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The Knowledge Economy and Innovation: A Glance at Their Relationship

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Abstract

This paper offers a conceptual review of the relationship between the knowledge economy and innovation, challenging simplistic, linear assumptions about how new ideas are generated. Given their increasing global significance, the study focuses on Fourth Industrial Revolution (4IR) technologies. Specifically it examines the nature, evolution, and defining features of the knowledge economy. Such an economy relies on increasing specialization, research, innovation, and continuous learning, with learning and experience being its most critical sources. Furthermore, the paper argues that innovation constitutes a fundamental dimension of the knowledge economy, noting that knowledge production is strictly related to innovations. Rather than a sequential chain, innovation is presented here as a complex, systemic process characterized by multiple feedbacks and loops.

This analysis highlights the systemic, non-deterministic nature of innovation and its strong relationship with knowledge. However, the capacity of companies to innovate depends heavily on the innovation ecosystem—the framework where stakeholders interact and collaborate—as well as the regulatory and legislative framework. Consequently, several factors, including the availability of sufficient human capital with appropriate education and advanced skills, the presence of robust infrastructure, and the role of institutions, are necessary to make companies' innovations effective. While this paper does not claim to provide definitive answers, it seeks to offer new insights for future research.

Keywords: knowledge economy, knowledge, learning, networks, innovation, technological progress, competitiveness

JEL Classification: D83, L01, O30, O32

1. Introduction

Knowledge—specifically scientific and technological expertise—and broader intangible factors play a critical role in shaping the complex transformation of companies and economies. This paper highlights the importance of the relationship between the knowledge economy and innovation, emphasizing that new ideas follow non-linear paths and noting the critical role of institutional credibility. Moreover, it focuses on Fourth Industrial Revolution (4IR) technologies, both due to their increasing global significance and the fact that patenting is more prevalent and measurable within this sector. In this context, innovation is viewed as a systemic process characterized by multiple feedback loops.

After establishing a clear methodology, this study examines the nature, evolution, and defining features of the knowledge economy through a review of relevant literature. This economic framework relies on increasing specialization, research, and continuous learning, as value creation and growth stem primarily from knowledge-driven sectors. Furthermore, innovation is a cornerstone of this economy, often fostered by scientific networks and effective innovation ecosystems where stakeholders collaborate to exploit Research and Development (R&D). This encompasses not only technological breakthroughs but also design, marketing, and organizational change. Consequently, technological evolution lies at the heart of business reorganization, driving competitiveness, sustainability, and resilience.

A company's capacity to innovate presupposes the availability of human capital with advanced skills and robust infrastructure (e.g., electricity and ICT frameworks like data centres). Such infrastructure enables the diffusion of emerging technologies, including cloud computing and artificial intelligence. Moreover, the institutional dimension is paramount; the regulatory framework and business environment shape the incentives and constraints of innovation. Finally, market sophistication—including credit availability, investment depth, and competitive intensity—represents an essential enabling condition.

The paper also provides a descriptive statistical analysis of patents related to Fourth Industrial Revolution (4IR)

technologies as a proxy for innovation activity. By examining U.S. patents from 2020 to 2024, the study sheds light on innovation trends in a dynamic global economy. Ultimately, this work aims to deepen the understanding of how knowledge and innovation strengthen corporate competitiveness and provide insights for future research. A discussion and conclusion conclude the paper.

2. Methodology of the Study

This study employs a descriptive-analytical methodology to investigate the evolution of the knowledge economy. The research is structured into two primary phases: A qualitative conceptual review and a quantitative descriptive analysis.

