International Journal of Business Management and Finance Research
Volume 8, Issue 6, pp. 32-43
2025

Mapping Deep Tech Technologies: Implications for Businesses and Policy Makers

♣***Fulvio Iavernaro***: *Politecnico di Bari, Italy.*
E-mail: fulvio.iavernaro@poliba.it

Enzo Capalbo: *ANTIKYTHERIA S.R.L, Italy.*
E-mail: enzo.capalbo@gmail.com

Giuseppe Filitti: *ANTIKYTHERIA S.R.L, Italy.*
E-mail: giuseppe.filitti@gmail

ABSTRACT: *This study provides a comprehensive patent-based analysis of deep tech innovation. Deep tech, encompassing advanced technologies such as artificial intelligence, robotics, quantum computing, and industrial automation, is recognized for its disruptive potential and reliance on intensive scientific research. By analyzing over 138,000 granted patents granted between 2015 and 2025, the study investigates temporal trends, geographical patterns, and key innovation actors. Results reveal a significant rise in deep tech patenting since 2010, with North America leading in patent quality and impact, Asia dominating in volume, and Europe exhibiting a balanced but moderate innovation output. Engineering and Industrial Technologies emerged as the most patent-intensive domain, while Biotechnology and specialized technologies showed the highest impact. The findings highlight the critical role of private firms in driving deep tech innovation and suggest strategic and policy implications for fostering technological leadership, particularly in Europe. This work contributes to the understanding of deep tech as a converging field of general-purpose technologies shaping future innovation ecosystems.*

Key Words: *Deep tech, innovation, patent analysis, research and development.*

1. Introduction

Deep technologies (deep tech) refer to a class of advanced and disruptive innovations grounded in significant scientific and engineering challenges (De la Tour et al., 2017). These solutions, often based on fields such as artificial intelligence, advanced materials, quantum computing, biotechnology, and robotics, are characterized by their potential to create profound societal and industrial impact through new startups (Perelmuter,, 2021).

In recent years, deep tech has gained increasing attention from policymakers, investors, and researchers due to its potential to address global challenges and shape the future of key sectors, such as healthcare, energy, manufacturing, and mobility (Romme et al., 2023). According to various reports, deep tech startups have attracted growing investment, and governments have begun to integrate deep tech into national innovation strategies and industrial policies (Harlé et al., 2017; Nedayvoda et al., 2020; Kask & Linton, 2023; Bellavitis et al., 2025). Despite this growing interest, a comprehensive understanding of how deep tech is evolving—what technologies are emerging, who is developing them, and where they are being pursued—remains limited.

Given the complexity and multidisciplinary nature of deep tech solutions, mapping their development trajectory is a non-trivial task. These technologies often span across domains, are developed simultaneously in

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*
♣*Corresponding Author: Fulvio Iavernaro*
Email: fulvio.iavernaro@poliba.it

diverse industries, and evolve within rapidly changing ecosystems (Perelmuter, 2021; Romme et al., 2023). Consequently, traditional literature-based reviews may struggle to capture the full extent of technological advancements in this field.

To address these limitations, patent analysis (Abbas et al., 2014) emerges as a valuable tool for investigating the evolution of deep tech. Patents represent early indicators of technological innovation and provide structured, comparable, and geographically disaggregated data on technological developments (Abraham & Moitra, 2001; Breitzman & Mogee, 2002). Prior studies have successfully applied patent analysis to trace the dynamics of specific technology domains, highlighting its effectiveness in uncovering innovation trends, identifying leading actors, and revealing regional patterns of technological specialization (e.g., Chen & Chen, 2011; Albino et al., 2014; Ardito et al., 2020).

In this study, we adopt a patent-based approach to provide a comprehensive overview of the development of deep tech solutions. In particular, we examine temporal trends, geographical distribution, and key applicants of patented technologies associated with the deep tech domain. By analyzing a curated sample of patent data, we aim to answer the following research questions: (i) How has deep tech innovation evolved over time? (ii) Which countries and regions are at the forefront of deep tech development? (iii) Which are the main organizations driving innovation in this domain?

Our goal is to contribute to a better understanding of the deep tech landscape by offering empirical evidence that can support strategic decisions for policymakers, investors, and R&D managers.

The paper is organized as follows: Section 2 presents the conceptual background and the definition of deep tech. Section 3 describes the methodology used for data collection and analysis. Section 4 reports the results of the patent analysis. Section 5 discusses the main findings, implications, and avenues for future research.

2. Theoretical Background

2.1. Deep tech

The term deep tech encompasses a wide range of scientific and engineering-based technologies with the potential to disrupt industries and generate transformative impact. Rooted in high barriers to entry and often involving long R&D cycles, deep tech solutions are not confined to a single discipline but emerge across multiple foundational technological domains (Perelmuter,, 2021; Romme et al., 2023; Bellavitis et al., 2025).

While the notion of deep tech spans a broad spectrum of scientific and engineering-based innovations, this study focuses on a specific subset of enabling technologies that are widely recognized as foundational to its development. In particular, we concentrate on patents related to Artificial Intelligence (AI), Autonomous Systems, Quantum Computing, Quantum Technologies, Quantum Algorithms, Robotics, Industrial Automation, and Robot Systems (De la Tour et al., 2017; Gourevitch et al., 2021; Rahimi-Midani, 2023). These technologies were selected due to their strategic importance in shaping the trajectory of deep tech innovation and their growing role in transforming multiple sectors of the economy.

Our decision to focus on this subset stems from two key considerations. First, these domains are characterized by a high degree of scientific intensity, complexity, and long development cycles—hallmarks of deep tech as defined in the literature (Brin, 2022; Zahid et al., 2025). Their advancement depends on breakthroughs in fundamental research, often requiring cross-disciplinary knowledge across physics, engineering, and computer science. Second, and equally important, these technologies exhibit the defining features of general purpose technologies (GPTs)—that is, they are not limited to a single field or application area, but have the capacity to drive innovation across diverse industries (Bresnahan & Trajtenberg, 1995; Brynjolfsson & Mcafee, 2017).

