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THE ECONOMIC DIMENSION OF EMERGING TECHNOLOGIES APPLIED IN THE DEFENCE SECTOR - A BIBLIOMETRIC FRAMEWORK

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Abstract: *Emerging technologies are increasingly transforming the defense sector, not only in terms of military capabilities but also through their economic implications. This paper investigates the economic dimension of emerging technologies in the defense sector by applying a bibliometric analysis of the scientific literature indexed in the Web of Science database. Using the bibliometrix package in R Soft and its Biblioshiny interface, the study maps publication trends and thematic clusters related to investment, markets and industrial impact. The results highlight dominant research streams and reveal existing gaps, offering a structured overview to support future research and policy development.*
Keywords: *Emerging technologies, defense sector, military, innovation, defense economics.*

1. INTRODUCTION

The emerging technologies are increasingly influencing the defense sector by transforming military capabilities, industrial structures and strategic balances. Advances such as artificial intelligence, autonomous systems, quantum technologies, additive manufacturing and cyber-physical systems are no longer confined to experimental or civilian contexts, but are progressively integrated into defense applications [1]. While the technological and strategic implications of these innovations have been widely discussed, their economic dimension, including investment patterns, market development, industrial capacity and cost-effectiveness [2], remains fragmented and insufficiently systematized within the academic literature. This creates a significant gap in understanding how emerging technologies translate into economic value and structural change within the defense sector.

The defense sector represents a distinctive application field for emerging technologies due to its dual-use nature, high entry barriers, strong state involvement, and long-term investment horizons. Unlike civilian markets, defense innovation is characterized by public procurement, security considerations, and strategic autonomy objectives, particularly in the context of the European Union. As a result, assessing the economic dimension of emerging technologies in defense requires a comprehensive perspective that integrates technological development with economic indicators such as research and development (R&D) investments, industrial competitiveness, market dynamics and defense budgets [3].

Previous research has largely focused on either the technological performance of emerging defense technologies or their strategic and security implications [4], [5]. A growing body of literature addresses innovation ecosystems, defense industrial bases, and dual-use technologies; however, these studies are often sector-specific, technology-specific, or policy-oriented, lacking a systematic and quantitative overview of the research domain. Moreover, existing reviews are typically narrative in nature, making it difficult to identify dominant research trends, influential actors, thematic clusters, and knowledge gaps related to the economic aspects of emerging technologies in the defense sector.

In response to these limitations, this paper adopts a bibliometric analysis approach to

systematically map and analyze the scientific literature on the economic dimension of emerging technologies in the defense sector. Using data extracted from the Web of Science (WoS) database and processed through the R Software, specifically the Biblioshiny interface of the bibliometrix package, the study examines publication trends, thematic evolution, keyword co-occurrence networks and conceptual structures. The research is conducted in several stages: formulation of a targeted search query, data extraction and cleaning, descriptive bibliometric analysis and thematic analysis.

The results reveal dominant thematic clusters, underexplored areas, and shows how economic narratives are linked to specific technologies such as artificial intelligence, autonomous systems, and additive manufacturing. By doing so, the paper contributes new insights into the interaction between technological disruption and economic dynamics in the defense sector.

The novelty of this study lies in its systematic, data-driven mapping of the economic dimension of emerging defense technologies, an approach that has not been sufficiently applied in this research field. The main contribution of the paper is threefold: first, it consolidates a fragmented body of literature into a coherent analytical framework; second, it identifies research trends and gaps relevant to policymakers, industry stakeholders, and researchers; and third, it provides a replicable methodological approach for future bibliometric studies in defense economics and technology assessment.

2. CONCEPTUAL BACKGROUND AND LITERATURE REVIEW

The economic dimension of emerging technologies in the defense sector has attracted growing attention within academic and policy-oriented research, reflecting the increasing role of technological innovation in shaping military capabilities and defense industrial systems. Emerging technologies are generally defined as technologies characterized by rapid development, high uncertainty and the potential to generate significant economic and societal impact [6]. In the defense context, these technologies often exhibit dual-use characteristics [7], allowing for both civilian and military applications, which further complicates their economic assessment [8].