A systematic review of relevant literature is conducted to analyze the innovation ecosystem as a fundamental pillar of the knowledge economy, accounting for institutional and infrastructural dimensions. In addition, to illustrate emerging trends, the study utilizes official patent data from 2020 to 2024 sourced from the United States Patent and Trademark Office (USPTO). While patents are widely used proxies for innovation, they are imperfect. Given this paper's emphasis on broader forms of innovation—such as organizational change, marketing, and design—patent data inevitably overlooks key areas. For instance, service-sector "soft innovations," such as superior customer experience protocols, can revolutionize a business yet are rarely patentable. Similarly, process improvements in SMEs are often incremental; for these firms, the cost and time required to file a patent often outweigh the benefits, leaving such advances absent from official records. Furthermore, organizational change does not constitute an "invention" in the legal sense, and marketing innovations focus on perception and reach—elements patents do not capture. Finally, while design is occasionally protected by "design patents," the functional innovation driving those designs often remains unrecorded. To address these gaps, this analysis focuses on Fourth Industrial Revolution (4IR) technologies. Because patenting is more prevalent and measurable within this sector, it provides a reliable lens—despite the general flaws in patent data—through which to highlight the empirical link between knowledge acquisition and innovation output. By synthesizing theoretical frameworks with recent patent data, the paper offers fresh insights into organizational transformation and serves as a reference for future academic inquiry.

3. Literature Review on the Knowledge Economy

As Schilirò (2009) argues, the factors determining the success of firms and national economies are more dependent than ever on the capacity to create and use knowledge. The reference definition of the knowledge economy is the one provided by the OECD (1996), which states that a knowledge-based economy is one in which the production, distribution, and use of knowledge are the primary drivers of growth, wealth creation, and employment for all industries.

The knowledge economy, or knowledge-based economy (KBE), is qualitatively distinct from the industrial economy. While the industrial model relies on natural resources and physical labor as key factors of production and derives competitive advantage from sources such as lower labor costs and superior machinery, the KBE takes a fundamentally different approach. As the literature consistently highlights (e.g., Yue, 2001; Harris, 2001; Foray, 2004; Powell & Snellman, 2004; Smith, 2002; Schilirò, 2022a, Hawamdeh, Kim, & Wang, 2023; Diessner et al., 2025; Tight, 2025), the KBE is grounded in the idea that people, their knowledge, and their intellectual capabilities are the primary sources of wealth and opportunity. Economic value is therefore generated through the creation, production, distribution, and consumption of knowledge and knowledge-based goods (Harris, 2001; Foray, 2004).

Lundvall (2004) emphasizes that knowledge-based economies also rely on increasing specialization, research, innovation, and learning. At the core of this model lies human capital, which includes investments in the production and dissemination of knowledge—such as education, vocational training, research and development, and information—as well as investments in maintaining the physical well-being of people, such as healthcare spending. Consequently, the knowledge-based economy prioritizes investments in human capital and knowledge creation over investments in physical or material capital. In fact, according to Powell and Snellman (2004), a characteristic of the knowledge economy, is an increasing relative share of the gross domestic product (GDP) that is attributable to intangible capital. Intangible capital is made up of intangible assets, which are non-material and non-physical assets, such as R&D, patents, trademarks, copyrights, brands, employee skills, discoveries of new products or processes, software programs, new ideas, and new processes used in the organization. As Schilirò (2012) argues this shift has had a profound impact on the global economy. The transition to the knowledge economy requires focusing on innovation and addressing inequality. Choi et al. (2020) claim that a policy based on social investment is most appropriate, especially in upper- and upper-middle-income countries around the world, given that the combination of technological advances, demographic changes, and globalization has put pressure on labor markets and exacerbated inequality. However, the expansion of the knowledge economy is not restricted to developed economies; emerging markets are progressively acknowledging the importance of nurturing knowledge-driven industries.

Diessner et al. (2025) observe that the term "knowledge economy" has (implicitly or explicitly) been used

interchangeably with other—closely related but arguably distinct—terms, including cognitive capitalism, digitalization, and the digital economy. Indeed, the digital economy and digital transformation occupy a central position in facilitating the KBE. The widespread adoption of the internet, big data, artificial intelligence (AI), and cloud computing has unveiled new pathways for innovation and business expansion. Companies that capitalize on these technologies are acquiring a competitive advantage by optimizing operational efficiencies, enriching customer experiences, and devising state-of-the-art products and services.

