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Sustainable Digital Transformation: The Dynamics of Technology Transfer and Intellectual Property in the European Context

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Abstract

The accelerated evolution of digital technologies has transformed digital transformation from a strategic option into a structural necessity for sustainable economic growth. The purpose of this paper is to analyze the economic impact of sustainable digitalization and the role of technology transfer in fostering economic development. The study employs an exploratory research design aimed at identifying the main barriers encountered in the registration of intellectual property rights and the obstacles to technology transfer that have emerged in the aftermath of recent global crises. The analysis investigates trends in artificial intelligence adoption, e-commerce expansion, digital financial services, and the contribution of the information and communications technology sector to gross value added within the European Union, with a particular focus on Romania. The findings underscore the critical role of technology transfer and IP protection in enhancing innovation capacity, strengthening competitiveness, and ensuring economic resilience during periods of disruption. The results also highlight the need for coherent policy measures, sustained investment in research and innovation, and the continuous development of digital competencies. Ultimately, sustainable digital transformation, anchored in effective technology transfer and robust IP management, emerges as a fundamental driver of long-term economic competitiveness and sustainable development within the European context.

Keywords: Technology Transfer, Intellectual Property Rights, Sustainable Digital Transformation, Economic Competitiveness, Digital Technologies

Introduction

The rapid progress of novel digital technologies among with their adoption within diverse sectors of activity highlighted the importance of implementing digital transformation. This process has a significant importance in compelling economic growth and enhancing durable competitiveness at the national as well as at the European levels. In order to be able to consider economic transformation as being sustainable, it is necessary for it to incorporate environmental-, economic- and societal- oriented solutions in order to maintain an effective harmony. The recent period of time was marked by the occurence of considerable enhancement of fields after they implemented digital instruments. These digital technologies palyed an important role in promoting technology transfer, but they also caused challenges concerning intellectual property rights.

Digital transformation can be analyzed from two points of view: one from the benefits provided by it and the second from the perspective of the possible challenges that may appear in the process of application. A key advantage lies in its ability to increase efficiency and foster innovation. However, digital transformation also raises difficulties, such as issues regarding technology transfer (TT), the protection of intellectual property (IP),as well as the need to adapt the legal and regulatory framework at both national and European levels.

The concept of technology transfer is not new and has long been addressed in the academic literature. Bozeman (2000) highlights that the 1980s represented a defining period for its analysis. Before 1980, technology transfer was understood primarily as the movement of technology across countries, whereas after 1980 the focus shifted towards domestic transfer, i.e., the circulation of technologies within the same economy or between national entities. According to Ramanathan (1994) technology transfer or TTrepresents the action of shifting technologies between entities, with its success depending on the receiving country's or organization's capacity to implement and effectively exploit the transferred technology.

From the perspective of intellectual property (IP), this concept has a long-standing history, created to safeguard the interests of inventors over the products and ideas they develop. Today, both at national and European levels, legal frameworks ensure the protection of copyrights, patents, and trademarks (Aristodemou and Tietze, 2018). Recent studies confirm that intellectual property plays a key role in sustainable development (Roffe and Santa Cruz, 2007), contributes to innovation (Pires and Ferreira, 2025), and supports the creation of economic value (Menell et al., 2025).

The novelty of this paper derives from the results obtained through the conducted research. Thus, the study provides an integrated approach to digital transformation, technology transfer, and intellectual property, from the perspective of sustainable development. The analysis illustrates how the digitalization process facilitates the economic growth of countries and stimulates innovation. Furthermore, this paper highlights the interrelations among these processes and outlines the strategic decisions that should be undertaken in the future to foster innovation and sustainability, both at the level of the European Union member states and in Romania.

Literature Review

Technology Transfer (TT) consists of a mechanism dedicated in making knowledge, advancements and innovations accesible to everyone. Its manner of delivery consists of initiatives from education and government, technology commercialization as well as scientific papers. The technology transfer process itself is intricate and embodies various factors and stakeholders which could have an impact on its implementation. In order to asses the variety of technology that is transferrable, the economic options and the stimulation of the receptive part, feasibility studies are required to be conducted.

Additionally, TT implicates a dynamic mechanism which provides the possibility to address different perceptions of the involved agents, that unfolded with the advancement of technology. In essence, it is an activity focused on knowledge exchange that impacts numerous fields of activity from economic, academic, technological to social with the use of dedicated instruments of technology transfer.The progress of innovation is facilitated by the governments, universities, industries triple helix (Shuguang et al., 2021).

The stimulation of technology transfer can be accomplished through patents. They are used to codify specialized capabilities and provide a separation of advanced technologies in addition the obligation of exclusivity, which companies are convenient in sharing whilst negotiating a licensing agreement. Contingent upon business strategies, patent holders have an interest on transferring their innovations on varied terms on the long-run. These transfers require core competences as well as technical expertise and additional information disclosed in the patent and available for the public (Martínez-Zarzoso and Chelala, 2021).

