Opportunities since the 1980

Deng Xiaoping's market reform had ushered a new era in the Chinese aerospace industry where new entrepreneurial opportunities emerged. The reforms enabled the state enterprises to become independent entities that were able to make commercial decisions.

D. Reshaping Socialism and Technology Accumulation

The re-orientation of the economic ideology in China provided an opportunity for the Chinese aerospace industry to globalize. The Open Door Policy launched in 1978 meant that the Chinese state was faced with the choice of encouraging global cooperation through joint venture and alliance on the one hand versus attracting wholly owned foreign investment on the other. Under Deng's economic

vision, joint venture in the aerospace sector was selected as the official approach to globalize high tech investment. By the mid-2010s, aviation clusters such as Beijing, Tianjin, Shanghai and Chengdu that have evolved from regional manufacturing units are now associated with foreign investment. The Chinese state has opted for some degree of control and equity investment from foreign investors as a requirement for their entry into China. For example, Airbus's high profile joint venture began its operation in the Tianjin aerospace cluster in 2008, and is currently a final assembly site for its A320 model. Airbus has further planned to open a second plant in Tianjin in 2017. Collinson and Narula's case study on the aerospace joint venture in China suggested that it involved capability transfer "in terms of both process routines (such as quality circles and lean management systems) and problem-specific knowledge, through formal training and on-the-job learning" [15]. Indeed, China's re-combinative innovation as seen in COMAC's ARJ-21 and C919, built on its accumulated knowledge acquisition during joint venture activities enabled COMAC and its predecessor to design high performance end products that utilized outsourced sub-systems from global suppliers. Outsourced components of ARJ-21 and C919 accounted for over 70 per cent of their total contents respectively, and therefore illustrated COMAC's capability in system integration.

E. Post-Soviet and Knowledge Transfer

The Russian policy on technology exchange during the 1950s was driven by ideological consideration while that in the 1990s was primarily based on economic concern. The break-up of the Soviet Union provided further entrepreneurial opportunities for the Chinese aerospace industry's technology learning. The transfer of aerospace knowledge to China during this period involved tacit knowledge. Stokes pointed out there was an influx of Russian and Ukrainian academics visiting China and technical exchanges that assisted the Chinese aerospace industry to acquire further skills to solve technical issues; he added that the lack of an effective regime since 1994 had led to substantial flow of manufacturing, electronics, and materials technology from the former USSR to China [16]. Pollpeter further elaborated the depth of cooperation between China and Ukraine in the late 2000s covering 29 long-term projects, ranging from the joint development of space rocketry, earthquake monitoring and remote sensing satellites, and satellites to monitor and study space weather to space projects, in conjunction with the exploration of the Moon and Mars, engine manufacture, welding in space, and use of solar energy [17]. The fact that the Chinese state was pragmatic and the judgmental decision was associated with the choice of a collaborative approach rather than a self-sufficiency approach enabled the aerospace industry to capture the knowledge available at the time.

F. Deepening of Economic Reform

The deepening of economic reform in the domain of state enterprises as seen in the more recent "Guiding Opinions on Promoting the Transformation of Defense Industries into Joint-Stock Enterprises" represents another entrepreneurial opportunity for the Chinese aerospace industry. The corporate autonomy gained by aerospace conglomerates since the 1980 has transformed their process and structure. The 2008 guideline enables AVIC, CASC, CASIC and COMAC to further transform their ownership structure and raise capital to fund research and development through listing of selected subsidiaries in Hong Kong, Shenzhen and Shanghai. In other words, judgmental decisions had been made to allow selected firms to seek funding externally rather than from the state. By the mid-2016, 27 of AVIC's subsidiaries, 12 of CASC's subsidiaries and 7 of CASIC's subsidiaries have been listed in the stock exchange; the listed firms are therefore subjected to the rules of the relevant securities regulatory commission. Overall, the judgmental decision enabled the aerospace conglomerates to become more financial independent from the state and open an important source of external funding for increasingly costly research aerospace activities.

VI. Discussion and Conclusion

In his 1965 speech to the US congress, President Johnson stated that a decision maker's hardest task was "not to do what is right, but to know what is right", hence highlighting the role of information in judgmental decisions. Building on Casson's entrepreneurial decision making framework, we have explored how the judgmental decisions made by the Chinese state has served as a globalizing force of the indigenous aerospace industry. The current stage of global exploitation of re-combinative innovation by China's four aerospace conglomerates has been preceded by technological learning and collaboration with leading foreign firms and institutions, which in turn embodied Chinese leaders' strategic response towards entrepreneurial events. The state's initiative has capitalized on opportunities and crises and allowed the conglomerates to continuously accumulate unprecedented resources within the presence of various constraints and impact upon re-combinative innovation. Existing literature has pointed to the implication of learning and technological accumulation upon the acquisition of technological capabilities and competitiveness [18]; in particularly, technological accumulation among late entry countries was heavily embedded within literature on political economies and innovation studies [19]. This paper has built upon the literature and highlighted the role of entrepreneurial decision making in explaining the accumulation of technological knowledge within the Chinese aerospace industry, which generated technological capabilities that contributed towards its many re-combinative innovations.

Why the Chinese state seems to have a comparative advantage in making judgmental decisions during uncertainty? Perhaps Stollberg-Rilinger's discussion of historical perspective in decision making where formalized decision procedures were accompanied by informal negotiations could be used to elaborate the Chinese state's judgmental decision making [20]. In other words, formal judgmental decisions performed symbolic functions where the entrepreneurial state negotiated pathways within its institution. Overall, a key characteristic of judgmental

decision within the Chinese state is a long term perspective which derives from a vision concerning the importance of the strategic industry and China's place in the global community. The aerospace industry is strategic in nature not only because the requirement of its outputs by the military, but also because of the technological relatedness and the linkage with the development of engineering and production technique. Additionally, it should be noted that the passion for aerospace could be traced to Song China's invention of rockets such as the Flying Fire Spear. Hence, judgmental decisions within the industry could be shaped by a sense of historical destiny. Finally, (as controversial among liberal democracy as it might be), the practice of democratic centralism further means that decision makers were able to formulate the decision problem, generate data and execute the decision that enhanced national interests in a timely fashion [21].

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