A KBE is built on four fundamental pillars, as exemplified by the World Bank (Chen & Dahlman, 2006): an economic incentive and institutional regime, educated and skilled workers, an effective innovation system, and a modern and adequate information infrastructure. Thus, these four elements—education and training, innovation, information technology infrastructure, and a sound institutional framework—form the foundation of the KBE (Schilirò, 2012). In such economies, the diffusion of scientific and technological knowledge is key, propelling both qualitative and quantitative transformation and evolution. Additionally, networks, both inside organizations and inter-organizational, play a crucial role. They are the source of intellectual capital and have deep implications for knowledge creation and sharing by facilitating the generation and diffusion of knowledge and significantly influencing innovation (Cross et al., 2003; Schilirò, 2009; Skrzypek, 2016).

Furthermore, as El-Farr and Kertechian (2024) underscore, in the knowledge economy, products and services are characterized by rapid obsolescence. Consequently, the speed of knowledge creation, innovation, and dissemination, as well as the widespread use of knowledge within organizations—along with other knowledge-intensive activities—are more important to organizational competitiveness than any other resource. In this economy, the quality of knowledge embedded in workers, along with their willingness to share knowledge and ability to create it, has become more important than financial or physical resources for achieving competitive advantage.

Harris (2001) argues that historically, the knowledge economy emerged with the post-industrial economy and the onset of the Third Industrial Revolution, driven by the potential of new information technologies. The importance of knowledge, learning, skills, specialization, design, and innovation capabilities has since grown significantly. These factors have become even more critical with the advent of the Fourth Industrial Revolution (4IR), caused by the development of several general-purpose technologies (GPTs), which infuse the physical world with the digital and biological (El-Farr & Kertechian, 2024). The 4IR is characterized by digital technologies such as the Internet of Things (IoT), cyber-physical systems (CPS), additive manufacturing, digital twins, digital platforms, cloud computing, Big Data, AI, intelligent robots, and blockchain, among others (Schilirò, 2022; Cho et al., 2023). In this digital environment, technological dynamics, fueled by the diffusion of scientific and technological knowledge, are central to processes of transformation and qualitative evolution, ultimately shaping companies' ability to compete in the marketplace (Schilirò, 2009). Ivaldi et al. (2021) highlight the relevance of the 4IR also in the context of the knowledge economy. This revolution demands new competencies in workplaces characterized by innovation and emerging skill models, where organizational learning processes play a key role in shaping new work cultures. However, the disruption caused by digital technologies places many traditional roles at risk. While the most visible effect may be a reduction in total employment, technologies such as AI are fundamentally transforming the nature of work and reshaping the entire organization of companies (Schilirò, 2023). Furthermore, as capital concentrates and AI-driven productivity gains rise, there is a growing risk of skill and income polarization alongside the transformation of work.

At the same time, the importance of knowledge in achieving a competitive advantage has been increasing exponentially. As El-Farr and Kertechian argue (2024), the era of digitalization is marked by exponential growth in data volume, speed, and diversity, and harnessing this data for knowledge extraction is invaluable. This extracted knowledge is not only shareable but also serves as a powerful catalyst for innovation. Therefore, effective knowledge management is essential.[1]

It is essential to clarify specific aspects of knowledge. In the digital economy, producing and reproducing knowledge is a far more costly process than handling information, as cognitive abilities are not easily made explicit or transferred to others. Consequently, some of the knowledge possessed by individuals remains unrevealed and is therefore tacit. Tacit knowledge refers to forms of personal knowledge that are uncodified and do not fall within the category of information. Codification, however, plays a crucial role in the knowledge economy, as it facilitates memorization, communication, and learning, while also providing a valuable foundation for the creation of new knowledge tools.

Another issue concerns the nature of knowledge as a good. David and Foray (2003) highlight the tendency toward excessive privatization of intellectual property rights, which can restrict access to information in areas where new

[1] Some scholars (e.g., Neef, 1999; Alavi & Leidner, 2001; Hislop, 2006) present knowledge management as a system or strategy with supporting processes to flourish knowledge-intensive activities within a firm.

knowledge has largely remained in the public domain—such as basic research, the natural sciences, and software. This privatization, they argue, creates a mechanism of artificial scarcity in sectors where abundance would otherwise prevail. According to David and Foray (2003), knowledge is not like other types of goods. Intellectual property cannot be equated with physical property, because knowledge and information possess a specific characteristic that economists call nonrival in use. This means that their use by one person does not preclude simultaneous use by others. Furthermore, the allocation of property rights for information goods does not typically confer exclusive ownership. Instead, the assignment and creation of intellectual property rights grant a monopoly over the economic exploitation of an idea (as in the case of patents) or a specific mode of disseminating an idea (as in the case of copyright), which is thereby made public. This mechanism allows for the organization of a market for such rights. A positive aspect of commercializing intellectual property is that it prevents ideas and discoveries from remaining the exclusive domain of the inventors, who may not be interested in disseminating them for the benefit of society. However, the creation of monopolies is not a perfect solution, as it can lead to resource inefficiencies.

