Knowledge economy and innovation

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Abstract

This paper presents an examination of the knowledge economy, its nature, evolution, and defining features. Such an economy relies on increasing specialization, research, innovation, and continuous learning. Innovation constitutes a fundamental dimension of the knowledge economy; hence, it emerges as the second central theme of this analysis. The findings indicate that the capacity of companies to innovate depends on several factors, including the availability of sufficient human capital with appropriate levels of education and advanced skills, the presence of robust infrastructure, and the role of institutions. In particular, the innovation ecosystem—where stakeholders interact and collaborate—together with the regulatory and legislative framework, serves to foster and sustain innovation.

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

JEL Classification: D83, L01, O30, O32

Introduction

Knowledge, particularly scientific and technological knowledge, and more broadly, intangible factors, plays a critical role in shaping the complex transformation processes of modern economies and companies. This paper first examines the nature, evolution, and defining features of the knowledge economy, which relies on increasing specialization, research, innovation, and continuous learning. The analysis reveals that a fundamental aspect of the knowledge economy is innovation, fostered by scientific community networks and arising both from the successful exploitation of R&D and from broader forms of innovation, such as design and development, marketing, and organizational change. Technological evolution and innovation lie at the core of business reorganization, driving competitiveness, strengthening sustainability and resilience, and contributing to the transformation

of entire production systems. A further central theme of this paper is innovation itself, which constitutes a cornerstone of the knowledge economy. The capacity for innovation presupposes the availability of sufficient human capital endowed with appropriate levels of education and advanced skills. Equally, it is contingent upon the existence of robust infrastructure: on the one hand, general infrastructure such as electricity, and on the other—and of particular salience in the contemporary context—information and communications technology infrastructure. This includes data centers and related digital platforms that not only enable technological innovation but also facilitate the diffusion and adoption of emerging technologies, such as cloud computing and artificial intelligence. Moreover, the institutional dimension is of paramount importance. The regulatory and legislative framework, together with the broader business environment, shapes both the incentives and the constraints under which innovation occurs. Finally, the sophistication of markets, encompassing the availability of credit, the depth of investment, the dynamism of trade, and the intensity of competition, represents an essential enabling condition that must not be underestimated. The paper also provides a descriptive statistical analysis of patents related to Fourth Industrial Revolution (4IR) technologies as an indicator of innovation activity. In particular, it examines patents in the U.S. over the period 2020–2024.

1. 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-based economy (KBE) is qualitatively distinct from the industrial economy. While the industrial model relies on labor as a key factor 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; Smith, 2002; Schilirò, 2016), the KBE is grounded in the idea that people, their knowledge, and their 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).

Knowledge-based economies also rely on increasing specialization, research, innovation, and learning (Lundvall, 2004). 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, a characteristic of the knowledge economy, according to Powell and Snellman (2001), there is an increasing relative share of the gross domestic product that is attributable to intangible capital. The intangible capital is made 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.

This shift has had a profound impact on the global economy (Schilirò, 2003; Schilirò, 2011). A knowledge-based economy is built on four fundamental pillars: education and training, innovation, information technology infrastructure, and a sound institutional framework (Schilirò, 2011). In such economies, the diffusion of scientific and technological knowledge, is key, propelling both qualitative and quantitative transformation and evolution. Additionally, networks play a crucial role by

facilitating the generation and diffusion of knowledge and significantly influencing innovation (Schilirò, 2009).

Furthermore, 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 (El-Farr and Kertechian, 2024). In the knowledge 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 in competitive advantage.