For example, artificial intelligence and robotics are increasingly embedded in sectors as varied as healthcare, manufacturing, agriculture, logistics, and finance, enabling new modes of automation, optimization, and decision-making (Mathew et al., 2023; Hussain et al., 2024). Likewise, quantum computing and quantum algorithms promise to revolutionize not only computing itself, but also areas such as cryptography, materials science, and drug discovery (Bova et al., 2021; Peelam et al., 2024. Industrial automation, often enhanced by robotics and AI, underpins the digital transformation of production systems, from smart factories to autonomous logistics platforms (Vyatkin, 2013).

By focusing on these technologies, we aim to capture a core segment of the deep tech landscape that is both scientifically grounded and economically transformative. This approach allows us to investigate the

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*
Corresponding Author: Fulvio Iavernaro
Email: fulvio.iavernaro@poliba.it

diffusion and evolution of deep tech through the lens of technological convergence and cross-sectoral impact, rather than within the boundaries of any single industrial domain. In doing so, we acknowledge that while deep tech emerges within specific knowledge areas, its transformative potential lies in its ability to scale and adapt across multiple societal and economic contexts.

This analytical choice aligns with recent classifications of deep tech by both public institutions and private research initiatives, which increasingly highlight AI, robotics, and quantum technologies as emblematic cases of deep tech with far-reaching implications (e.g., OECD, 2024; European Commission, 2023; Tubke et al., 2023). Moreover, this focus enables a clearer mapping of patent activity at the intersection of scientific research and commercially relevant technological development—an essential criterion for identifying deep tech trajectories in empirical studies.

2.2 Patent Analysis

Beyond their legal and commercial functions, patents serve as a rich source of information for analyzing the progression and diffusion of technological innovation. While traditionally considered instruments to protect intellectual property and secure competitive advantages (Long, 1991; Golin, 2008), patents also offer insights into the strategic priorities of inventors and organizations, as well as the dynamics of technological change.

Each patent discloses an invention that must meet core criteria: it must be new, non-obvious, and industrially applicable[1]. As such, patent data encapsulate significant R&D efforts and technological novelty. This has led scholars in the fields of innovation studies and technology management to consider patents not only as legal rights but also as empirical indicators of inventive activity (Pavitt, 1985; OECD, 2009).

Unlike other metrics that may rely on self-reporting or financial proxies, patents are filed through structured procedures and provide standardized documentation across countries and technological domains. They include a wealth of bibliometric and classification data—such as applicant identity and nationality, technological fields (through IPC or CPC codes), citation networks, and grant dates—which can be leveraged to study both the quantity and quality of technological developments (Harhoff et al., 2003; OECD, 2009).

Due to these characteristics, patent analytics has become a cornerstone method for identifying technological trends over time, detecting shifts in innovation focus, and comparing innovation capacity across regions and institutions (Gao et al., 2025; Albino et al., 2014). In particular, in sectors like information and communication technologies, biotechnology, or advanced manufacturing, patents have been employed to uncover emerging technologies, forecast innovation trajectories, and support decision-making for R&D investment and policy formulation (e.g., Jiang et al., 2024; Ovsyannikov & Zhdaneev, 2024; Grassano & M'barek, 2025).

3. Methodological Approach

3.1. Data Collection

In order to identify patents related to deep tech innovation, we relied on the Orbis Intellectual Property (Orbis IP) database developed by Bureau van Dijk. Given the multifaceted and science-driven nature of deep tech, the search strategy was carefully designed to capture both the general characteristics of this technological domain and its most prominent fields of application.

Specifically, the first set of keywords was selected to broadly reflect the conceptual foundations of deep tech (Perelmuter, 2021; Romme et al., 2023). Terms as "Advanced technology," "Cutting-edge technology," "Disruptive technology," "Next-generation technology," "High-tech innovations," "Tech breakthroughs," "Future technology," "R&D," "Scientific research," "Tech development," "Experimental technology," "Tech innovation," "Scientific applications," "Science-based innovations," "Tech-based science," and "Scientific discoveries" were used. These keywords were selected to reflect the breadth of activities and technological trajectories that characterize deep tech ventures, ranging from early-stage scientific exploration to experimental development and advanced applications. These descriptors were intended to capture the general ecosystem of organizations and inventions operating within the deep tech space, where innovation is typically driven by fundamental research rather than market demand alone.

[1] See for instance: https://www.epo.org/en/new-to-patents/is-it-patentable; https://www.uspto.gov/help/patent-help#type-browse-faqs_1902

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*
Corresponding Author: Fulvio Iavernaro
Email: fulvio.iavernaro@poliba.it

These general terms were paired with a second set of keywords targeting specific technological domains that are widely recognized as central to deep tech (De la Tour et al., 2017; Gourevitch et al., 2021; Rahimi-Midani, 2023). This included references to Advanced technology," "Cutting-edge technology," "Disruptive technology," "Next-generation technology," "High-tech innovations," "Tech breakthroughs," "Future technology," "R&D," "Scientific research," "Tech development," "Experimental technology," "Tech innovation," "Scientific applications," "Science-based innovations," "Tech-based science," and "Scientific discoveries." These domains are emblematic of the deep tech paradigm in that they are built on advanced scientific principles and frequently require multidisciplinary expertise across areas such as computer science, physics, and engineering. By combining these two layers of keyword filtering—general and domain-specific—we ensured that the patents collected reflect both the definitional breadth and the technological depth of deep tech innovation.

Both sets of terms were searched within the fields Brand names, Description and history, Size estimate, Full overview, History, Main activity, Main customers, Main distribution site, Main domestic country, Main foreign countries or regions, Main production site, Main sales representation sites, Membership of network, Primary business line, Primary national activity, Product and services, Secondary activity, Secondary business line, Strategic alliances, Strategy organization and policy, Trade description.

