An Analysis of the Process of Transforming Military Technology into Civilian Technology

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Abstract. In the period without global conflict, many countries with advanced military technology have sought to apply these technologies to civilian fields, recognizing their potential advantages in maximizing defense R&D returns and addressing societal demands. Against this backdrop, this study aims to leverage literature review, empirical data analysis and comparative research methods to systematically clarify the driving factors and resultant impacts of the military-to-civilian technology transformation process. As a result, the study finds that the transition between military and civilian technologies is driven by multiple factors, including technological potential, the international environment, the benefits of the transition, and government and institutional support. Furthermore, the study points out that this transition can help increase employment opportunities and promote industrial upgrading, but it also carries risks such as environmental pollution, air disasters and other problems. The findings of this study can provide practical theoretical guidance and directional reference for policymakers and industries to further explore and optimize the military-to-civilian conversion path.

Keywords: Military Technology, Civilian Technology, Economic Impact, Pollution, Air Transportation

1. Introduction

The transformation of the military technology for civilian use is the process of adapting technologies developed for military purposes to civilian applications. Following World War II, many countries started the project to transform some military technologies into civilian sectors in the subsequent peacetime. The application of military technology in civilian contexts is often influenced by international conditions. When peace and development become prevailing trends, the threat of the war will disappear. Governments prefer to reduce military expenditures when the perceived need for large-scale weaponry diminishes in the absence of imminent threats. Meanwhile, to ensure the national security without downsizing the military industries and the economic benefit, the military industries are motivated to adapt their technologies for civilian use. They enhance the production's performance to meet civilian requirements. Subsequently, these technologies and products will become increasingly popular as civilian industries integrate them into their operations. Finally, the military technology will be applied as civilian technology in many aspects of civilian life.

However, there remains insufficient systemic analysis of how technological disparity and political-economic conditions interact to shape its pathways and outcomes. Employing a comparative analysis of historical case studies and policy data, this study examines the key drivers, multifaceted impacts, and prospective challenges of the military-to-civilian technology transfer (MTCT) process. Findings from this research can inform more effective policy frameworks, assist industries in navigating dual-use technology strategies, and contribute to understanding the broader societal and environmental implications of technological conversion in an era of geopolitical shift.

2. The driven factors of military-civilian technology transfer

2.1. Technical potential

The feasibility of applying military technologies in civilian sectors stems partly from what can be called technical potential. which means the disparity in technological advancement across different industries, fields, or places at a given time. This difference determines the direction of the technology transmission adjustment. In one country, the direction that technology will move is determined by the department and its technology. If a department is grasping advanced technology while another does not, the technology will move to the department that grasps a lower level of technology. During wartime or the early Cold War, most countries' focus and investment were directed predominantly towards developing the military industries. Consequently, military technology became significantly more advanced than civilian applications. In peacetime or periods of reduced tension, this created a strong technical potential gradient, driving the transfer of technology from military to civilian industries.

The transformation of technology in The United States (U.S.) during the Cold War can illustrate this regulation. From 1947 to the late 1970s, intense rivalry with the USSR led the U.S. to concentrate its research and development (R&D) efforts in defense. The United States' investment in defense research and development once accounted for more than 80% of the federal government's research and development expenditure before the end of the 1970s, and made significant progress in nuclear technology, micro-electronics, and other new technologies.

After the 1980s, the Japanese semiconductor industry began to threaten American industries, while the technology in the military department was more advanced than that in other sectors, such as business and civilian departments. To be on the upper hand, many advanced technologies started to move from military industries into other sectors. With the new technology, other industries developed rapidly and gained strong competitiveness. As a result, the regulation of technical potential is a factor that influences the technology transformation.

2.2. International conditions

International conditions significantly influence the direction of technology transformation. The government determines strategic priorities, including the allocation of resources toward military or civilian technology, based on its assessment of the global landscape. When threats to the national security or interests, the government will pay more attention to combining the technology with the military applications and ignore the combination of that and other industries or departments.

In comparison, after the tension period, such as World War II and the early and middle stages of the Cold War (1947-1980), the primacy of peace and economic development becomes more pronounced. To gain more market share, the government shifted the focus from the military to civilian and related areas by transforming military technologies for the in other industries. To secure a market advantage, governments may use policy tools such as enacting laws and encouraging private-sector involvement.