Moreover, there appears to be insufficient empirical evidence demonstrating how altering legal conditions and property rights—which implies modifying the institutional framework—produces effective results for producers, such as in the case of incentive policies. One thing, however, seems certain: institutions play a crucial role in the knowledge economy. They reduce uncertainty and provide stability by offering institutionalized knowledge in the context of often incomplete and asymmetric information (Schilirò, 2012). Patterns of innovation do not emerge out of thin air; they emerge from the institutional context and are historically dependent. Kostiainen and Sotarauta (2003) underscore that to promote a knowledge-based economy, it is not enough for institutions to merely exist; they must also be strong, credible, and stable. Furthermore, universities and research centers play a key role in favoring knowledge development and diffusion, as well as the growth of the knowledge economy, by influencing innovation capacity (McKelvey et al. 2018). The creation of sustainable institutions is, therefore, a prerequisite; the development of a knowledge-based community relies heavily on both institutional structures and human capital.

To summarize the characteristics of a knowledge economy, as heighted in the literature:

i. Knowledge as a factor of production and wealth generation.
ii. A fundamental shift in investment toward the creation and exploitation of knowledge and other intangible assets—such as R&D, software, design, development, and human and organizational capital—as the basis of competitive advantage.
iii. The presence of cheap, powerful, and pervasive general-purpose information and communication technologies.
iv. The establishment of knowledge-based industries and knowledge-related occupations.
v. The growing importance of learning, with interactive learning as a key driver of the economic performance of firms, regions, and nations.
vi. The central role of innovation, arising both from the successful exploitation of R&D and from broader forms of innovation such as design and development, marketing, and organizational change. Moreover, increased collaboration and open innovation are also crucial.
vii. The extremely important role of universities and the higher education sector as economic actors, not only in attracting and retaining R&D but also as agents of knowledge diffusion and regeneration. In a knowledge-based economy, their role as providers of human capital and drivers of innovation is more crucial than ever.

In conclusion, the evolution of the knowledge economy and the technological progress embedded in it has determined that knowledge is now an infrastructure. This creates huge opportunities, but there are risks. One is the polarization of the ownership of useful knowledge. The other is related to who will have the right to use it.

4. Innovation and Knowledge: Their Relationship

As argued in the previous section, a fundamental characteristic of the knowledge economy is the central role of innovation. This section will deepen the understanding of the relationship between the knowledge economy and innovation, assuming a non-linear approach to how new ideas are generated. In a broad sense, innovation refers to the application of knowledge to create new or improved products, services, or processes. It involves not only the generation of new ideas but also their implementation in practical contexts.

Contemporary innovation activity relies on collaborations between enterprises, driven by the dynamics of knowledge and capabilities in a context of intense competition. Consequently, a major development in innovation analysis is the recognition that innovations are not the outcome of a single individual (i.e., the entrepreneur) but increasingly result

from teamwork (Bruland & Mowery, 2009). Thus, innovations are fostered by networks within the scientific community and arise from research activities, learning, and the successful exploitation of R&D. Fagerberg (2005) also emphasizes that innovating companies are able to learn from interactions with external sources. Therefore, the ability to absorb external knowledge—referred to as absorptive capacity by Cohen and Levinthal (1990)—is essential for innovative companies.