Geographically, the search was limited to entities based in Western Europe, Eastern Europe, the European Union (including both EU-14 and EU-27 groupings), and the Euro Area. This regional focus reflects our objective to examine deep tech developments within the broader European innovation ecosystem, which is characterized by a strong scientific base, diverse industrial capabilities, and increasing policy support for advanced technologies.

Regarding the temporal scope, we considered patents with a publication date between January 1, 2015, and March 17, 2025. This range was chosen to capture a relevant window of recent and emerging technological developments, taking advantage of the database's inclusion of pre-published or scheduled publication data where available.

The final dataset was obtained by applying a Boolean logic that required the simultaneous fulfillment of all search conditions: the presence of general deep tech keywords, specific high-tech domain terms, a European location, and a publication date within the specified timeframe. This approach ensured a focused yet comprehensive identification of patents that embody the scientific, technological, and economic dimensions of deep tech innovation in Europe.

This approach resulted in a sample of 312,461 published patents. Of these, 138,907 had also been granted, meaning they successfully completed the examination process and received legal protection. Therefore, we focus on granted patents to conduct our analysis.

3.2. Patent Analytics

This section provides a detailed overview of the patent analytics used in our analysis. First, we investigate the temporal dynamics of patenting activity, both in aggregate and within specific geographic regions or technological domains, using annual patent counts as a proxy for R&D output (Albino et al., 2014). Second, we analyze the geographical distribution of innovation by assigning each patent to a country based on its priority filing (Martino et al., 2025). This is complemented by an assessment of the average quality of patents across regions, measured by the mean number of forward citations—i.e., citations received from subsequent patents (e.g., Harhoff et al., 2003). Third, a parallel analysis is conducted across technology domains, examining both the volume and average impact of patents within each field. Finally, we evaluate the role of individual organizations by identifying the most active patent assignees, based on the total number of patents owned.

4. Results

Figure 1 illustrates the trend in deep tech patents over time, spanning from the year 2000 to march 2025. On the vertical axis, we see the number of patents, starting at zero and peaking at 18,000, while the horizontal axis marks the years in five-year intervals. What stands out immediately is the remarkable growth in deep tech patents over this 25-year period. Starting at a relatively modest level—well under 2,000 patents in 2000—the numbers climb steadily, with a noticeable acceleration after 2010. By 2025, the figure soars to over 16,000, approaching the 18,000 mark. This upward trajectory suggests a few key takeaways. First, deep tech

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*
Corresponding Author: Fulvio Iavernaro
Email: fulvio.iavernaro@poliba.it

innovation has gained significant momentum, particularly in the last decade and a half. The steeper rise post-2010 could reflect advancements in fields like AI, quantum computing, or biotechnology, as well as increased investment and interest in these areas. Second, the trend hints at a broader shift in technological focus, with companies and researchers prioritizing cutting-edge, transformative technologies.

However, it's important to note that the data for the most recent years (2023-2025) likely underrepresents the true number of deep tech patents. This is because patents filed during these years are still undergoing the approval process and may not yet be granted. The actual figures for this period could be higher once pending applications are finalized. Despite this caveat, the overall trend remains clear: deep tech is experiencing explosive growth. If this pattern continues, we can expect these technologies to play an even more dominant role in shaping future innovations. The graph not only highlights past progress but also signals a promising—and perhaps exponential—growth trajectory for the years ahead.

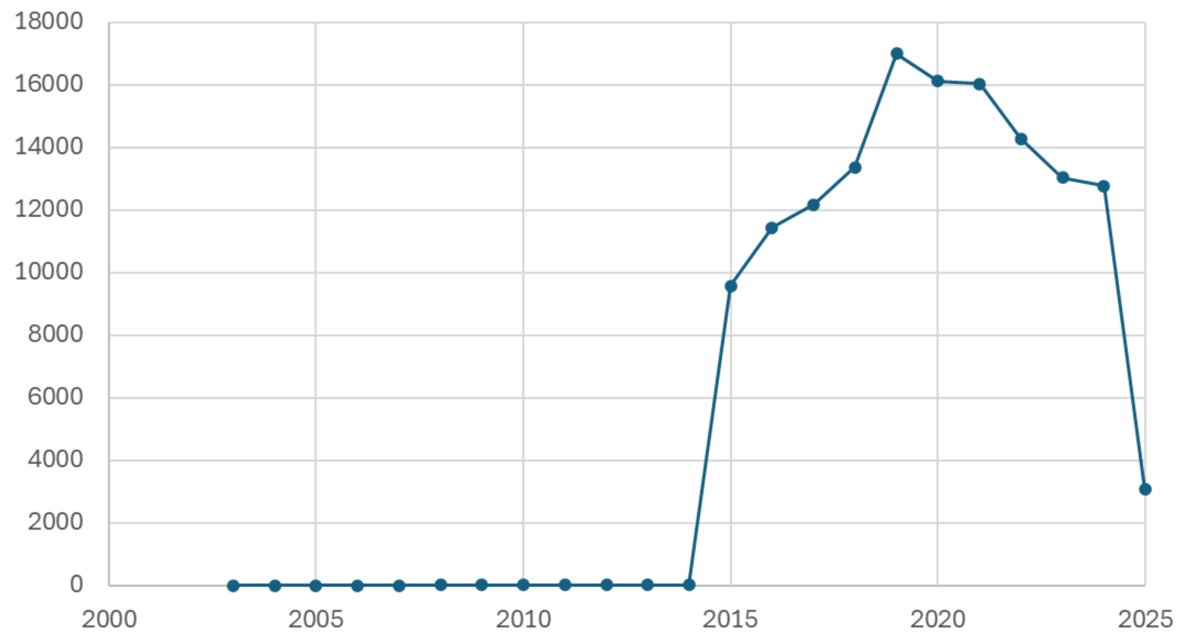

Figure 1. Temporal trend.