From a conceptual perspective, the defense sector differs fundamentally from civilian markets in terms of innovation dynamics and economic structure. Defense innovation is largely driven by public investment [9] long development cycles and procurement systems [10] dominated by government demand. Several studies highlight that the economic value of emerging defense technologies cannot be assessed solely through traditional market mechanisms, as strategic considerations, security externalities, and industrial policy objectives [11] play a decisive role. Consequently, economic analyses in this field often combine elements of defense economics, innovation studies and industrial organization.

The literature on emerging technologies in the defense sector can be broadly grouped into three main research streams. The first stream focuses on technological innovation and military capability development, examining how emerging technologies such as artificial intelligence [12], autonomous systems, and quantum technologies enhance operational effectiveness and strategic advantage [13], [14]. While these studies provide important insights into technological potential, economic considerations are frequently treated implicitly or as secondary outcomes.

A second stream of research addresses defense industrial bases and innovation ecosystems. Scholars in this area analyze the role of public–private partnerships, research and development investments [15], and industrial capacity in sustaining technological leadership. This literature emphasizes issues such as fragmentation of defense markets, economies of scale, and the need for coordinated investment strategies [16]. Economic indicators such as R&D expenditure, industrial output, and supply chain resilience are commonly discussed, yet often without a systematic comparison across technologies.

The third research stream explicitly examines the economic implications of emerging technologies in defense. Studies within this stream investigate topics such as cost-

effectiveness, budgetary impact, market formation, and the commercialization of dual-use technologies. Recent contributions highlight the growing importance of emerging technologies in reshaping defense procurement models and influencing long-term cost structures [17]. However, these analyses are typically technology-specific or policy-driven, limiting their generalizability and making it difficult to identify overarching research trends.

Despite the growing body of literature, several gaps remain evident. First, there is a lack of integrative studies that systematically map how economic dimensions are addressed across different emerging technologies in the defense sector. Second, the multidisciplinary nature of the field has resulted in a fragmented research landscape, with limited cross-fertilization between economics, engineering, and security studies. Third, existing reviews are predominantly narrative, providing valuable qualitative insights but lacking quantitative, data-driven synthesis.

By identifying publication patterns, thematic clusters, and conceptual linkages, bibliometric analysis helps clarify how the economic dimension of emerging defense technologies is conceptualized and studied over time. This study builds on and extends the existing literature by providing a structured overview of research trends and gaps, thereby contributing to a more coherent understanding of the economic role of emerging technologies in the defense sector.

3. RESEARCH DESIGN AND METHODOLOGY

This study adopts a bibliometric research design to examine the economic dimension of emerging technologies in the defense sector. Data were retrieved from the Web of Science Core Collection using the following topic-based query string: TS = ((“emerging technolog” OR “disruptive technolog” OR “advanced technolog*” OR “dual-use technolog*”) AND (“defen*” OR “military” OR “security”) AND (“economic*” OR “investment” OR “market” OR “cost*” OR “budget*” OR “industrial policy”))**. The search was conducted in January 2025 and limited to the period 2005–2025 in order to capture the emergence and consolidation of defense-related emerging technologies following the post-Cold War transformation of defense innovation systems and the rapid diffusion of digital and autonomous technologies after the mid-2000s. Only peer-reviewed articles and review papers published in English were retained. Records were excluded if they: focused exclusively on technical or operational aspects without economic content, addressed civilian technologies with no defense or security relevance, or referred only marginally to emerging technologies. After removing duplicates and applying title, abstract, and keyword screening, a final corpus of 211 documents published in 194 sources was obtained. The refined dataset was analyzed using the bibliometrix package (version 4.4.0) in R, supported by the Biblioshiny interface. Keyword co-occurrence and thematic networks were generated using the association strength normalization method, with a minimum keyword frequency threshold of five occurrences to filter out noise and enhance interpretability. Network visualizations were produced using the Louvain clustering algorithm, while thematic maps were generated using default centrality and density parameters. These settings ensure consistency and replicability of the bibliometric analysis.

4. RESULTS AND BIBLIOMETRIC ANALYSIS

This section presents the main results of the bibliometric analysis, providing an overview of the temporal evolution of scientific publications, research dynamics, and emerging trends related to the economic dimension of emerging technologies in the defense sector.

