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The study on the Driving Effect of Defense Science and Technology Innovation

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ABSTRACT
National defense science and technology innovation plays an irreplaceable role in driving the development and transformation of national defense science and technology industry. An in-depth analysis of the driving effect of national defense science and technology innovation on national defense science and technology industry is of great significance for understanding the mode and path of national defense science and technology innovation, further exerting its driving function, and promoting the development and transformation of national defense science and technology industry. The driving effect of national defense technology innovation on national defense and technology industry is mainly reflected in three aspects: cost, quality, and industrial structure.

Keywords: *national defense science and technology innovation; national defense science and technology industry; driving effect*

1. INTRODUCTION

Engels once pointed out: "Once technological advances can be used and have already been used for military purpose, they often immediately cause changes or even revolution in the way of war compulsively against the will of the commander." Accordingly, defense science and technology innovation has been taken as the commanding height for winning future wars. With defense science and technology becoming the main standard for measuring national defense strength, promoting defense science and technology innovation and highlighting its driving effect to defense science and technology industry, have become the inevitable requirement for implementing the overall national security view [1]. Innovation-driven development is an urgent need and fundamental requirement to adapt to and lead the new normal. In order to provide a more effective strategic deterrent force for national security, the defense science and technology industry must seize the commanding heights of the development and application of science and technology [2]. The in-depth analysis of the driving ways and means of defense science and technology innovation on national defense science and technology industry is of great significance to exert its driving effect and promote the development and transformation of national defense science and technology industry.

1.1. Related Work

Innovation is emphasized in all walks of life nowadays, and even all kinds of repetitive behaviors of imitation and plagiarism are advertised as "innovation". We may have been commonplace to innovation. However, the understanding of the important role of innovation in social and economic development did not begin to be theorized and systemized until Schumpeter's "Economic Development Theory". In Schumpeter's view, innovation is "the introduction of a new combination of factors of production into the production system that has never existed before", so as to improve the overall economic efficiency. Innovation is not a pure scientific research, but from the whole process of R&D, manufacture, production to final commercialization. A large number of scholars have done a wealth of research on the path and method through which innovation drives economic development. One of the important achievements is the innovation process model. It reflects the specific driving and generating mechanism by studying the combination form and flow mode of innovation elements in this process. In the early stage, as people only emphasized the commercialization of innovation, the linear model of "innovation → economy" was formed. Although this linear model is simple and intuitive, it cannot reflect the nature of innovation and the communication and interaction between various links in the innovation process. With the deepening of the research on innovation, people found that "innovation is not a linear process", but the organic combination of technology, economy and social interaction. On this basis, some scholars depicted the innovation process from different perspectives, including the Interaction Model proposed by Rothwell and Robertson, the Chain-linked Model proposed by Kline and Rosenberg, etc. On the basis of fully recognizing the importance of scientific and technological innovation, Deng Xiaoping, the chief architect of reform and opening up policy, put forward the famous conclusion that "science and technology is the first productive force". With the full release of scientific research vitality, various scientific and technological innovations have emerged one after another, which has injected a strong endogenous driving force into

China's economic development. From the point of the economy, science and technology are the primary productive forces; In terms of military, science and technology are the primary fighting force. As an important intelligence resource serving national defense and military, the military function contained in national defense science and technology innovation makes it a necessary component of military strength. However, the military function of national defense scientific and technological innovation that appears in the form of knowledge must ultimately be realized through weapons and equipment with lethal properties. The transformation from knowledge to real objects resides in the entire process of resource allocation in the defense economy. Once the national defense science and technology innovation is integrated into the physical form of weapons and equipment, its actual value is not only reflected in military effects, but also in huge economic effects. National defense science and technology innovation provides advanced technology and processes for the defense economy, especially the defense industry, to develop and produce various new weapons and equipment, transform and improve the industrial structure and product structure of the defense economy, and promote the development of the defense economy. However, at present, there are few literatures to study the driving effect of national defense science and technology innovation on national defense science and technology industry, so as to understand the action mode and path of national defense science and technology innovation.