Table 1 presents a detailed analysis of deep tech patents across various technological domains, offering insights into innovation trends through three key metrics: the total number of patents, their average forward citations (a proxy for quality and influence), and their average family size (reflecting the breadth of international protection and perceived value). Engineering and Industrial Technologies emerges as the most active domain, with a substantial 48,167 patents—far surpassing other fields. This dominance suggests widespread innovation in this sector, likely driven by its broad industrial applications. However, the relatively low average forward citations (0.49) indicate that while these patents are numerous, they may not be as frequently cited or impactful as those in other categories. The moderate family size (6.49) points to decent but not exceptional international protection, hinting at a balance between regional and global filings. In contrast, Biotechnology and Life Sciences, with 22,130 patents, stands out for its higher-quality innovations. The average forward citations (1.23) are notably higher than in engineering, signaling that these patents are more influential in subsequent research. The large family size (9.62) further underscores their global value, as inventors seek extensive protection across multiple jurisdictions—a common practice for high-stakes biotech advancements. The "Other" category is particularly intriguing, boasting the highest average forward citations (2.25) by a significant margin. This suggests the presence of highly impactful, possibly disruptive patents that don't fit neatly into the listed domains. The smaller family size (3.50) could imply that these innovations are more specialized or targeted, with less need for global patent coverage. Chemistry and Chemical Processes, while modest in patent count (305), shows a remarkably large family size (17.60), the highest in the table. This indicates that inventors in this field prioritize extensive international protection, likely due to the high commercial or strategic value of their innovations. However, the low forward citations (0.39) raise questions

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*
Corresponding Author: Fulvio Iavernaro
Email: fulvio.iavernaro@poliba.it

about their academic or industrial influence relative to their perceived legal worth. Information and Communication Technologies (ICT) and Optics and Measurement Technologies also demonstrate interesting patterns. ICT, with 26,512 patents, combines moderate forward citations (0.80) with a solid family size (8.40), reflecting its dual role as a driver of both incremental and high-value innovations. Optics and Measurement Technologies, though smaller in volume (12,245 patents), shows balanced metrics, with decent citations (0.69) and family size (7.56), suggesting steady, globally relevant advancements. Consumer Goods and Leisure, despite its large patent count (15,730), lags in both forward citations (0.49) and family size (3.32), implying that innovations here may be more incremental or localized. Similarly, Environmental and Energy Technologies (5,844 patents) and Materials Science and Nanotechnology (916 patents) show middling performance, with room for growth in both influence and global reach.

Table 1. Analysis by technology domain.

Technology domain	Number of patents	Mean forward citations	Mean number of authorities
Biotechnology and Life Sciences	22,130	1.23	9.62
Chemistry and Chemical Processes	305	0.39	17.60
Consumer Goods and Leisure	15,730	0.49	3.32
Engineering and Industrial Technologies	48,167	0.49	6.49
Environmental and Energy Technologies	5,844	0.66	4.91
Information and Communication Technologies	26,512	0.80	8.40
Materials Science and Nanotechnology	916	0.39	7.31
Optics and Meaurement Technologies	12,245	0.69	7.56
Other	7,071	2.25	3.50

Figure 2 illustrates the temporal trend of patents granted across different technology domains between 2003 and 2025, complementing the previous analysis. Each curve represents a specific technology group, allowing us to observe how patenting activity has evolved over time within each field. A clear increase in patenting activity can be observed starting around 2014, particularly within the domain of Engineering and Industrial Technologies, which stands out as the most prolific group throughout the entire period. This domain experienced a sharp rise in the number of granted patents, peaking around 2019–2020 with more than 5,000 patents, before entering a gradual decline in the following years. Other technology domains, such as Consumer Goods and Leisure, Information and Communication Technologies, and Biotechnology and Life Sciences, also show notable levels of activity. These sectors peaked between 2018 and 2020, following a similar trend to Engineering and Industrial Technologies, although with significantly lower volumes. The decline observed after the peak years may reflect a combination of factors, such as delayed publication of recent patents, changes in R&D investment priorities, or saturation in certain technological areas.Some technology groups, including Environmental and Energy Technologies, Materials Science and Nanotechnology, and Optics and Measurement Technologies, display more stable or modest trends, with fewer fluctuations and overall lower patent volumes. These domains, while smaller in scale, still contribute consistently to the deep tech innovation landscape.

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*
Corresponding Author: Fulvio Iavernaro
Email: fulvio.iavernaro@poliba.it

