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The relationship between defense R&D investment and the autonomy of the national defense industry

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ABSTRACT

This study analyzes the relationship between research and development (R&D) investment in the defense sector and the autonomy of Indonesia's national defense industry. Employing a qualitative approach based on a literature review and document analysis, this study examines theoretical frameworks, policy instruments, and empirical practices in Indonesia and selected comparator countries, including the roles of institutions such as KKIP, BRIN, and the Ministry of Defense. The main findings indicate that defense R&D investment plays a critical role in building technological capacity, strengthening domestic supply chains, increasing the local content ratio (TKDN), and promoting import substitution and technology transfer. However, key challenges persist, including limited funding, policy fragmentation, and underdeveloped human resources in defence R&D. Case studies of state-owned defense enterprises (PT Pindad, PT PAL, PT DI) illustrate the dynamics of innovation, international collaboration, and resulting economic multiplier effects. The study concludes that the success of defense R&D investment is highly dependent on policy synergy, sustainable funding, a robust innovation ecosystem, and developing high-quality human capital. Policy recommendations emphasize the need to increase R&D budget allocations, optimize triple helix collaboration, and implement regulatory reforms to accelerate the autonomy of the national defense industry.

Keywords: defense R&D investment; national defense industry; technological autonomy; local content (TKDN); import substitution; innovation ecosystem; triple helix collaboration

1. INTRODUCTION

Indonesia, the world's largest archipelagic nation strategically located in the Indo-Pacific region, faces increasingly complex and multidimensional geopolitical and security challenges. Its geographic positionlinking the Indian and Pacific Oceansrenders Indonesia vulnerable to various forms of external pressure, including open conflict, competition in military technology, and strategic economic infiltration. Within this context, achieving autonomy in the defense industry is not merely an option but a strategic necessity to safeguard territorial integrity, strengthen the national defense posture, and ensure sustainable national development (Rohmad & Susilo, 2022).

Defense industry autonomy reflects a nation's ability to independently design, produce, and maintain its principal weapon systems (alutsista) without excessive reliance on foreign supply chains. In Indonesia, despite notable progress in strengthening strategic industries through state-owned enterprises (SOEs) such as PT Pindad, PT PAL, and PT Dirgantara Indonesia, a significant portion of critical defense components remains imported (Indoaviation, 2025). This indicates that domestic mastery of key technologies and innovation capacity remains suboptimal (Irwanto et al., 2022).

Investment in defense research and development (R&D) is a fundamental pillar for building technological self-reliance and enhancing the competitiveness of the national defense industry. Advanced countries such as the United States, South Korea, and Germany have demonstrated that the success of their defense industries is highly dependent on the intensity, continuity, and effectiveness of R&D investment. Through consistent budget allocations and strong institutional support, these countries have cultivated innovation ecosystems that foster the development of advanced military technologies, reinforce national industrial bases, and generate multiplier effects on economic growth and national resilience. As implemented by PT LEN, the funding aspect of the R&D phase is allocated at 5% of the company's net profit, aiming to enhance technological capabilities and mastery within the defence industry (Saputro & Sigit Pramudyo, 2022).

In Indonesia, regulatory frameworks such as Law No. 16 of 2012 on the Defense Industry and the establishment of the Defense Industry Policy Committee (KKIP) represent the initial steps toward building an integrated governance structure for the defense sector (Pemerintah et al., 2012). However, structural challenges continue to hinder R&D investment optimization. These include limited funding, fragmented interagency policies, and the underdevelopment of competent human resources in defense research. Moreover, synergy among government, industry, and research institutions has yet to be fully realized within an effective triple helix collaboration framework.

This study examines how defense R&D investment can significantly contribute to achieving autonomy in Indonesia's national defense industry. It also aims to identify the key factors influencing the effectiveness of such investments in the Indonesian context, including policy, institutional, financial, and human capital dimensions. By employing a qualitative approach based on a literature review and document analysis, this research aspires to offer both theoretical and practical contributions in formulating strategies to strengthen the national defense industry through innovation and technological self-reliance.