1.2. Our Contribution

The main contribution of this paper is to reveal the role of national defense science and technology innovation in driving the development of national defense technology industry through in-depth analysis of the optimization of defense economic resources brought about by national defense science and technology innovation, in terms of cost, quality, and industrial structure. This paper provides a theoretical analysis method for reference to further exert the driving effect of national defense science and technology innovation.

1.3. Paper Structure

The rest of the paper is organized as follows. Section 2 introduces the low-cost driving effect of national defense technology innovation, which mainly expounds that national defense science and technology innovation can reduce the production cost of national defense economy by acting on labor and capital; Section 3introduces the high-quality driving effect of national defense science and technology innovation. It mainly expounds that national defense science and technology innovation can enhance the competitiveness of national defense science and technology industry by increasing the diversification of military products and improving the quality of military products. Section 4 introduces the structure optimization effect of national defense science and technology innovation, mainly expounds that national defense science and technology innovation can drive the adjustment of industrial structure of national defense science and technology, so as to achieve transformation and upgrading. Section 5 makes the conclusion.

2. LOW-COST DRIVING EFFECT OF DEFENSE SCIENCE AND TECHNOLOGY INNOVATION

The first working mechanism of defense science and technology innovation is the low-cost driving effect. In the context of market economy, enterprises are pursuing the maximization of economic profits. By improving production efficiency and reducing production costs, they can improve their efficiency and promote their growth. As a participant of market economy, national defense science and technology enterprises also face fierce competition in the market. With the progress of market economy reform and the deepening of civil-military integration, national defense science and technology industrial enterprises in China are also facing more and more competitive pressure. Cost is an unavoidable issue for every defense technology industrial enterprise. In the generation of combat power, we must consider the economic affordability of the country, society, and enterprises. Cost reduction is of great significance not only to reduce financial burden, but also improve the competitiveness of national defense technology and industrial enterprises. Through using innovative science and technology in the production activities of national defense economy, we can optimize the combination of factors, improve labor productivity, and reduce constraints of resource scarcity, thereby achieving the target of reducing costs [3]. The paper will elaborate the low-cost driving effect from the following two aspects, and the amount of national defense economy as Y, labor as L, capital as K, and technological innovation as T(t).

2.1. Impact of Defense Science and Technology Innovation on Labor Costs

One of the roles of defense science and technology innovation in optimizing resource allocation is maintaining a stable output level through reduce the amount or frequency of labor under the condition that other factors are unchanged. This form can be called labor-promoting innovation, that is, Hicks neutral in economics. Under a certain capital-output ratio, the relative ratio of input factors $(K * F_K)/(L * F_L)$ can remain unchanged. The production function in this case can be expressed as:

$$Y=F[K, L*T(t)]. \quad (1)$$

The technology index is T(t), and $T'(t) \geqslant 0$. According to the production function, it can be known that defense science and technology innovation has essentially replaced

the labor force. This labor-promoting innovation has the same output and effect as increasing labor stocks.

Nowadays the populations of all countries, especially those in developed countries, are facing the impact of declining birthrates and aging. The labor costs are very high. Wars can't be inseparable from human input. A large part of the high military expenditures is used for military salaries and welfare in many countries. The equipping and rationing of soldiers in war will require logistics to meet their operational and subsistence needs. Because of the impact of China's family planning policy and the advent of a low birth rate, population growth has gradually entered an inflection point, and labor costs are also rapidly increasing. Labor costs have become an important factor restricting the improvement of a country's overall military strength. Therefore, many countries are carrying out military reforms, reducing the number of regular troops, and creating a new type of military that is smaller and more technological. At present, when the reduction in the size of the military is continuous, countries can still maintain the same or higher combat effectiveness, which fully reflects the impact of defense science and technology innovation on the labor force stock. In the mechanization era, due to the lack of a unified information platform, the transportation, warehousing, storage, and usage of munitions materials need to organize a large number of personnel for inventory, statistics, and processing. With modern information technology being widely used in the military, these materials will be stored in a unified information system through bar code technology, radio frequency technology, etc. At the aid of relevant professional software, only a small number of personnel can handle the information. By establishing the accurate logistics awareness system, US military have saved a lot of costs for the management of military resources and greatly improved its logistics support efficiency.