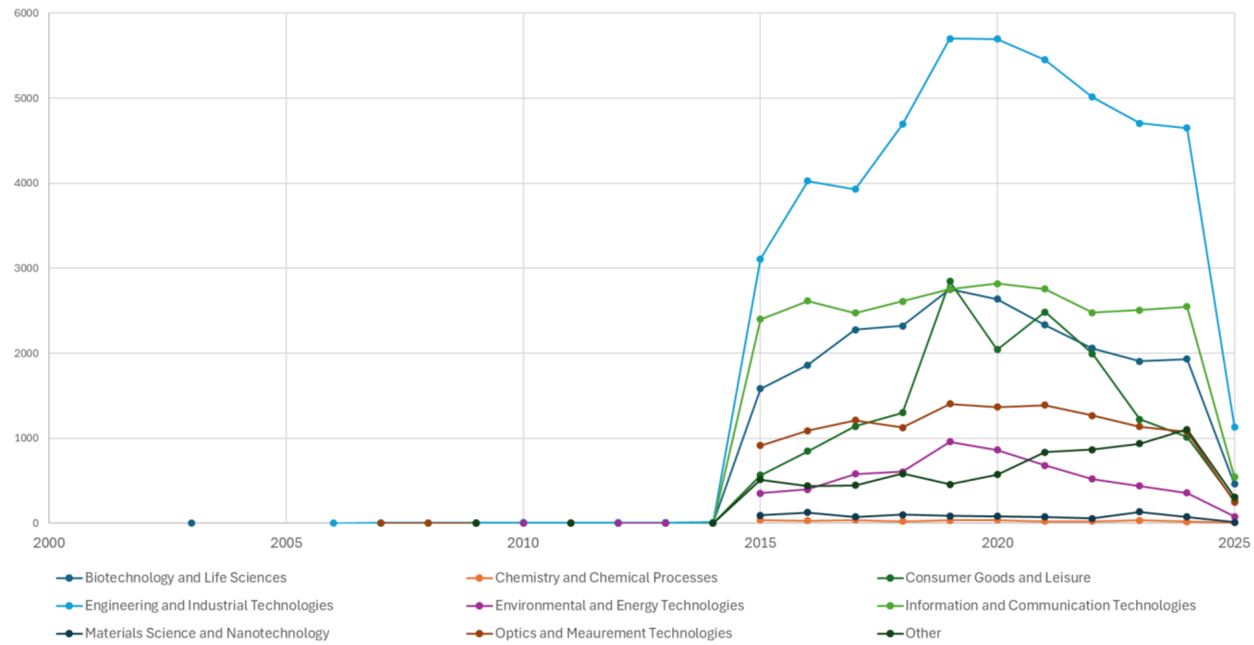

Figure 2. Temporal trend by technology domain.

Table 2 provides a geographical breakdown of deep tech patents, revealing distinct patterns of innovation activity, patent quality, and international protection strategies across different continents. The data highlights how regional innovation ecosystems vary significantly in both output and impact.

North America stands out dramatically as the global leader in patent quality, with an exceptionally high mean citation rate of 3.06 – nearly ten times higher than any other region. This remarkable figure, combined with a solid international protection strategy (mean 7.79 countries), underscores the United States' dominance in producing highly influential, cutting-edge technologies. The overwhelming majority of these North American patents undoubtedly originate from the U.S., reflecting its position as the world's foremost innovation hub. Asia emerges as the quantity leader with 56,353 patents – more than any other continent – though with more moderate quality indicators. The mean citation rate of 0.30 suggests these patents are somewhat less influential than North American ones, while the relatively low mean of 5.72 countries for patent protection indicates a more regional focus. Notably, about 90% of these Asian patents come from just two countries: China and Japan. This concentration reveals these nations as the powerhouses of Asian technological development, though their innovation outputs appear to have different characteristics than their North American counterparts.

Europe presents an interesting middle ground, ranking third in patent volume (19,335) with respectable but not outstanding metrics. The mean citation rate of 0.16 suggests European patents have moderate influence, while the relatively low mean of 6.54 countries for protection might indicate a preference for European Patent Office filings rather than global coverage. Within Europe, France stands out as the most significant contributor, followed by Germany, Poland, and Spain – traditional European technological leaders maintaining strong innovation ecosystems. The "International" category shows surprisingly strong performance with both high volume (30,066 patents) and the second-highest citation rate (0.41). This likely represents patents filed through systems like the Patent Cooperation Treaty (PCT), where inventors deliberately seek broad international protection from the outset, typically for higher-value inventions. Russia and Oceania show some notable characteristics despite their smaller volumes. Russia's patents demonstrate relatively high citation impact (0.35) and strong international protection (10.03 countries), suggesting its inventors focus on quality and global reach. Oceania, while small in absolute numbers, shows balanced metrics that might reflect Australia and New Zealand's strategic approaches to innovation. South America and Africa lag significantly in both quantity and quality metrics. South America's 3,141 patents have minimal citation impact (0.007), though the mean of 13.41 countries for protection is unexpectedly high – possibly reflecting strategic filings by multinational corporations rather than domestic innovation. Africa's extremely low patent count (467) and zero citations highlight the continent's ongoing challenges in deep tech innovation,

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*
Corresponding Author: Fulvio Iavernaro
Email: fulvio.iavernaro@poliba.it

despite showing some effort in international protection (7.56 countries). The Middle East's near-absence from the data (just 3 patents) is particularly striking, suggesting this region has yet to establish itself in the global deep tech innovation landscape. These geographical disparities reveal much about global innovation dynamics. North America's quality leadership contrasts with Asia's quantity advantage, while Europe maintains a steady presence. The data suggests that while some regions focus on producing highly influential technologies, others prioritize volume or specific protection strategies. The minimal contributions from Africa, South America, and the Middle East highlight significant global imbalances in technological development and patenting activity that may have important implications for future economic competitiveness.

Table 2. Analysis by geographic area.

Geographic area	Number of patents	Mean forward citations	Mean number of authorities
Africa	467	0.00	7.56
South America	3,141	0.01	13.41
Europe	19,335	0.16	6.54
Oceania	1,348	0.10	12.57
Asia	56,353	0.31	5.72
International	30,066	0.42	7.72
Middle East	3	0.00	1.00
North America	24,615	3.07	7.79
Russia	3,592	0.36	10.03
Total	138,920		

Table 3 provides insights into how different world regions specialize across various deep tech domains, revealing distinct geographical strengths and innovation patterns. The data paints a picture of regional technological specialization that aligns with known economic and industrial profiles. Asia emerges as the dominant force across nearly all technology sectors, with particularly strong showings in Consumer Goods (12,847 patents), Engineering and Industrial Technologies (15,856), and Information and Communication Technologies (8,985). This broad-based leadership reflects Asia's comprehensive technological capabilities, though the overwhelming numbers in consumer goods and industrial technologies suggest these may be areas of particular focus. The significant output in biotechnology (8,547 patents) also stands out, indicating substantial investment in life sciences. North America shows a different specialization pattern, with its strongest presence in Information and Communication Technologies (7,851 patents) and Biotechnology (4,425). The ICT dominance aligns with the region's well-known strengths in software and digital technologies, while the biotech numbers confirm the U.S.'s position as a global life sciences leader. Interestingly, North America has relatively fewer patents in consumer goods and industrial technologies compared to Asia, suggesting a focus on higher-value, knowledge-intensive sectors. Europe presents a more balanced portfolio, with Engineering and Industrial Technologies (12,397 patents) as its clear strength, followed by Information and Communication (3,717) and Biotechnology (1,678). This industrial technology focus reflects Europe's traditional manufacturing prowess and mechanical engineering expertise. The relatively lower numbers in other sectors indicate a more specialized, rather than broad-based, technological approach. The "International" category shows significant activity across multiple domains, particularly in Biotechnology (6,641), Engineering (11,506), and ICT (5,232). These numbers likely represent inventions deemed valuable enough to warrant international patent protection from the outset, suggesting these may be particularly important or commercially promising technologies. Africa and South America show much smaller but interesting patterns. Africa's patent activity is concentrated in Biotechnology (30) and Engineering (76), while South America shows slightly more diversity with Biotechnology (566) and Engineering (1,413) as relative strengths. Both regions have minimal presence in advanced fields like materials science and nanotechnology. Oceania's modest numbers reveal a focus on Biotechnology (253) and Engineering (515), possibly reflecting Australia's medical research strengths and industrial applications. The Middle East's near-absence from the data (just 3 patents total) is striking and suggests minimal deep tech patenting activity in the region.