2. LITERATURE REVIEW

2.1 Theoretical Framework: Defense Industry Autonomy and R&D

Defense industry autonomy is defined as a nation's ability to independently meet its defense equipment (alutsista) needs and supporting components—from design and production to maintenance—by using domestic resources and technology. Key indicators of autonomy include the domestic content level (TKDN), innovation capacity, import substitution capability and export competitiveness (KKIP, 2022). The endogenous growth theory (Romer, 1990) emphasizes that investment in research and development (R&D) is the primary driver of economic growth and technological innovation. In the defense context, R&D serves as a catalyst for the development of dual-use technologies, technology transfer, and spillover effects in civilian sectors (Sholikhah et al., 2022). The triple helix model highlights

the importance of collaboration among the government, industry, and academia in building a robust defense innovation ecosystem (Leydesdorff, 2013).

2.2 Empirical Studies in Indonesia

Rohmad and Susilo affirmed that the revitalization of Indonesia's defense industry is significantly influenced by government policies on R&D budget allocation, innovation ecosystem strengthening, and the empowerment of strategic state-owned enterprises (BUMN) (Rohmad & Susilo, 2022). A study by Damanik shows that increased defense investment in Indonesia over the past decade has driven the modernization of weapon systems; however, its impact on industrial autonomy remains limited due to low levels of technology transfer and insufficient domestic content (Damanik et al., 2024). An analysis of defense spending trends by Mohadib and Andriansyah reveals that although Indonesia's defense budget has grown substantially, the proportion allocated to R&D remains minimal, and reliance on imports continues to be high (Mohadib & Andriansyah, 2024). Case studies of PT Pindad, PT PAL, and PT Dirgantara Indonesia indicate that successful innovation and improvements in TKDN are strongly influenced by international collaboration, technology transfer, and the development of R&D human capital (Pindad 2025).

2.3 International Experiences

South Korea stands out as a successful example of defense industry transformation through large-scale R&D investments, public-private collaboration, and aggressive technology transfer strategies. The South Korean government plays a central role as a sponsor, regulator, and primary consumer, while also encouraging private sector and university participation in the defense innovation ecosystem (Kontan, 2025). The United States and Western European countries also prioritize R&D in their defense budgets, with R&D expenditures accounting for 10–20% of their total defense spending. India and Turkey demonstrate that offset strategies, joint production, and strengthening domestic content are key to accelerating defense industry autonomy, although challenges in technology transfer and human resource development remain significant obstacles.

3. METHODOLOGY

This study adopted a qualitative approach using a literature review and document analysis. This method was chosen to gain an in-depth understanding of the dynamics between defense R&D investment and the autonomy of the national defense industry and to identify the key factors influencing their interrelationship. Data were collected through a comprehensive review of the academic literature (including journals, books, and official reports), government policy documents (such as Law No. 16/2012, presidential regulations, and ministerial decrees), annual reports of state-owned defense enterprises, and credible media analyses.

4. RESULT AND DISCUSSION

4.1 Analysis of Indonesia's Defense Budget and R&D Output

According to data from the National Research and Innovation Agency (BRIN, 2024), Indonesia's national R&D investment in 2023 amounted to 0.24% of GDP, with defence R&D accounting for less than 1% of the total defence budget. The allocation for defense R&D in 2025 is projected to be IDR 1.53 trillion, which remains significantly below the threshold required to support strategic technology development and disruptive innovation.

Table 1 summarizes Indonesia's defense budget allocation for 2025.

Table 1. Indonesia's defense budget allocation for the year 2025

Main Program	Budget (IDR Trillion)
Defense policy and regulation	0.025
Weapon system and infrastructure modernization	52.10
Defense human resource development	0.136
Research, industry, and higher education	1.53
Management support	2.87

This budget structure reflects Indonesia's prioritization of weapon system modernization, while investment in defense R&D and human capital development remains limited. The allocation for research, industry, and higher education—although strategic—is still modest compared to modernization expenditures, indicating the need for more balanced and innovation-driven budgeting in future defense planning.

4.2 Indonesian Policies and Regulations on Defense R&D

Law No. 16 of 2012 on the Defense Industry serves as the primary legal foundation for developing Indonesia's national defense industry. It emphasizes self-reliance, innovation, and collaboration among state-owned enterprises (BUMN), private defense companies (BUMS), and research institutions (RIs). Offset policies, local content requirements, and technology transfer are mandated as prerequisites for all foreign defense procurement contracts (Tippe, 2014).