2.2. Impact of Defense Science and Technology Innovation on Capital Cost

Another role of national defense science and technology innovation in optimizing resource allocation is maintaining a stable output level through reducing the capital stock under the condition that other factors remain unchanged. This form can be called capital-promoting innovation, that is, Solow neutrality in economics. Under a certain labor-output ratio, the relative ratio $(L * F_L)/(K * F_K)$ of input factors can remain unchanged. The production function in this case can be expressed as:

$$Y=F[K*T(t),L]. \quad (2)$$

According to the production function, it can be known that defense science and technology innovation has essentially played a role of replacing capital. The capital-promoting innovation has the same output effect as increasing capital stock.

The formation of the final product of national defense economy is limited by the scarcity of resources. For example, rare metals such as titanium, platinum, and nickel used in the production of weapons and equipment have very limited storage in the natural world. Therefore, reducing waste during the production process and efficient using of resources are essential. Capital-promoting innovation can better solve this problem. 3D printing technology has enjoyed world-renowned treatment since its emergence, which largely depends on its innovation in traditional production processes. Using 3D printing technology can save a lot of raw materials and greatly reduce the physical capital cost. For example, the largest overall Ti6AI4V titanium alloy reinforced frame in the US F-22 aircraft requires a blank die forging weighing 2796 kg, while the actual formed part is less than 144 kg and the material utilization rate is less than 4.9%. In 2005, China successfully realized manufacture of 4 kinds of aircraft titanium alloy secondary bearing structures. The utilization rate of parts materials increased by 5 times, and the cost has been reduced by more than 1/2. The basic characteristic of China's resource endowment structure is that capital is scarce and labor is abundant. The drawbacks of the national defense economy development method that relies on increasing material capital investment are increasingly apparent [4]. Enhancing capital-promoting innovation is the primary choice to transform China's defense economic development model.

3. THE HIGH-QUALITY DRIVING EFFECT OF DEFENSE SCIENCE AND TECHNOLOGY INNOVATION

The second working mechanism of defense science and technology innovation is the high-quality driving effect. Both of the force deterrence in a peaceful era and the confrontation in a wartime era, good weapons and equipment are essential. The innovation of military equipment has a huge impact on the war. In World War II, Germany took the lead in completing the mechanized military science and technology revolution, using advanced military industry to support its huge mobile combat force, thus rapidly destroying many Western Europe through the use of "blitzkrieg". The United States shattered Japan's illusion of fighting on its own ground by a newly developed atomic bomb, thus greatly speeding up the process of ending World War II. No matter what kind of weapon, its production cannot be separated from technological innovation. The high-quality driving effect of defense science and technology innovation refers to its role in promoting the diversification of military products and increasing the military's quality.

3.1. The Impact of Defense Science and Technology Innovation on The Diversification of Military Products

In the new era, the complex environment and diversified tasks faced by the army have set higher requirements on the performance and types of equipment [5]. With aiming at

different operating environments, defense science and technology innovation can enhance the environmental applicability of military products through parallel design, and directly develop revolutionary new products to meet specific needs for special tasks. The diversification of military products plays an important role in increasing the competitiveness of national defense technology enterprises. The fourth-generation fighter F-35 currently includes the Air Force (CTOL), Vertical Takeoff and Landing (STOVL), and Shipborne (CV), which is the result of its defense science and technology industry sector for different environments and mission requirements. Due to its diversified design, F-35 has attracted much attention since the development phase, and with the gradual easing of U.S. restrictions on exports of sophisticated weapons, many countries have shown a strong willingness to purchase. In 2012, Japan and the US government signed a contract to purchase 4 F-35 fighters. The purchase price of each fighter plane is 10.2 billion yen. Its diversified design has brought significant foreign exchange earnings to the United States. In the early development of our national defense science and technology industry, due to the relatively weak technical means, the variety of sophisticated weapons was very limited except for “two bombs and one star”. But after the unremitting efforts of several generations of national defense science and technology research personnel, we could manufacture many cutting-edge weapons and equipment. A relatively complete national defense science and technology industry system consisting mainly of military research and production departments such as weapons, nuclear energy, aviation, aerospace, electronics, ships, and military supplies has been initially established. A large number of weapons and equipment with independent intellectual property rights have appeared, such as the strategic missiles of the Dongfeng series, J-10 fighter jet, etc. They fill the gaps in these fields of my country’s defense science and technology industry and narrowed the gap with developed countries. It is of landmark significance to break through foreign technological restrictions and promote the development of China's national defense economy.