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 (Harris, 2001). 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, caused by the development of several general-purpose technologies (GPTs), which infuse the physical world with the digital and biological (El-Farr and Kertechian, 2024). This Fourth Industrial Revolution is characterized by digital technologies such as the Internet of Things, cyber-physical systems (CPS), additive manufacturing, digital twins, digital platforms, cloud computing, Big Data, artificial intelligence, intelligent robots, and blockchain, among others (Schilirò, 2021; Schilirò, 2022). In this new digital economy, 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). In the context of the knowledge economy, the Fourth Industrial 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 (Ivaldi et al., 2021). While the disruption caused by digital technologies introduced by the Fourth Industrial Revolution puts many jobs at risk, the most evident effect is not necessarily a reduction in the number of jobs. Rather, technologies such as AI will transform the nature of work itself and reshape the entire organization of companies (Schilirò, 2023). In this new environment, the importance of knowledge in achieving a competitive advantage has been increasing exponentially. In fact, as argued by El-Farr and Kertechian (2024), the era of digitalization is marked by exponential growth in data volume, speed, and diversity. Harnessing this data for knowledge extraction is invaluable. This extracted knowledge, in addition to being shareable, serves as a powerful catalyst for innovation. Therefore, effective knowledge management is essential.[1]

It is important to clarify certain 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. Some of the knowledge possessed by individuals remains unrevealed and 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 knowledge has largely remained in the public domain, such as basic research, the natural sciences, and software, thereby creating a mechanism of artificial scarcity in sectors where abundance would otherwise prevail. According to David and Foray (2003), knowledge

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

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*, meaning that their use by one person does not preclude 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 to modify the institutional framework, produces effective results for producers, for example with regard to 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, 2011). Moreover, to promote a knowledge-based economy, it is not enough for institutions to merely exist; they must also be strong, credible, and provide stability (Kostiainen & Sotarauta, 2003). The creation of sustainable institutions is therefore a precondition, as the development of a knowledge-based community relies particularly on institutional structures and human capital.
To summarize the characteristics of a knowledge economy (Schilirò, 2011):
i) 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.
ii) The presence of cheap, powerful, and pervasive general-purpose information and communication technologies.
iii) The establishment of knowledge-based industries and knowledge-related occupations.
iv) The growing importance of learning, with interactive learning as a key driver of the economic performance of firms, regions, and nations.
v) 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.
vi) 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.

2. Innovation and Knowledge

As argued in the previous section, a fundamental characteristic of the knowledge economy is the central role of innovation. This innovation is fostered by networks within the scientific community that develop in such an economy and arises from research activities, learning, and the successful exploitation of R&D. Competitive companies are able to translate new knowledge and technological advancements into broader forms of innovation, including design and development, marketing, and organizational change. To stimulate innovation in a knowledge economy, it is necessary to invest in human capital. Human capital encompasses investments in the production and dissemination of knowledge, particularly in education, vocational training, research and development, and

information. It also includes investments that support the physical well-being of individuals, such as healthcare spending. Human capital is therefore considered indispensable for introducing the technological and organizational innovations on which factor productivity depends.

However, innovation did not start with the so-called knowledge-based economy; in fact, it is not a new phenomenon (Fagerberg, 2005). It is important to emphasize, as Fagerberg (2005) argues, that innovation does not follow a linear model. The linear model, in fact, overlooks the many feedbacks and loops that occur between the different stages of the innovation process. Furthermore, as Kline and Rosenberg (1986) point out, firms usually innovate because they perceive a commercial need. They typically begin by reviewing and combining existing knowledge, and only if satisfactory results are not achieved do they consider investing in research. According to von Hippel (1988) and Lundvall (1988), learning and experience are considered the most important sources of innovation.

An important development in the analysis of innovation is the recognition that innovations are not the outcome of a single individual (i.e., the entrepreneur) but increasingly result from teamwork (Bruland and Mowery, 2009). Fagerberg (2005) also emphasizes that companies that innovate 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 firms. Moreover, 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 (Sotirofski, 2024). Innovations require well-designed strategies to actively support them. Companies must develop coherent innovation strategies that address both the complexities and opportunities of disruptive innovation. Establishing a strong innovation ecosystem that engages all stakeholders is essential (Schilirò, 2022a).

An important 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 centers, which support the adoption of emerging technologies such as cloud computing and artificial intelligence.

Empirical evidence shows that digital technologies positively influence firms' radical innovation (Zheng et al., 2025). Consequently, digital technologies and the underlying knowledge processes play a crucial role in enhancing firm innovation.