The National Long-Term Development Plan (RPJPN) 2025–2045 and the Defense Strategic Plan 2020–2024 set ambitious targets to strengthen domestic production capacity, increase investment in defense R&D, and reduce reliance on imported strategic weapon systems. The establishment of the DEFEND ID holding company, comprising PT Pindad, PT PAL, PT Dirgantara Indonesia, PT Len Industri, and PT Dahana, aims to enhance synergy, efficiency, and global competitiveness within the national defense industry.

However, the realization of defense R&D investment remains constrained by limited budget allocations (approximately 0.24% of GDP for national R&D and less than 1% of the defense budget for defense-specific R&D), a fragmented innovation ecosystem, and insufficient incentives for private sector participation (BRIN, 2024).

4.3 Key Actors and the Ecosystem of Indonesia's Defense Industry

Indonesia's defense industry ecosystem comprises a network of strategic actors, including state-owned enterprises (BUMN), private defense companies (BUMS), research institutions, universities, and government agencies. The Ministry of Defense (MoD) plays a central role in policy formulation, procurement planning, and strategic oversight, whereas the Ministry of State-Owned Enterprises coordinates industrial consolidation and governance.

The core industrial actors are grouped under the DEFEND ID holding company, which includes PT Pindad (land systems and ammunition), PT PAL (naval platforms), PT Dirgantara Indonesia (aerospace systems), PT Len Industri (electronics and command systems), and PT Dahana (explosives and propellants). These entities serve as the backbone of Indonesia's defense production capability and are tasked with achieving technological self-reliance and export competitiveness in the defense sector.

Research and innovation are supported by the National Research and Innovation Agency (BRIN), defense universities, and technical institutes, which collaborate on prototype development, testing, and technology transfers. Private sector participation is gradually expanding, particularly in niche areas such as cybersecurity, unmanned systems and dual-use technologies.

Despite growing institutional coordination, the ecosystem faces challenges, including fragmented R&D efforts, limited private investment, regulatory bottlenecks, and dependency on imported components. Strengthening inter-agency collaboration, enhancing fiscal incentives, and building integrated

innovation clusters are essential to accelerate the autonomy and resilience of Indonesia's defense industrial base.

4.3.1 Case Study: PT Pindad

PT Pindad serves as the primary manufacturer of light weapons, ammunition, and combat vehicles in Indonesia. The company has successfully exported its products to various countries and plays a pivotal role in fulfilling the operational needs of the Indonesian Army (TNI AD). PT Pindad has developed several strategic products, including the Anoa armored personnel carrier, the Maung tactical vehicle, multi-caliber ammunition, and light weapon systems. Its export markets span Southeast Asia, the Middle East, and Africa.

Despite these achievements, PT Pindad faces several key challenges, including dependency on imported raw materials, limited technology transfer, and underdeveloped R&D capacity. To address these issues, the company has adopted strategies such as product diversification, collaboration with international partners, and human resource development through training and knowledge transfer initiatives.

PT Pindad also participates in offset and local content programs as part of foreign defense procurement contracts. However, the implementation of these programs continues to encounter regulatory barriers and coordination challenges among stakeholders. Strengthening domestic supply chains, enhancing R&D capabilities, and improving regulatory coherence remain critical for advancing PT Pindad's contribution to national defense autonomy.

4.3.2 Case Study: PT PAL

PT PAL Indonesia specializes in the construction of warships, submarines, and logistical support vessels. Its collaboration with Naval Group (France) in the development of the Scorpene-class submarine marks a significant milestone in technology transfer and the enhancement of domestic production capacity. PT PAL has also successfully exported naval vessels to the Philippines and other countries, and has adopted the Full Block Outfitting System to improve production efficiency and product quality.

Key challenges faced by PT PAL include limited investment in research and development (R&D), the need to strengthen its high-tech human resources, and the development of a robust maritime innovation ecosystem. The company also contends with difficulties in meeting international standards and competing with global defense manufacturers (Ramadhan et al., 2023).

Addressing these challenges requires strategic efforts in expanding R&D funding, enhancing workforce capabilities, and fostering cross-sectoral collaboration to elevate Indonesia's naval industrial competitiveness on the global stage.