3.2. The Impact of Defense Science and Technology Innovation on The Quality of Military Products

Another approach to the high-quality driving effect of national defense science and technology innovation is improving the quality of military products. Increasing military types is to meet the diverse mission requirements of the army, while the enhancement of military quality is to improve the stability of military performance and fighting capacity. In the process of military procurement, weapons with superior performance will be more competitive. Engine technology is a sticking point in the development of fighter aircraft with independent intellectual property rights. From the first domestically produced turbojet-5 to the most advanced turbojet-15, the development of fighter engines in China has gone through about 10 stages. Our country has made great progress in terms of thermal control, output power, working time and stability. The superior performance made the military products more competitive during the acquisition. At the same time, in other areas, breakthroughs and innovations in key technologies of bronze drums have further improved the overall performance of weapons and enhanced the competitiveness of China's relevant weapons and equipment in the military trade market. For example, in 2013, the FD-2000 air defense missile system developed by the Second Research Institute of China Aerospace Science and Industry Corporation, which was combined with the related technology of the Russian-made Sam-10 air defense missile system, defeated the S-400 of the Russian National Defense Export Corporation, the Aster air defense missile system of the European Missile Company and Lockheed's MIM-104 air defense missile system, and won the order for the Turkish Army’s T-Loramids long-range air defense system. Although Turkey cancelled the bid due to the interference of political and diplomatic factors, it also reflected the FD-2000 air defense missile's advantages in performance and price from another aspect. In the international military product market in recent years, China's exports have shown a rapid growth. China has sold 250 Hongdu K-8 trainers and ground-attack aircraft to Egypt, Ghana, Sudan and Venezuela, and exported 100 F-7 fighters to the developing countries such as Bangladesh, Namibia, and Nigeria. The numbers of China's defense patent applications from 2014 to 2018 are showed in Table 1.

TABLE 1. NATIONAL DEFENSE PATENT APPLICATIONS

Year	2014	2015	2016	2017	2018
National Defense Patent Applications	4962	12749	13028	12283	14045

The rapid increase of defense patents has further promoted the scale of arms export. According to authoritative figures released by the Stockholm International Peace Research Institute, China's arms imports fell by 56%, and the number of arms exports increased by 275% from 2000 to 2017; while the country ranked second in the total military exports of $54.1 billion in the world in 2019, which provided certain funding guarantees for the expansion of the defense science and technology industry sector's reproduction. China's arms export has also changed the export mode which used to be low-grade and low-cost in the past, gradually moving to the middle and high-end in the international military trade market to meet the needs of different types of users.

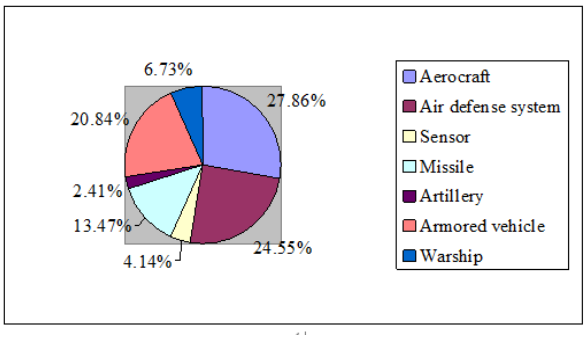

Figure 1. Proportion of China'svarious arms export (2009-2017)