The U.S.-Japan semiconductor rivalry in the 1980s exemplifies this shift. In 1986, Japanese firms held 65% of the market share of the dynamic random access memory chip, threatening a key and profitable U.S. industry like semiconductor. In response, the U.S. government formulated the special Military-to-Civilian policies and issued Executive Order No. 12591 to stimulate the transformation of the technology from the military field to the civilian field, to ensure that the new knowledge from the lab can be applied in new productions. As a result, the process of transforming the military technology to business applications became faster from 1987 to 1989, directing most of the technological resources towards civilian fields [1]. Thus, this case confirms that the varying international conditions are a decisive factor in shaping the transfer of military technology to civilian use.

2.3. Benefits of transformation

The anticipated benefits of technology transfer can serve as a primary motivator for relevant agencies and industries. Applying military technology to civilian applications can benefit many fields, such as the economy, the environment, and society.

Nuclear power, commercial air travel and other sectors are creating more jobs from power plant operators to airline staff. For instance, the nuclear technology will be an alternative power source for humans, so that power enterprises will get more time to find more fossil fuels [2]. In 1970, the American government also tried to address the economic issues through the transformation of technology [3]. After 1978, the Chinese defense industry applied turbine-cooling technology from the aerospace sector to the petroleum sector to recover associated gas. This application processed billions of cubic meters and recycled thousands of tons of hydrocarbons. This transformation created more economic benefits and provided more power for the relevant industries or applications and also helped the military industries gain more economic interests.

2.4. Governmental and institutional support

The transformation of military applications for civilian use is critically dependent on external support. The government provides funding, policy guidance, and institutional frameworks to enable this process. The government established an institution called The Academy of Finland to fund and coordinate fundamental physics research, including nuclear projects. The nuclear technology developed dramatically, and subsequent civilian applications of nuclear technology have emerged in areas such as medicine [4]. Similarly, the U.S. also established the Atomic Energy Act in 1946. It can nurture and guide the development of nuclear science and technology, as well as their civilian applications. After that, in 1953, most of the applications were developed by the government laboratory system. These cases demonstrate that governmental and institutional support will promote the transformation of the technology to provide services for human beings.

3. The multi-dimensional impacts of military technology civilianization

3.1. Economic influence

The transfer of military technology to civilian sectors, driven by government policy or industrial collaboration, generates multifaceted economic effects [5].

3.1.1. Enhancement of industrial competitiveness

Military technologies are more advanced than those in the secondary industries in civilian fields. The transfer can improve some traditional industries, enhancing their competitiveness and profitablity. Industry restructuring and integration can further improve the economic benefits [6]. For example, Russia's industries are combined with banks and other financial institutions in both horizontal and vertical integration. This has strengthened their competitiveness in both the domestic market and the international market and increased government tax revenues through higher corporate profits. Thus, technology transfer is a way to enhance the competitiveness of industries.

3.1.2. Creation of new economic opportunities

The integration of military and civilian technologies can foster entirely new industries. Jet engines, applied by the ME 262, were later applied to civil aviation. It not only promotes the development of traditional aviation industries with outdated technology, but also creates new industries called tourism industries for economic development. In post-war Europe, the application of such military-derived technologies in civil aviation industries helped improve flight speed and reliability, attracting new power for economic recovery or development.

3.1.3. Promote the process of developing the global economy

Some technology from military fields can build the connection between each country and stimulate the development of global economy. The global positioning system (GPS), originally developed for military navigation, exemplifies this dynamic. Its civilian adoption has created a worldwide industry spanning device manufacturing, location-based services, logistics, and precision agriculture, fostering deep cross-border supply chains and markets. Their competition promoted the international market of nuclear material, industries service, and technology [7]. These interaction between each economic collectively shaping global technical standards and market structures.

3.2. Social impacts

3.2.1. Job creation

The application of military technology in civilian fields stimulates job creation both in new industries and modernized traditional industries with new labor requirements. Additionally, the new industries generated will promote other relevant industries, such as construction, thereby expanding overall employment opportunities [8]. The civilian aviation, propelled by technologies like jet engines, has generated an estimated 62.7 million jobs globally, including 9.9 million direct jobs within airlines, air navigation service providers, and airports [9].

3.2.2. Enhancement of social efficiency and quality of life

The adaptation of advanced military technologies for civilian use drives substantial gains in societal efficiency, thereby elevating the quality of life. In transportation, technologies like jet travel have reduced the time required for long-distance travel by air [10,11]. In the energy sector, nuclear technology provides a high-efficiency alternative. In the energy sector, nuclear technology offers a viable option for power generation and can provide more electric energy for people with lower consumption [4]. A boiling water reactor BWR only consumes 170 tons of nuclear material

(1.9%enrichment) to provide 1300-MW electricity power, while a coal-fired supercritical-pressure power plant requires more but provides 500-MW power [12,13]. Furthermore, it cannot be applied only in medical fields, such as the use of isotopes to treat illnesses.