The concept of the innovation ecosystem has been widely used and become popular in innovation studies. According to this approach (Granstrand & Holgersson, 2020; dos Santos et al., 2023; Baldwin et al., 2024; Cui et al., 2024; Sotirofski, 2024), innovations emerge within ecosystems where diverse stakeholders—including research institutions, entrepreneurs, corporations, investors, and governments—form a strong social fabric characterized by mutual interest, complementary resources, and trust. These ecosystems facilitate collaboration, knowledge sharing, and technological advancement among businesses.[2] Therefore, establishing a strong innovation ecosystem that engages all stakeholders is essential (Schilirò, 2022a).

To actively support innovation, well-designed strategies are also required. Companies must develop coherent innovation strategies that address both the complexities and opportunities of disruptive innovation (Bogetoft et al., 2024).

Moreover, Leydesdorff et al. (2013), Kline (1985), and Fagerberg (2005) contend that innovation does not follow a linear model, arguing that this model overlooks the numerous feedback loops that occur between the different stages of the innovation process. Therefore, innovation is not just driven by science (push) or the market (pull); it's driven by the constant "feedbacks and loops" between all stages and all players (R&D, manufacturing, design, users, suppliers, etc.)

Despite the strong relationship between the knowledge economy and innovation (as previously discussed), innovation is not a recent phenomenon and pre-dates its development (Fagerberg, 2005). This interplay between knowledge and innovation necessitates collaboration among different players and the integration of diverse perspectives and expertise, significantly enhancing companies' innovative capacity. Competitive companies are those able to translate new knowledge and technological advancements into broader forms of innovation, including design and development, marketing, and organizational change.

Stimulating innovation in a knowledge economy necessitates investment in both human capital and emerging technologies. Human capital encompasses investments in the production and dissemination of knowledge (including education, vocational training, research and development, and information) as well as investments that support the physical well-being of individuals, such as healthcare spending. This form of capital is considered indispensable for introducing the technological and organizational innovations on which factor productivity depends. Additionally, a knowledge and innovation-driven economy requires concurrent investment in emerging technologies and key sectors such as semiconductors, AI, and renewable energy.

Furthermore, the knowledge production process underpins Endogenous Growth Theory (Romer, 1986). Romer's original theoretical contribution posits that knowledge constitutes a new basic form of capital. Within this theoretical framework, knowledge dynamics underscore the role of both human and physical capital accumulation in driving innovations.

According to von Hippel (1988) and Lundvall (1988), learning and experience are among the most important sources of innovation. Lundvall (1988), in particular, emphasizes innovation as an interactive process, whose implications have theoretical and practical problems that differ from those in mainstream economic theory. In his view, decisions are not made on the basis of a fixed amount of information; rather, by focusing on the process of learning, decisions are made in response to the continually changing quantity and nature of information available to the actors. Similarly, Kline and Rosenberg (1986) argue that firms tend to innovate primarily in response to perceived commercial needs.

A critical condition for innovation to flourish is the presence of adequate infrastructure. Innovation relies heavily on such infrastructure. Mowery and Rosenberg (1998) emphasize that many of the most significant industrial innovations depended on substantial infrastructural investments. These investments must often be accompanied by radical changes in the organization of production and distribution. This is particularly true for digital infrastructure, including data centres, which support the adoption of emerging technologies such as cloud computing and artificial intelligence (Schilirò, 2022). Empirical evidence (e.g., Zheng et al., 2025) shows that digital technologies positively influence businesses' radical innovation. Consequently, digital technologies and the underlying knowledge processes play a

[2] Cui et al. (2024) note that the conceptual framework of innovation systems has undergone a significant evolution, transitioning from the 1.0 linear innovation paradigm characterized by closed innovation, through the 2.0 innovation system paradigm marked by open innovation, to the 3.0 innovation ecosystem paradigm that emphasizes embedded and symbiotic innovation.

crucial role in enhancing business innovation. This implies that innovation processes necessitate profound organizational and technological transformations. The overarching objective of enterprises investing in innovation is to maximize the value derived from resources allocated to research and innovation-related activities. Achieving this objective requires enterprises to strategically integrate research, finance, and innovation, while simultaneously cultivating collaborative networks with universities, research centres, and other companies to facilitate the development and diffusion of novel innovations.