The form of war is in a transitional stage from information to intelligence. Space forces and network forces are formed in major countries. If we can quickly develop high-quality new intelligent equipment and weapons, we can occupy the commanding heights of intelligent warfare, thereby gaining first-mover advantage and winning future wars. By optimizing the path of national defense science and technology innovation, it is possible to realize the collaborative sharing of innovation knowledge, the optimal allocation of innovation resources, and the rapid development of new equipment [6]. To win intelligent warfare, it is necessary to realize the transformation and upgrading of the defense science and technology industry through the defense science and technology innovation, promote the upgrading of China's high-quality equipment by the organization and implementation of major scientific and technological projects, Improve the international competitiveness of basic research and intelligent technology, and acquire the technological advantages of intelligent war equipment to cope with future wars.

4. The Structure Optimization Effect of Defense Science and Technology Innovation

Industrial structure refers to the proportional relationship among various industries. Some scholars pointed out in the process of studying economic growth, "Economic growth is based on the growth of various industrial sectors, and the process of economic growth is essentially a comprehensive result of the growth process of various industrial sectors. Therefore, economic growth requires maintain a reasonable proportional structure. A reasonable and advanced industrial structure can make rational use of economic resources and coordinate the development of various industries, which is conducive to achieving better economic benefits. Unreasonable and low-level industrial structure will reduce the quality of economic growth and eventually hinder economic development." [7] Just like national economy, the development of national defense science and technology industry also requires a reasonable industrial structure. First, a reasonable industrial structure can promote the smooth flow of production factors and improve the efficiency of resource allocation, thereby enhancing the productivity of national defense science and technology industry. Second, the new leading industry will replace the old leading industry and provide inexhaustible driving force for the development. Third, the adjustment of the industrial structure will bring about the specialization and refinement of social division, and promote a substantial increase in labor productivity. The structural optimization effect of defense science and technology innovation is the economic effect of the industrial structure adjustment caused by innovation [8].

The national defense science and technology innovation has a significant effect on the structure optimization of national defense economy [9]. In order to consolidate the new power after the founding of the People's Republic of China, the overall framework of national defense science and technology industry was initially formed under the guidance of the central government's policy of giving priority to the development of heavy industry. In the past, because the foundation of our national defense science and technology industry is relatively weak, the production targets of national defense science and technology industry are only weapons and equipment with low technical requirements and relatively simple technological processes, while weapons and equipment with high technical requirements still rely on Soviet assistance. The product structure of the defense technology industry is relatively simple. It had formed an industrial structure with excess production of backward weapons and equipment, and severe shortage of high-tech weapon equipment.

In order to improve the production of weapons and equipment, the government have gradually increased its investment in national defense science and technology industry and given great encouragement and support to defense science and technology innovation. China has organized and implemented a series of large national defense science and technology projects of strategic significance at different times, such as the "two bombs and one star" project, the "09" nuclear submarine project, the "Yinhe" computer project, the "Shenzhou" manned spaceflight project, the "Chang 'e" lunar exploration project, and the "Beidou" global position system project. In order to effectively maintain national security and unity, the state has implemented "high-tech projects" and increased its investment in the defense science and technology industry. Most of the weapons and equipment developed and produced are high-tech weapons and equipment. Through the adjustment of military scientific research and production capacity, our country eliminated a number of backward production capacities, strengthened its core capabilities, released general capabilities, and greatly optimized its industry layout. Recent years, the major breakthroughs and innovations of defense science and technology have greatly increased the production capacity of China's high-tech weapons and equipment, and promoted the upgrading of the industrial structure of national defense science and technology industry.

5. CONCLUSION

The 19th CPC National Congress has clearly stated that "innovation is the primary driving force for development and the strategic support for building a modern economic system." In the face of the new normal of the continuous deepening of economic reform and the rapid advancement of new military reforms, it is necessary to further strengthen the strategic supporting position of defense science and technology innovation, improve the management system, promote the transformation efficiency of scientific and technological achievements, give full play to the driving effect of defense science and technology innovation, and enhance the vitality and competitiveness of national defense science and technology industry.

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