Analyzing the annual distribution of publications over the period 2005–2025, the results indicate a generally upward trend in the number of published articles, reflecting a growing academic interest in the economic implications of emerging technologies within the defense sector. In the early period (2005–2010), the number of publications remains relatively low and volatile, suggesting that

economic aspects of emerging defense technologies were still a marginal research topic.

From 2011 onwards, the publication output showed a gradual increase, indicating a consolidation phase of the research field. A more pronounced growth was observed after 2016, when the number of articles rises significantly, reaching sustained higher levels. This acceleration coincides with increased policy attention, defense innovation initiatives, and growing investments in disruptive and dual-use technologies, particularly within the European Union. Although minor fluctuations were identified in subsequent years, the overall trend remains positive, with a marked surge after 2021 and a peak in 2025. This recent growth highlights the increasing relevance of economic analyses in understanding the impact of emerging technologies on defense industries, procurement systems, and strategic autonomy.

Figure 1 provides an overview of the geographical and conceptual distribution of research on emerging defense technologies, highlighting the thematic links through which economic aspects are addressed in the literature.

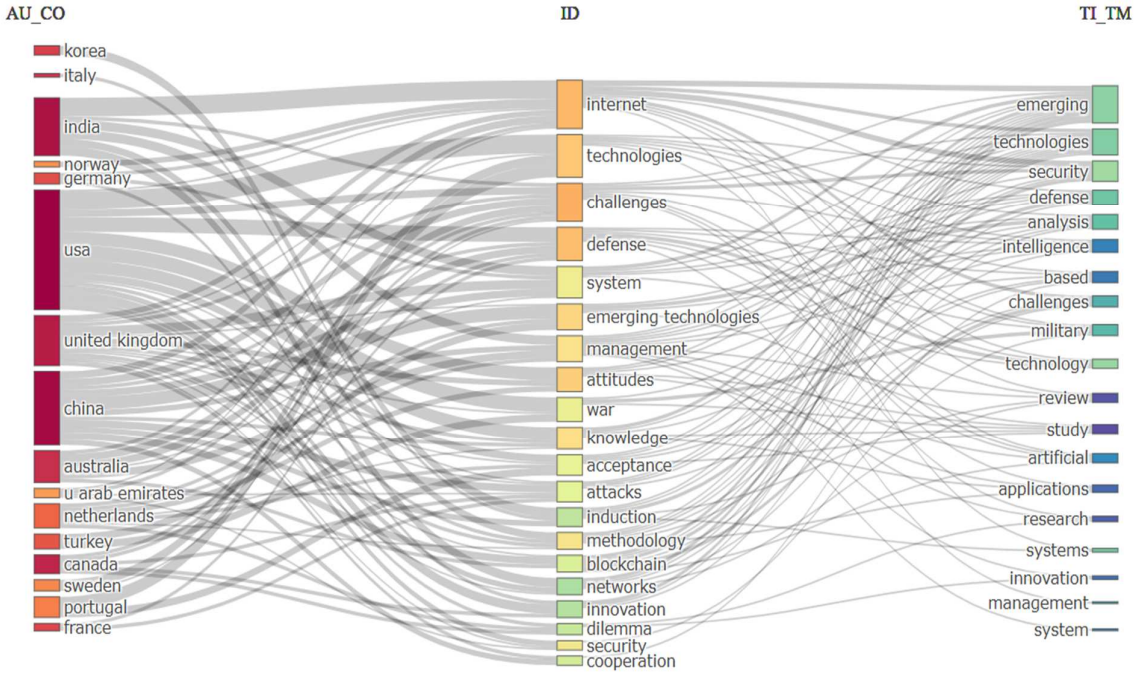


Fig. 1. Geographical and thematic structure of research on emerging defence technologies

From a geographical perspective, the figure shows that research output is concentrated in a limited number of countries, with strong contributions from the United States, the United Kingdom, China, and several European countries, including Germany, Italy, the Netherlands, France, and Sweden. This concentration reflects the presence of advanced defense industrial bases and sustained public investment in defense-related research and development, underlining the close relationship between technological innovation and national economic capacity. The central keyword layer reveals a strong emphasis on terms such as technologies, emerging technologies, defense, security, management, innovation, and blockchain. Notably, several of these concepts are directly linked to economic dimensions, including management, innovation, networks, cooperation, and blockchain, which are commonly associated with industrial organization, investment strategies, and market development in the defense sector.