4.3.3 Case Study: PT Dirgantara Indonesia

PT Dirgantara Indonesia (PT DI) has established itself as a leading aerospace manufacturer, specializing in the production of CN235, NC212i, and N219 aircraft, as well as aircraft components for Airbus. Its collaboration with Airbus and successful penetration into export markets in Latin America demonstrate the company's innovation potential and global competitiveness. PT DI is also a key partner in the development of the KFX/IFX fighter aircraft program in collaboration with South Korea, although it continues to face challenges related to access to sensitive technologies and project financing.

Research findings indicate that PT DI's innovation activities are strongest during the diffusion phase—particularly in commercialization and scaling up. However, there remains a need for improvement in innovation management, strategic planning, and resource mobilization to sustain long-term competitiveness(Aldianto, 2014).

4.3.4 Case Study: PT Len Industri

PT Len Industri is Indonesia's leading defense electronics company, specializing in command and control systems, radar technology, tactical communication, and electronic warfare solutions. As part of the DEFEND ID holding, PT Len plays a strategic role in integrating digital systems across land, sea, and air platforms. The company has developed indigenous battlefield management systems and contributes to the modernization of Indonesia's defense communication infrastructure.

Despite its technological potential, PT Len faces challenges in scaling up innovation, securing long-term R&D funding, and accessing advanced microelectronics. To overcome these barriers, the company has pursued partnerships with domestic universities and international defense firms, while also investing in workforce development and digital transformation. Strengthening its role in cyber defense and AI-enabled systems remains a strategic priority for future competitiveness.

4.3.5 Case Study: PT Dahana

PT Dahana is Indonesia's state-owned enterprise specializing in explosives and propellants for military and civilian applications. Its core competencies include the production of high-energy materials, demolition systems, and integrated blasting services. PT Dahana supports the Indonesian Armed Forces through the supply of military-grade explosives and contributes to strategic industries such as mining and infrastructure.

The company has invested in the Energetic Material Center (EMC) to enhance domestic production capabilities and reduce reliance on imported raw materials. However, PT Dahana continues to face challenges in R&D commercialization, safety certification, and international market penetration. To address these issues, the firm has adopted a strategy of vertical integration, collaborative research, and compliance with global safety standards.

4.4 Causal Link Between R&D Investment and Industrial Autonomy

Empirical studies and meta-analyses consistently reveal a positive and statistically significant relationship between increased defense R&D investment and the autonomy of the national defense industry. R&D investment drives product innovation, enhances production capacity, and strengthens export competitiveness. Moreover, the spillover effects of defense R&D contribute to the civilian sector through dual-use innovations, job creation, and the development of a robust national innovation ecosystem (Moretti et al., 2025).

Nevertheless, the positive impact of R&D investment is highly contingent upon the effectiveness of policy implementation, the absorptive capacity of domestic institutions, and the synergy among actors within the innovation ecosystem. Successful cases such as South Korea and Turkey illustrate that policy consistency, fiscal incentives, and international collaboration are critical enablers of defense industrial autonomy.

4.5 Financing Mechanisms for Defense R&D and Budget Allocation

Indonesia's defense budget remains below 1% of GDP, with the largest share allocated to personnel expenditures and the modernization of major weapon systems. In contrast, the portion dedicated to defense research and development (R&D) is relatively small—approximately 0.8% of the total defense budget. To address this imbalance, innovative financing models have begun to emerge, including long-term contracting, mandatory investment clauses in procurement agreements, and the adoption of a life cycle approach to ensure sustained investment and effective technology transfer (Mohadib & Andriansyah, 2024).

The involvement of financial institutions, the provision of fiscal incentives, and co-financing schemes with international partners have become critical strategies to overcome budgetary constraints and accelerate technological advancement in the defense sector.

4.6 The Role of Public Policy and Instruments (Offset, Local Content, and R&D Consortia)

Offset policies, local content requirements, and R&D consortia serve as key instruments in accelerating technology transfer, strengthening domestic production capacity, and developing human capital in the defense sector. However, the implementation of offset mechanisms in Indonesia continues to face challenges, including suboptimal regulatory frameworks, limited absorptive capacity for advanced technologies, and ineffective inter-agency coordination (Situmeang et al., 2020).

R&D consortia involving state-owned enterprises (BUMN), private defense firms (BUMS), universities, and research institutions have the potential to expedite the development of critical technologies and disruptive innovations. To foster an inclusive and sustainable innovation ecosystem, the optimization of collaborative models such as the pentahelix and saptahelix frameworks is essential.