Academia Publishing Group

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*
Corresponding Author: Fulvio Iavernaro
Email: fulvio.iavernaro@poliba.it

Table 3. Combined analysis by geographic area and technology domain.

	Technology domain								
Geographic area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Africa	30	9		76	5	39	2	10	296
Asia	8,547	71	12,847	15,856	2,377	8,995	404	3,630	3,626
Europe	1,678	35	1,139	12,397	1,372	3,717	222	2,111	256
International	6,641	70	1,162	11,506	1,417	5,232	155	3,348	535
Middle East				1		1			1
North America	4,425	75	384	6,403	608	7,851	113	2,719	2,037
Oceania	253	23	28	515	9	149	5	113	253
South America	556	22	170	1,413	56	528	15	314	67

Note: 1=Biotechnology and Life Sciences; 2=Chemistry and Chemical Processes; 3=Consumer Goods and Leisure; 4=Engineering and Industrial Technologies; 5=Environmental and Energy Technologies; 6=Information and Communication Technologies; 7=Materials Science and Nanotechnology; 8=Optics and Measurement Technologies; 9=Other.

Table 4 highlights the leading patenting organizations in the deep tech sector, each holding over 1,000 patents. At the forefront is Koninklijke Philips with an impressive 45,010 patents, showcasing its long-standing commitment to innovation in health technology and advanced electronics. Valeo, a major player in automotive systems, follows with 13,928 patents, underlining its strategic investment in deep tech fields such as autonomous driving and smart mobility. Zhejiang Shaoxing Supor, known for its advanced manufacturing capabilities, and INVENTIO AG, a leader in vertical transportation technologies, also demonstrate substantial patent activity. Key contributors in semiconductor and embedded systems include ARM LIMITED and ADVANCED RISC MACH LTD, both essential to the evolution of computing hardware in deep tech. SIEMENS (Mobility + Medical), with 3,997 patents, represents the convergence of medical technology and smart infrastructure. Automotive technology is further represented by HELLA, CLARION, and AVL LIST GMBH, which focus on smart lighting, infotainment, and powertrain systems respectively. IBM, though historically known for software and enterprise systems, maintains a strong presence in emerging deep tech domains such as AI and quantum computing. Biotech and life sciences are also present, with MedImmune contributing over 1,100 patents, reflecting the growing overlap between deep tech and biopharmaceutical innovation. ANALOG DEVICES, with expertise in signal processing and sensing technologies, rounds out the list. Overall, the data reflects and confirms the cross-sector nature of deep tech. Moreover, it is worth mentioning that neither academic/research institutions not government organizations figure among the most patent-intensive organizations, reflecting the key role of the private sector.

Table 4. Patent intensive organizations.

Organization	Number of patents
Koninklijke Philips	45010
Valeo	13928
Zhejiang Shaoxing Supor	5745
INVENTIO AG	4600
ARM LIMITED	3848
SIEMENS (Mobility + Medical)	3997
ADVANCED RISC MACH LTD	2136
AVL LIST GMBH	1748
HELLA	2107
CLARION	1546
ANALOG DEVICES	1117
MedImmune	1169
IBM	1664

5. Discussion

This study aimed to provide a comprehensive, data-driven exploration of deep tech innovation through a patent-based lens. By analyzing over 138,000 granted patents published between 2015 and 2025 across

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*
Corresponding Author: Fulvio Iavernaro
Email: fulvio.iavernaro@poliba.it

Europe and beyond, the paper offered a detailed picture of the evolution, geographical distribution, and organizational drivers of deep tech. Using annual patent counts, forward citations, and international patent family data, we tracked the growth trajectory of critical technologies such as AI, robotics, quantum computing, and industrial automation—highlighting not only where innovation is happening, but also who is leading it and in which domains.

Our findings confirm the rapid and sustained growth of deep tech innovation, particularly since 2010. Engineering and Industrial Technologies emerged as the most patent-intensive field, followed by Information and Communication Technologies and Biotechnology. Geographically, North America—especially the United States—leads in both patent quality and global reach, as measured by citation impact and international patent coverage. Asia, with China and Japan at the forefront, dominates in volume but shows more modest citation performance, suggesting a quantity-over-quality orientation. Europe, while maintaining a steady presence, lags behind in both influence and output, especially when compared to its global peers. At the organizational level, private firms overwhelmingly dominate the patent landscape, with companies such as Philips, Valeo, and IBM emerging as major contributors. Public research institutions and universities appear underrepresented in terms of volume but gain prominence when patents are ranked by impact, indicating their significant—if less visible—role in shaping foundational knowledge.

From a theoretical perspective, this study contributes to the emerging literature on deep tech by providing one of the first large-scale empirical analyses based on patent data. In doing so, it not only reinforces the value of patents as indicators of technological development but also demonstrates how deep tech can be conceptualized as a converging set of general purpose technologies (GPTs). The observed disparities across regions and domains shed light on the different innovation models at play—ranging from incremental industrial improvements to foundational scientific breakthroughs. These findings help scholars better understand where deep tech innovation is accelerating, which areas may require further basic research, and how cross-domain technological synergies are evolving.