Banmairuroy et al. (2022) argue that innovation is a key explanatory factor behind differences in firm performance and serves as an indicator of a firm's competitiveness. Innovation is therefore a key driver of business development, competitiveness, and long-term sustainability. Furthermore, innovation can enhance operational efficiency, reduce costs, and lead to the development of groundbreaking products and services that capture market share (Johansen and Isaeva, 2021; Boly et al., 2022). In a knowledge economy, however, education and the quality of human capital also play a fundamental role, alongside modern information and communication infrastructure.

Finally, numerous scholars emphasize that innovation is not only about quantitative aspects but, above all, about qualitative ones, namely, the quality of innovation. This quality can be measured by indicators such as university performance, the relevance of academic publications, and the international scope of patent applications. The innovation literature often uses patents as a reliable and meaningful measure of innovation performance. However, most studies have relied solely on the number of patents as a crude indicator of innovation success, failing to provide insights into the quality of innovation (Marku, 2018).

Since the pioneering study by Griliches (1990), patents have been widely used as a measure of innovation efforts. The growing availability of patent data on a global scale has further facilitated research on innovation. Citation data and innovation surveys have emerged as important complementary sources for assessing innovation outcomes. However, the literature has developed numerous indicators to evaluate innovations. For example, Dziallas and Blind (2019), in their review, identify approximately 82 unique indicators and factors for assessing innovations. Their analysis reveals that process-related indicators are more prevalent than product-related ones in the literature. Furthermore, publications highlight both qualitative and indirect indicators. Nevertheless, the literature largely overlooks innovation indicators applicable to the early stages of the innovation process.

4.1 Patents as Indicator of Innovations

Regarding patents as indicators of innovation—or, more precisely, as imperfect indicators as discussed in the methodology section—we can examine U.S. patenting activity related to Fourth Industrial Revolution (4IR) technologies over the five-year period from 2020 to 2024. Overall, U.S. patent activity remains substantial: the USPTO recorded approximately 324,042 granted patents in 2024, representing a roughly 3.8% to 4% increase over 2023.[3] In particular, AI-related patents have grown explosively in the U.S. over the five years. The USPTO's 2023 AI-patent dataset (AIPD 2023) indicates that over 200,000 patent documents in 2023 are predicted to involve AI. Furthermore, computer/digital data technologies represent a dominant signal of the Fourth Industrial Revolution. In fact, computing and digital data processing CPC codes rank among the top technology classes and account for a substantial share of filings, with computer technologies comprising approximately 12% of global filings and exhibiting strong growth since 2012.

Among the 4IR fields exhibiting the largest patent growth:

- AI, machine learning, computer vision, and NLP lead the pack, showing the fastest growth among 4IR fields.
- Semiconductor, chip, and computing hardware patents, which support AI acceleration, are also prominent.
- IoT and robotics remain large and steadily expanding categories, with IoT patenting closely tracking the growth of connected devices and robotics showing notable growth in AI-robotics combinations.

Patent filing remains a signal of strategic investment in AI-stack, edge devices (IoT), robotics control, and battery/energy tech. US portfolios often emphasize enduring/value patents even if total filing growth is outpaced by other countries. Alos, it is worth noting that corporate leaders in U.S. patent grants and applications continue to include major technology and semiconductor firms, such as Samsung, TSMC, Qualcomm, and Nvidia, along with large U.S. tech companies, with contributions from Asian firms in U.S. filings steadily increasing.

Table 1 shows the number of US AI-related patents filed by year for the period 2020–2024.

[3] However, the unexamined applications reached a significant peak of over 800,000 in 2024. This supports the argument about patent data being an imperfect or lagging proxy; in fact, a technology innovated in 2022 might only appear in these 2024 figures due to examination delays.