3.2.3. Risk of accidents and public anxiety

Some adaptation of military technologies can introduce novel risks that provoke public concern and anxiety. The catastrophic structural failures of the de Havilland Comet I jetliner in the 1950s severely disrupted the early development of commercial jet travel [9]. A prominent other example is autonomous vehicle technology, whose perception and decision-making systems have roots in military robotics and remote sensing. Despite its potential to revolutionize transport, its deployment has been marked by fatal accidents that exposed critical limitations.

3.3. Environmental impacts

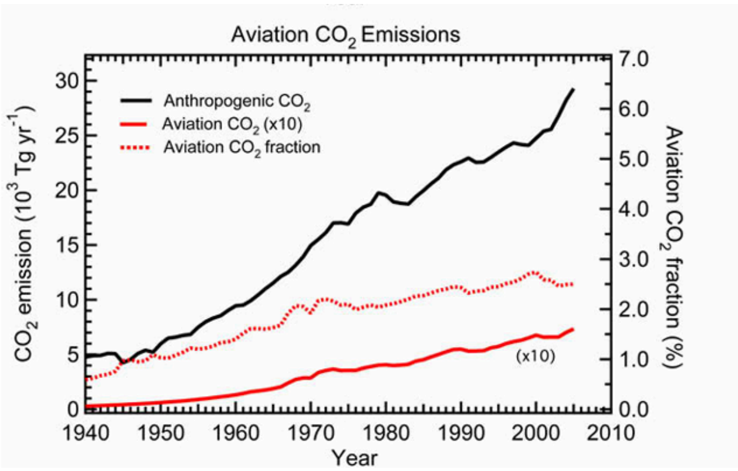

Figure 1. Aviation and global climate change in the 21st century [14]

The civilian application of military-origin technologies often entails negative environmental externalities. There are mainly two types of greenhouse gas pollution: operational pollution and accident-related contamination. The aviation industry contributes to climate change through the emission of CO_2, NOx, H_2O, and particulate matter, as well as the formation of persistent linear contrails and aviation-induced cloudiness. These outputs alter the microphysical and chemical properties of the atmosphere, contributing to radiative forcing and global warming (shown in Figure 1) [14].

The field of aerospace and rocketry, with its origins in ballistic missile programs. Launch vehicles, depending on their propellant type, can release substances like chlorine, alumina particles, and soot directly into sensitive upper atmospheric layers. Moreover, launch failures or unplanned re-entries can lead to the ground deposition of highly toxic or corrosive fuels and debris, causing localized but severe ecological damage. These risks highlight that the environmental footprint of transferred technologies extends beyond conventional greenhouse gas emissions to include unique chemical pollution profiles and acute contamination events.

4. Discussion

4.1. Challenges

The process of transforming the military technology will be shaped by a complex interplay of constraints and facilitators. First of all, it might be opposed by some environmental protection organizations, such as the environmental preserve organization in Finland [4]. Additionally, technical or economic obstacles are present, such as the high cost of adaptation and the use of immature technologies [3]. Furthermore, the inherent complexity and specialized nature of military systems often necessitate extensive and costly redesign to meet civilian safety, reliability, and usability standards.

4.2. Future directions

The civilian application of military technology is expected to further develop with several features. A predominant focus will be on enhancing the security of systems, particularly in high-risk domains and sectors. Concurrently, significant efforts will be directed toward reducing associated costs to improve economic viability and accessibility [15]. Moreover, the development of military technology in civilian life will also pay attention to the environmental protection. Environmental sustainability will become a critical design criterion, driving innovation to mitigate adverse impacts.

5. Conclusion

This study has examined the multifaceted process of transforming military technology for civilian application. The process is not a spontaneous occurrence but a complex undertaking driven by several factors, such as technical potential and political conditions. This transfer also causes both positive and negative impacts. The imperative of shifting international conditions from conflict to economic competition, the pursuit of tangible economic and strategic benefits, and proactive governmental support through policy and funding. It also stimulates economic growth and the birth of new markets. However, environmental pollution and high-risk accidents should also be given attention. This research has several limitations. It relies heavily on qualitative case analysis and secondary literature. Empirically measuring the scale, efficiency, or net impact of the transfer processes has been overlooked. Future research should employ empirical data collection and collect case studies across different national innovation systems.

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