For managers, the growing trend in patenting activity, especially since 2010, confirms that deep tech is not just a scientific endeavor but a commercially relevant frontier. The fact that the vast majority of patents are owned by private organizations underscores the increasing strategic importance of deep tech for business competitiveness. However, given that this trend is still relatively recent, there remains space for new entrants—though time may be limited due to the rapid pace of innovation. Firms seeking to enter or expand in this domain should also be aware of the regional concentration of high-impact innovation. The overwhelming dominance of U.S.-based organizations suggests that North America may serve as a key source of technological knowledge, competitive intelligence, and potential collaboration. Meanwhile, European firms may consider leveraging transatlantic partnerships to accelerate their own capabilities.

In terms of strategic decision-making, managers should carefully examine not only which technologies are patent-intensive, but also which are high-impact. For instance, some domains—such as Biotechnology and "Other" specialized technologies—show significantly higher average citation rates, indicating stronger technological influence. This suggests that even fields with fewer patents may hold disproportionate innovation value. Additionally, the underrepresentation of stand-alone technologies such as display, tracking, and user interfaces suggests either high entry barriers or technological maturity. These could represent saturated markets or areas ripe for radical innovation—an important distinction for R&D strategy.

From a policy perspective, the findings point to a series of actionable insights. First, while European policymakers have increasingly recognized deep tech as a strategic priority, the continent's innovation performance remains modest when benchmarked against the U.S. and parts of Asia. This calls for stronger investment in deep tech R&D, enhanced support for university–industry collaboration, and incentives for scaling up science-based startups. Encouragingly, when patents are ranked by their influence, universities begin to emerge as key players—suggesting untapped potential in academic research that could be better integrated into industrial innovation pipelines.

Second, the disparities across regions highlight the need for differentiated policy approaches. For Europe in particular, catching up may require not only increased public funding but also structural efforts to internationalize innovation and attract top global talent. Facilitating knowledge flows through international co-patenting, cross-border projects, and harmonized intellectual property frameworks may help bridge the gap. At the same time, fostering deeper collaboration between academia and industry could mitigate the risk of technological lock-in, a common problem when firms focus only on near-term incremental improvements.

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*
Corresponding Author: Fulvio Iavernaro
Email: fulvio.iavernaro@poliba.it

Lastly, while patent data provide valuable insights into technological trends, they also come with limitations—especially in terms of geographical bias. Since our data rely on granted patents, primarily within the European ecosystem and global filings visible through the Orbis IP database, some underreporting from emerging economies or non-English-speaking regions may occur. Future research could address this by incorporating PCT or triadic patent families to capture a more balanced global view.

In conclusion, this study advances our understanding of deep tech by mapping its empirical contours and revealing the drivers behind its rise. The theoretical, managerial, and policy implications drawn from this work suggest that deep tech is more than a buzzword—it is a structural shift in how innovation is generated, protected, and commercialized. Sustained attention to its evolution will be critical for staying ahead in the next wave of technological transformation.

Funding:

This work has been supported by the project "#DeepSouth – un nuovo Ecosistema dell'Innovazione per il Mezzogiorno" funded by MUSA - Multilayered Urban Sustainability Action - project, funded by the European Union - NextGenerationEU, under the National Recovery and Resilience Plan (NRRP) Mission 4 Component 2 Investment Line 1.5: Strengthening of research structures and creation of R&D "innovation ecosystems".

References

Abbas, A., Zhang, L., & Khan, S. U. (2014). A literature review on the state-of-the-art in patent analysis. *World Patent Information, 37,* 3–13. https://doi.org/10.1016/j.wpi.2013.12.006

Abraham, B. P., & Moitra, S. D. (2001). Innovation assessment through patent analysis. *Technovation, 21(4),* 245–252. https://doi.org/10.1016/S0166-4972(00)00040-7

Albino, V., Ardito, L., Dangelico, R. M., & Petruzzelli, A. M. (2014). Understanding the development trends of low-carbon energy technologies: A patent analysis. *Applied Energy, 135,* 836–854. https://doi.org/10.1016/j.apenergy.2014.08.012

Ardito, L., Messeni Petruzzelli, A., Albino, V., & Garavelli, A. C. (2020). Unveiling the technological outcomes of microgravity research through patent analysis: Implications for business and policy. *IEEE Transactions on Engineering Management, 69(6),* 3848–3859. https://doi.org/10.1109/TEM.2020.3003890

Bellavitis, C., Tran, M. H., & Wiklund, J. (2025). Strategic pivoting in deep tech: An investigation of NSF I-Corps teams. *Strategic Change, 34(2),* 305–313. https://doi.org/10.1002/jsc.2755

Bova, F., Goldfarb, A., & Melko, R. G. (2021). Commercial applications of quantum computing. *EPJ Quantum Technology, 8(1),* 2. https://doi.org/10.1140/epjqt/s40507-020-00091-1

Brin, D. (2022). *Convergence: Artificial intelligence and quantum computing: Social, economic, and policy impacts.* John Wiley & Sons.

Breitzman, A. F., & Mogee, M. E. (2002). The many applications of patent analysis. *Journal of Information Science, 28(3),* 187–205. https://doi.org/10.1177/016555150202800301

Bresnahan, T. F., & Trajtenberg, M. (1995). General purpose technologies: "Engines of growth"? *Journal of Econometrics, 65(1),* 83–108. https://doi.org/10.1016/0304-4076(94)01598-T

Brynjolfsson, E., & McAfee, A. (2017). The business of artificial intelligence. *Harvard Business Review, 95(7),* 1–2.