The title-term layer further reinforces the economic perspective of the research field. Frequent connections to terms such as innovation, management, systems, applications, and review indicate that emerging technologies are often analyzed not only in terms of military performance but also through lenses related to system integration, organizational efficiency, and technological diffusion. These aspects are

closely tied to economic considerations such as cost-effectiveness, scalability and return on investment in defense innovation.

Figure 2 displays the most frequent title bigrams in the analyzed literature, offering insights into how research on emerging technologies in the defense sector is framed at the conceptual level.



Fig. 2. Dominant title bigrams in emerging defense technologies research

The dominance of the bigram emerging technologies confirms the central role of technological transformation as the primary entry point for academic inquiry. Closely associated bigrams such as artificial intelligence, unmanned aerial, and satellite communications indicate that research attention is concentrated on high-impact and capital-intensive technologies with strong implications for defense innovation and industrial development. From an economic perspective, the presence of bigrams such as disruptive technology, technology initiatives, recent advances, and industrial revolution suggests that emerging technologies are frequently discussed in relation to structural economic change, productivity enhancement, and long-term competitiveness within the defense sector. These terms reflect an interest in technological disruption and its potential to reshape defense markets, investment priorities, and industrial capabilities.

The prominence of national security highlights the strong policy-driven nature of the research field, where economic considerations are often embedded within strategic objectives.

Figure 3 presents the evolution of dominant research topics over the period 2005–2025, based on bigrams extracted from article abstracts and reveals a clear temporal progression in the thematic focus of the literature, reflecting both technological maturation and shifting economic priorities within the defense sector. In the early phase of the analyzed period (2005–2010), research topics are relatively sparse and primarily associated with foundational and application-oriented concepts such as commercial products, commercial applications, low cost, and air force. The presence of these terms indicates an initial concern with cost reduction, commercialization potential, and efficiency gains, suggesting that economic considerations were already present at an early stage.

Between 2011 and 2016, the literature shows a diversification of topics, including technology development, information security, space sector, systems integration and risk management. This period corresponds to a growing emphasis on system-level integration and infrastructure development, which are closely linked to economic aspects such as investment allocation, lifecycle costs and industrial coordination. The emergence of risk management further highlights increasing awareness of economic uncertainty and cost-related risks associated with advanced defense technologies.