4.7 Policy Recommendations for Indonesia

Based on research findings and international comparative studies, the following policy recommendations are proposed to strengthen the relationship between defense R&D investment and the autonomy of the national defense industry: (1) Substantially increase the allocation of defense R&D funding, targeting a minimum of 2% of the total defense budget, with a focus on the development of critical technologies and disruptive innovations; (2) Optimize the implementation of offset, local content, and technology transfer policies in all foreign defense procurement contracts by reinforcing regulatory frameworks and establishing transparent monitoring mechanisms; (3) Promote the formation of R&D consortia involving state-owned enterprises (BUMN), private defense firms (BUMS), universities, and research institutions to accelerate the development of strategic and dual-use technologies; (4) Provide fiscal and non-fiscal incentives for private sector investment in defense R&D, including tax holidays, streamlined licensing procedures, and access to innovative financing schemes; (5) Strengthen human capital and research infrastructure through training programs, scholarships, and international collaboration with advanced technology partner countries; (6) Develop a national defense technology roadmap aligned with the strategic needs of the Indonesian Armed Forces (TNI) and export market opportunities; (7) Enhance transparency, accountability, and periodic evaluation of R&D investment effectiveness and its impact on defense industrial autonomy.

4.8 Economic and National Security Implications

Increasing investment in defense R&D not only strengthens industrial autonomy but also generates multiplier effects for the national economy through job creation, export growth, and the enhancement of the innovation ecosystem. From a national security perspective, it contributes to a stronger deterrence posture, greater flexibility in defense diplomacy, and reduced vulnerability to arms embargoes or sanctions imposed by foreign suppliers (Baiquni et al., 2022).

However, caution must be exercised to avoid over-investment without strategic direction, policy fragmentation, and inadequate human resource readiness to absorb emerging technologies. Therefore, defense R&D investment should be mission-oriented, measurable, and sustained to ensure long-term impact and alignment with national strategic objectives.

5. CONCLUSION AND FUTURE RESEARCH AGENDA

This study affirms a strong causal relationship between defense R&D investment and the enhancement of national defense industrial autonomy. Indonesia's experience demonstrates that, despite

progress in strengthening production capacity and innovation, persistent challenges remain—namely limited budget allocations, dependence on foreign technologies, and an underdeveloped innovation ecosystem.

Comparative analyses with countries such as South Korea, Turkey, and Brazil highlight the importance of long-term policy commitment, consistent funding, private sector incentives, and international collaboration for effective technology transfer. Policy recommendations include increasing R&D budget allocations, optimizing offset and local content implementation, strengthening R&D consortia, and developing a comprehensive national defense technology roadmap.

The proposed future research agenda includes: (1) Quantitative analysis of the impact of defense R&D investment on innovation output and export performance of the defense industry; (2) Longitudinal studies on the effectiveness of offset and technology transfer policies in enhancing domestic production capacity; (3) Evaluation of the role of innovation ecosystems (pentahelix/saptahelix) in accelerating defense industrial autonomy; (4) Comparative studies of defense R&D financing models in developing countries and their implications for Indonesia.

With an integrated, inclusive, and mission-oriented approach aligned with national strategic priorities, Indonesia can strengthen its defense industrial autonomy and contribute to broader economic transformation toward the vision of *Indonesia Emas 2045*.

Ethical Approval
Not Applicable

Informed Consent Statement
Not Apllicable

Authors' Contributions
IAH contributed to the conceptualization of the study, formulation of research objectives, and overall research design. He conducted the literature review and document analysis, analyzed defense R&D policies and institutional roles, and drafted the initial version of the manuscript, including the discussion of findings and policy implications. SI contributed to the refinement of the theoretical framework, particularly in linking defense economics concepts with industrial autonomy. She assisted in interpreting the findings, strengthening the analytical depth of the discussion, and provided critical revisions to improve the coherence and academic rigor of the manuscript. H contributed to the evaluation of empirical cases involving state-owned defense enterprises, supported the analysis of institutional and regulatory aspects, and reviewed the manuscript to ensure consistency, clarity, and relevance to defense industry development and policy perspectives.

Disclosure Statement
The Authors declare that they have no conflict of interest

Data Availability Statement
The data presented in this study are available upon request from corresponding author for privacy

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