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

One reason innovation is important for business is that it 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 (Banmairuroy et al., 2022). 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 can be measured by indicators such as university performance, the relevance of academic publications, and the international scope of patent applications.[2] 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.

2.1. Patents as Indicator of Innovations

Regarding patents as indicators of innovation, we can examine U.S. patents 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 598,000 patent applications in 2023. 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

[2] 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).

as Samsung, TSMC, Qualcomm, and Nvidia, along with large U.S. tech companies, with contributions from Asian firms in U.S. filings steadily increasing.
The table 1 below shows the US AI-related patents by year: 2020-2024.

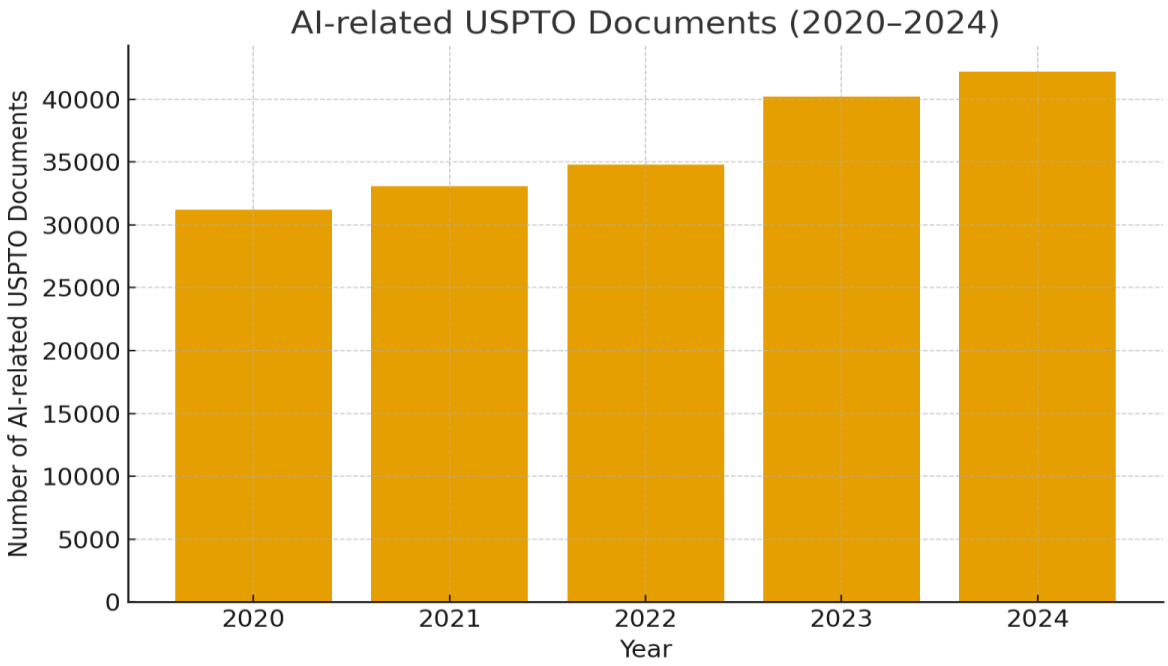
Table 1

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)*

Figure 1



Source: elaboration of data from Table 1

Figure 1 presents the data from Table 1 in the form of histograms.

Table 1 (and Figure 1) show 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. Both the table and the corresponding figure further underscore the significance of AI in driving innovative activity.

Conclusions

This paper has examined the knowledge economy, highlighting its evolution and defining features. It emphasizes that the knowledge economy relies on increasing specialization, research, innovation, and continuous learning. 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. The capacity of firms to innovate is influenced by multiple interrelated factors, including the availability of well-educated and skilled human capital, robust physical and digital infrastructure, and a supportive institutional and regulatory framework.

The study emphasizes the importance of the innovation ecosystem, 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 over 2020–2024 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 sum, innovation remains the cornerstone of the knowledge economy, shaping both firm-level success and broader economic transformation.

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