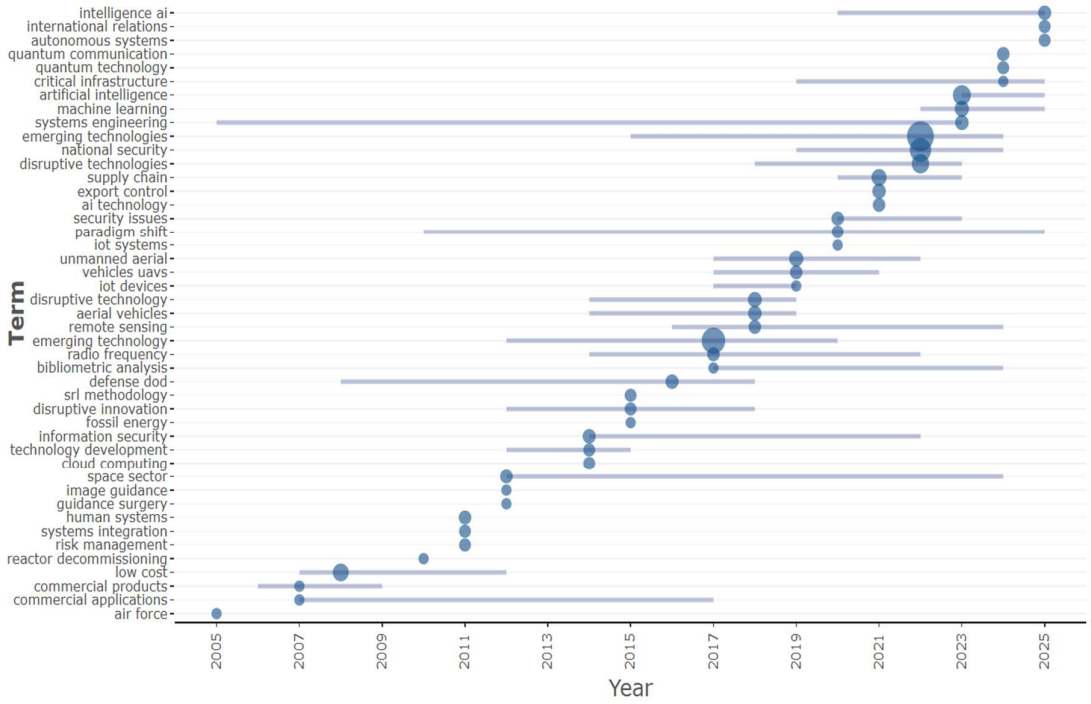


Fig. 3. Temporal evolution of key research topics

From 2017 onwards, a noticeable shift toward more disruptive and data-intensive technologies can be observed. Topics such as emerging technologies, disruptive technologies, artificial intelligence, machine learning, internet of things systems and unmanned aerial vehicles become increasingly prominent. These technologies are typically characterized by high R&D intensity, significant capital requirements, and substantial long-term economic impact on defense industries and supply chains. The growing visibility of supply chain, export control, and security issues during this period reflects rising concerns related to industrial resilience, market access, and regulatory constraints, all of which have strong economic implications. In the most recent years (2021–2025), the literature increasingly addresses advanced and strategically critical technologies such as quantum technology, quantum communications, critical infrastructure and autonomous systems. These topics are closely associated with strategic investment decisions, technological sovereignty, and the restructuring of defense industrial bases. The simultaneous presence of national security and emerging technologies underscores the tight coupling between economic investment strategies and security-driven policy objectives in contemporary defense research.

Figure 4 presents the co-occurrence network of key terms derived from article abstracts, highlighting the relationships among dominant concepts and the underlying structure of the research field. Node size reflects term frequency, while links indicate the strength of co-occurrence, allowing for the identification of central themes and thematic clusters. The network is dominated by highly connected core nodes such as emerging technologies, systems, security and military, which form the conceptual backbone of the literature. These terms are strongly interconnected, indicating that emerging technologies are predominantly analyzed at the system level within a defense and security framework. This systems-oriented perspective has important economic implications, as system integration, interoperability, and lifecycle management are closely linked to cost structures, investment decisions, and long-term sustainability of defense capabilities.

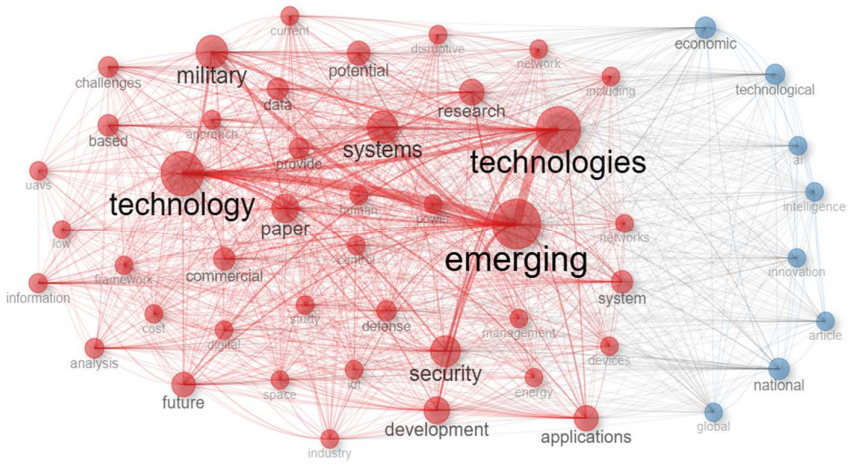


Fig. 4. Conceptual network of emerging defense technologies research

From an economic standpoint, several nodes embedded within the core cluster point to the implicit presence of economic analysis in the literature. Terms such as commercial, cost, industry, development, and applications are directly connected to the central technological concepts, suggesting that economic considerations are frequently addressed through discussions of commercialization pathways, industrial participation, and development processes. The co-occurrence of development and industry with emerging technologies reflects the investment-intensive nature of defense innovation and the role of industrial ecosystems in generating economic value.