Table 1. US AI-related patents documents by year (2020-2024)

Year	AI-related USPTO documents
2020	31, 200
2021	33,100
2022	34,800
2023	40,200
2024	42,200

Source: USPTO — Artificial Intelligence Patent Dataset (AIPD)[4]

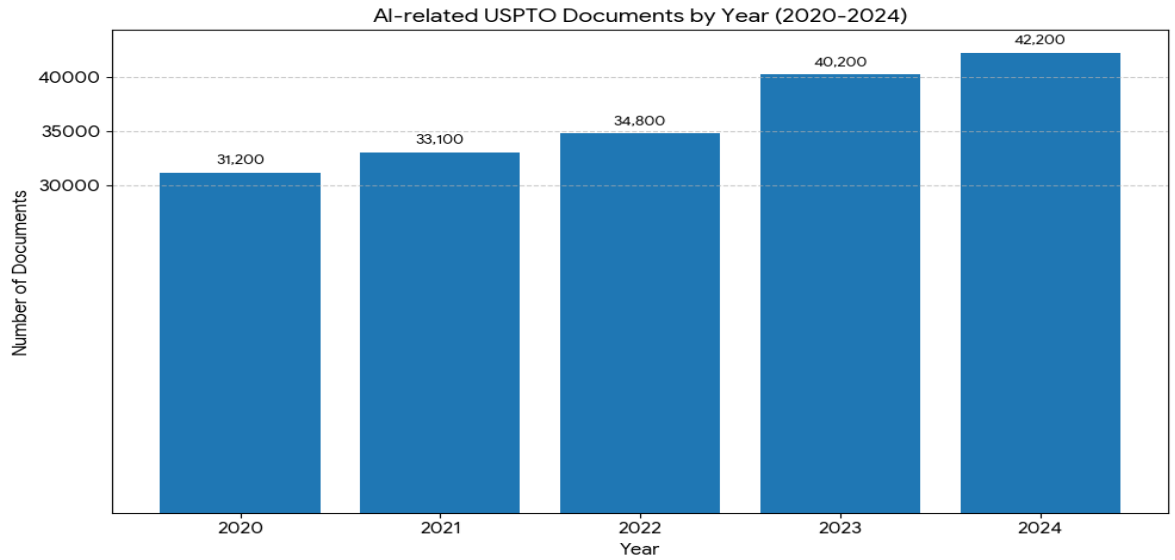

Figure 1

Source: elaboration of data from Table 1

Figure 1 visualizes the data from Table 1 in the form of histograms. Table 1 and the corresponding Figure 1 underscore the significance of AI in driving innovative activity. This data shows a substantial increase in AI-related patents in the U.S. over the five-year period analyzed, indicating rapid year-over-year growth in AI patent filings. This growth indicates the strong dynamism of US corporations in AI, especially in microprocessors for GenAI and data centers. This trend is explained by the record investment in R&D, which in 2023 for the country was equal to $940 billion, driven largely by the private sector.

[4] Retrieved October 8, 2025, from https://www.uspto.gov/ip-policy/economic-research/research-datasets/artificial-intelligence-patent-dataset

5. Discussion and Conclusion

This paper examines the knowledge economy, focusing on its relationship with innovation while highlighting its evolution and defining features. It emphasizes that the knowledge economy depends on increasing specialization, research, innovation, and continuous learning, while underscoring the key role of institutions. The analysis demonstrates that innovation is not only a fundamental dimension of the knowledge economy but also a key driver of competitiveness, sustainability, and the transformation of production systems. A firm's innovative capacity depends on multiple interrelated factors, including the availability of a well-educated and highly skilled workforce, robust physical and digital infrastructure, and a supportive institutional and regulatory framework.

The study emphasizes that innovation is not a linear process but presents multiple feedbacks and loops. Furthermore, the importance of the innovation ecosystem is underscored, where interactions and collaborations among stakeholders—firms, research institutions, and policymakers—play a critical role in fostering technological and organizational innovation. Moreover, the sophistication of markets, encompassing financial resources, investment dynamics, and competitive intensity, further enables the realization and diffusion of innovative activities.

The descriptive analysis of U.S. patents related to Fourth Industrial Revolution technologies, particularly those involving AI, from 2020 to 2024 confirms the growing significance of innovation as a tangible indicator of knowledge-based economic activity. These findings collectively underscore that sustaining innovation requires a holistic approach, integrating human capital development, technological infrastructure, institutional support, and market dynamism.

In conclusion, innovation remains the cornerstone of the knowledge economy, determining firm-level success and driving broader economic transformation. The critical relationship between the knowledge economy and innovation, as highlighted in this study, is pivotal and warrants further exploration. Consequently, this topic represents an essential avenue for future research.

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Data sharing statement

No additional data are available.

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