Chen, Y. S., & Chen, B. Y. (2011). Utilizing patent analysis to explore the cooperative competition relationship of the two LED companies: Nichia and Osram. *Technological Forecasting and Social Change, 78(2),* 294–302. https://doi.org/10.1016/j.techfore.2010.06.014

De la Tour, A., Soussan, P., Harlé, N., Chevalier, R., & Duportet, X. (2017). *From tech to deep tech.* Boston Consulting Group.

Harhoff, D., Scherer, F. M., & Vopel, K. (2003). Citations, family size, opposition and the value of patent rights. *Research Policy, 32(8),* 1343–1363. https://doi.org/10.1016/S0048-7333(02)00124-5

Harlé, N., Soussan, P., & de la Tour, A. (2017). *What deep-tech startups want from corporate partners.* The Boston Consulting Group & Hello Tomorrow.

Hussain, M. D., Rahman, M. H., & Ali, N. M. (2024). Artificial intelligence and machine learning enhance robot decision-making adaptability and learning capabilities across various domains. *International Journal of Science and Engineering, 1(3),* 14–27.

Jiang, M., Yang, S., & Gao, Q. (2024). Multidimensional indicators to identify emerging technologies: Perspective of technological knowledge flow. *Journal of Informetrics, 18(1),* 101483. https://doi.org/10.1016/j.joi.2023.101483

Kask, J., & Linton, G. (2023). Five principles for overcoming obstacles in deep-tech startup journeys. *Journal of Small Business and Enterprise Development, 30(1),* 1–3. https://doi.org/10.1108/JSBED-06-2022-0229

Gao, X., Xia, S., Xiong, Y., Zhu, X., Ling, Y., & Cao, M. (2025). The underexplored effects of economic transition on intellectual property rights protection: An economic geography perspective. *Scientometrics.* Advance online publication. https://doi.org/10.1007/s11192-025-05123-4

Gollin, M. A. (2008). *Driving innovation: Intellectual property strategies for a dynamic world.* Cambridge University Press.

Gourevitch, A., Portincaso, M., de la Tour, A., Goeldel, N., & Chaudhry, U. (2021). *Deep tech and the great wave of innovation.* Boston Consulting Group.

Grassano, N., & M'barek, R. (2025). Trends in patents in life sciences: Focus on pharmaceuticals and medical technologies. *[Publication details pending]*.

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*

Corresponding Author: Fulvio Iavernaro
Email: fulvio.iavernaro@poliba.it

Long, P. O. (1991). Invention, authorship, "intellectual property," and the origin of patents: Notes toward a conceptual history. *Technology and Culture, 32(4),* 846–884. https://doi.org/10.2307/3106155

Martino, N., Ardito, L., Messeni Petruzzelli, A., & Rotolo, D. (2025). Mapping the development of hydrogen-based technologies (HBTs) through patent analysis. *EuroMed Journal of Business, 20(2),* 493–513. https://doi.org/10.1108/EMJB-01-2024-0004

Mathew, D., Brintha, N. C., & Jappes, J. W. (2023). Artificial intelligence powered automation for Industry 4.0. In *New horizons for Industry 4.0 in modern business* (pp. 1–28). Springer International Publishing. https://doi.org/10.1007/978-3-031-33811-1_1

Nedayvoda, A., Mockel, P., & Graf, L. (2020). Deep tech solutions for emerging markets. *World Bank Group.* https://openknowledge.worldbank.org/handle/10986/34084

OECD. (2009). *OECD patent statistics manual.* OECD Publishing. https://doi.org/10.1787/9789264056442-en

OECD. (2024). *OECD agenda for transformative science, technology and innovation policies* (OECD Science, Technology and Industry Policy Papers, No. 164). OECD Publishing. https://doi.org/10.1787/ba2aaf7b-en

Ovsyannikov, I. R., & Zhdaneev, O. V. (2024). Forecast of innovative activity in key areas of energy transition technologies based on analysis of patent activity. *International Journal of Hydrogen Energy, 87,* 1261–1276. https://doi.org/10.1016/j.ijhydene.2024.02.081

Pavitt, K. (1985). Patent statistics as indicators of innovative activities: Possibilities and problems. *Scientometrics, 7(1),* 77–99. https://doi.org/10.1007/BF02020142

Peelam, M. S., Rout, A. A., & Chamola, V. (2024). Quantum computing applications for Internet of Things. *IET Quantum Communication, 5(2),* 103–112. https://doi.org/10.1049/qtc2.12054

Perelmuter, G. (2021). *Present future: Business, science, and the deep tech revolution.* Greenleaf Book Group.

Rahimi-Midani, A. (2023). Deep tech practices in aquaculture. In *Deep technology for sustainable fisheries and aquaculture* (pp. 17–60). Springer Nature Singapore. https://doi.org/10.1007/978-981-99-6999-3_2

Romme, A. G. L., Bell, J., & Frericks, G. (2023). Designing a deep-tech venture builder to address grand challenges and overcome the valley of death. *Journal of Organization Design, 12(4),* 217–237. https://doi.org/10.1007/s41469-023-00148-0

Tubke, A., Evgeniev, E., Gavigan, J., Compano, R., & Confraria, H. (2023). *Leveraging the deep-tech green transition & digital solutions to transform EU industrial ecosystems* (JRC133774). European Commission, Joint Research Centre. https://doi.org/10.2760/038583

Vyatkin, V. (2013). Software engineering in industrial automation: State-of-the-art review. *IEEE Transactions on Industrial Informatics, 9(3),* 1234–1249. https://doi.org/10.1109/TII.2013.2258165

Zahid, J. I., Ferworn, A., & Hussain, F. (2025). Framework for integrating robotics, artificial intelligence, quantum computing, and sixth generation mobile networks. In *Automation, robotics & communications for Industry 4.0/5.0* (p. 218). Springer. https://doi.org/10.1007/978-3-031-52646-4_16

International Journal of Business Management and Finance Research
Vol. 8, No. 6, pp. 32-43
2025
DOI: *10.53935/2641-5313.v8i6.529*
Corresponding Author: Fulvio Iavernaro
Email: fulvio.iavernaro@poliba.it