The network also reveals a secondary cluster, visually distinguished by a different color, comprising terms such as economic, technological, innovation, national and global. Although this cluster is less dense and more peripheral, its connections to the main technological core indicate that economic and innovation-related concepts are increasingly integrated into the broader research discourse. The relative separation of explicit economic terminology suggests that economic issues are often treated as complementary or contextual elements rather than as primary analytical drivers. The presence of terms such as research, analysis, framework, and management highlights the methodological and organizational dimensions through which economic aspects are explored. These concepts are typically associated with efficiency assessment, decision-making processes, and governance structures, all of which are central to evaluating the economic performance of emerging technologies in the defense sector.

Figure 5 presents the thematic evolution of research topics derived from article abstracts across four consecutive periods: 2005–2010, 2011–2015, 2016–2020, and 2021–2025. The diagram reveals a clear progression in thematic priorities, reflecting both technological maturation and the increasing integration of economic considerations in the defense sector.

In the initial period (2005–2010), research themes are relatively limited and primarily focused on emerging technologies and low cost. The explicit presence of low cost indicates that early research paid particular attention to affordability, efficiency, and cost reduction, suggesting that economic concerns initially centered on minimizing expenditures and improving cost-effectiveness in defense applications. During the 2011–2015 period, the thematic structure becomes more diversified. The emergence of themes such as aerial vehicles alongside emerging technologies reflects growing investment in unmanned and autonomous systems. This shift corresponds to increased funding and industrial engagement in specific technological domains, signaling a move from general cost considerations toward targeted investment in high-potential defense technologies.

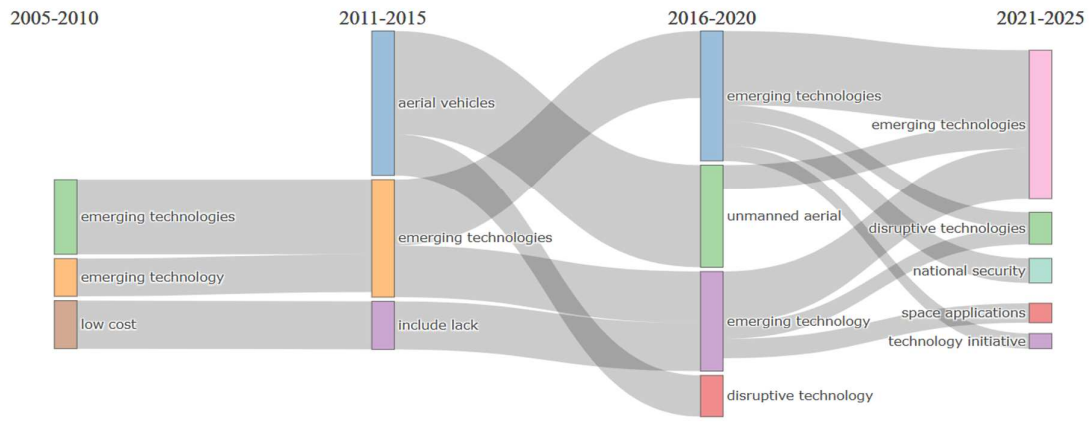


Fig. 5. Evolution of themes in defence-related emerging technologies research

Between 2016 and 2020, the literature exhibits a stronger focus on emerging technologies, unmanned aerial and disruptive technology. This period marks a transition toward explicitly disruptive and innovation-driven themes, which are typically associated with higher R&D intensity, longer development cycles, and significant economic impact on defense industries and supply chains. The reduced emphasis on cost minimization and the increased attention to disruption suggest a strategic shift toward long-term value creation and technological competitiveness.

In the most recent period (2021–2025), thematic evolution culminates in a more complex and policy-oriented structure. Dominant themes include emerging technologies, disruptive technologies, national security, space applications, and technology initiative. These topics reflect a mature research domain in which economic considerations are closely intertwined with strategic investment decisions, industrial policy, and technological sovereignty.

5. CONCLUSION

This study investigated the economic dimension of emerging technologies in the defense sector through a comprehensive bibliometric analysis of scientific publications indexed in the Web of Science database over the period 2005–2025. By applying descriptive, network-based, and thematic analyses using the bibliometrix package and the Biblioshiny interface in R Soft, the paper provides a structured overview of how economic considerations are embedded in research on emerging and disruptive defense technologies.

The results reveal a clear and sustained growth in academic interest, particularly after 2016, reflecting the increasing strategic and economic relevance of emerging technologies for defense systems and industries. The temporal analysis highlights an evolution from early research focused on cost efficiency and commercial applications toward more recent studies emphasizing disruptive technologies, investment-intensive systems, and strategic initiatives linked to national security and industrial resilience.

The bibliometric mapping further demonstrates that the economic dimension of emerging defense technologies is primarily addressed implicitly rather than explicitly. Economic aspects are embedded within discussions on innovation management, system integration, industrial development, and policy frameworks, while direct references to costs, markets, or return on investment remain comparatively limited. This pattern suggests that economic considerations are often subordinated to technological and security narratives, despite their critical importance for defense planning, procurement, and long-term sustainability.

Several clearly defined research gaps emerge from the analysis. First, despite the prominence of technologies such as artificial intelligence, unmanned systems and satellite

communications, there is a shortage of studies that quantitatively link these technologies to firm-level and sector-level economic outcomes, including cost efficiency, productivity, and competitiveness within the defense industrial base. This limits the ability of policymakers and industry to assess the economic return on investments in these technologies. Second, comparative economic analyses of emerging defense technologies across different regional ecosystems remain underdeveloped, particularly for the European Union in comparison with the United States and China. This gap constrains evidence-based policy design in areas such as defense industrial strategy, supply-chain resilience and technological sovereignty. Third, although disruptive technologies such as AI-enabled systems, autonomous platforms, and blockchain-based defense applications are widely discussed, there is insufficient analysis at the public-finance and program level of their long-term budgetary impacts, opportunity costs, and financial risks. As a result, governments lack robust economic frameworks for evaluating trade-offs between investing in cutting-edge technologies and sustaining conventional defense capabilities.

The main contribution of this study lies in providing a systematic, data-driven overview of a fragmented and multidisciplinary research field. By combining temporal trends, conceptual networks, and thematic evolution, the bibliometric analysis uncovers latent economic narratives and clarifies how economic issues intersect with technological and strategic discussions in the defense sector. The study also offers a replicable methodological framework that can be applied to other domains of defense economics or technology policy analysis.

Based on these findings, several recommendations can be formulated. Future research should place greater emphasis on explicit economic evaluation frameworks, integrating technological assessments with quantitative economic indicators. Policymakers and defense stakeholders may benefit from more interdisciplinary research linking economics, engineering, and security studies, particularly to support evidence-based investment decisions and industrial strategies. Additionally, future research should focus on developing a formal conceptual framework that distinguishes between micro-level, meso-level, and macro-level dynamics in order to better capture the economic complexity of emerging defense technologies.

Despite its contributions, this study has several limitations. The analysis is limited to publications indexed in the Web of Science database and to English-language peer-reviewed articles, which may exclude relevant research published in other databases or formats. Moreover, bibliometric methods capture patterns and relationships within the literature but do not assess the quality or empirical validity of individual studies.

To conclude, this bibliometric analysis demonstrates that the economic dimension of emerging technologies in the defense sector is an increasingly relevant yet underexplored area of research. By highlighting key trends, gaps, and conceptual structures, the study contributes to a more coherent understanding of how emerging technologies shape not only military capabilities but also the economic foundations of modern defense systems.

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Dimensiunea economică a tehnologiilor emergente aplicate în sectorul apărării - un cadru bibliometric

Rezumat: Tehnologiile emergente transformă din ce în ce mai mult sectorul apărării, nu doar în ceea ce privește capabilitățile militare, ci și prin implicațiile lor economice. Această lucrare investighează dimensiunea economică a tehnologiilor emergente din sectorul apărării prin aplicarea unei analize bibliometrice a literaturii științifice indexate în baza de date Web of Science. Folosind pachetul bibliometrix din R Soft și interfața sa Biblioshiny, studiul cartografiază tendințele de publicare și clusterele tematice legate de investiții, piețe și impact industrial. Rezultatele evidențiază fluxurile de cercetare dominante și dezvăluie lacunele existente, oferind o imagine de ansamblu structurată pentru a sprijini cercetarea și dezvoltarea politicilor viitoare.

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