Studies have shown the way in which patents aid organizations in performing research and development (R&D) on transfer technologies and improve the overall market performance. The public-private collaboration can play an important role in optimizing technology transfer. It can be created by joining university assistance with private commercial channels (Abramo and D'Angelo, 2021).

The TT framework can also be noticed at the educational level as well as the academia. Higher education research centers acquire researchers with interests in topics as learning and teaching foreign languages, science as well as other subjects. Different studies are accomplished in controlled laboratory settings with the scope of studying the main cognitive processes. Afterwards, the results obtained are utilized within the professional development and in the educational curriculum (Bhatnagar et al., 2022).Universities are essential to the development of new technology and answers to societal issues. However, these technologies need to be successfully introduced to the market in order to make a big difference. A comprehensive strategy that includes institutional infrastructure, strategic alliances, and robust regulations to support commercialization initiatives is necessary for successful technology transfer(Tolin and Piccaluga, 2024).

Another essential component of technology transfer strategies is the management of intellectual property. Universities need to make sure that their inventions are safeguarded by trademarks, copyrights, or patents. This procedure offers a legal framework that permits the commercialization of ideas in addition to protecting the institution's ownership rights. Establishing explicit regulations that specify ownership and commercialization rights for

researchers, professors, and the institution is essential to effective intellectual property management(Savitha and Krishnamurthy, 2022).

Strong linkages between academic institutions and industrial partners are frequently necessary for the commercialization of academic research. These partnerships can take many different forms, such as strategic alliances, spin-off businesses, licensing agreements, and cooperative research projects.

Innovation development, which has historically been linked to a company's own R&D efforts, is a crucial source of growth and profitability. However, in recent years, businesses have been progressively sourcing technology and information from outside sources.Over time, the accumulation of resources and opportunities in less technologically advanced divisions leads businesses to look for new, more creative forms or scopes of activity, ranging from R&D to processing. Due to their unavoidable complementarity and the trend toward a larger proportion of R&D in entrepreneurial activity, these kinds of procedures must be closely coordinated with the development of human resources (knowledge, experience, skills, and cooperation) (Urbinati et al., 2018).

According to Heiden and Peters (2020)an IP strategy should take into account long-term and broad factors including corporate reputation and future R&D trajectories, as well as the growth of the OI paradigm and its opportunities and hazards. Maintaining competitive advantage and controlling outbound open innovation (OI), which refers to the inside-out flows of knowledge and technology, depend on effective intellectual property (IP) management. The open innovation (OI) paradigm states that businesses should actively purchase and sell intellectual property (IP). In OI, and more especially in outbound OI, which refers to the inside-out transfers of technology and information from one company to another, such as through patent licensing, IP is very significant(Huggins et al., 2019).

The rate at which domestic businesses seek out new information and the rate at which they obtain funding for new technologies they adopt from overseas, a process known as international technology transfer, or ITT, are related to the rate of technological convergence. In this instance, ITT depends on how quickly technology-seeking businesses adopt new solutions.Large companies are likely to favor the defensive approach since they may rely on their internal R&D infrastructures for innovation. On the other hand, highly inventive smaller businesses might be motivated by a similar intellectual property strategy, especially if they focus on a technological niche like biotechnology. In fact, when it comes to protecting their intellectual property, highly inventive small and medium-sized businesses (SMEs) may be even more aggressive than big businesses(Rocha et al., 2022).

Certain kinds of technological knowledge are protected by IPR mechanisms including patents, copyrights, and trademarks.The primary examples of how IPR norms have been extended to international policy over time are intellectual property agreements administered by the World Intellectual Property Organization and agreements on multi-lateral investment and trade. At least in industries like health, IPR issues are significant, if not the most significant. There is disagreement over the impact of IPRs on International Technology Transfer (ITT) (Martínez-Zarzoso and Coka, 2025)

ITT and access to technology capital can be obtained via a number of ways. The first is foreign direct investment (FDI), which enables the use of current models for the deployment or application of new technology.The expansion of higher-technology industries and a more complicated production character are two of this approach's main advantages. Second, businesses raise their R&D spending through worldwide cooperation, which raises the production's technological intensity and progress. Third, global connections enable businesses to expand the use of new technology across more branches or industries (Cardenas, 2021).

Partnership networks, or the small world of strategic technical alliances, are the finest places for technology transfer that leads to technological innovation.In the context of social innovation, the traditional perspective on technology transfer is constrained because it refers to the creation of technologies that are based on functional logic, which may be carried out without taking society into consideration.Therefore, the movement of "knowledge" in high-tech, technological processes, tools, procedures, or materials is what is basically meant by technology transfer(Adomako and Nguyen, 2023).

Businesses can access considerable volumes of data thanks to digital technologies, which they can use to boost their profitability or enhance the functionality of their larger corporate networks.Data monetization specifically refers to the practice of a business using data for its own direct or indirect financial gain. These procedures could involve using insights from data analytics to create new goods and services for the clients the data represents (Grewal et al., 2019).

Big Data is one technology that plays a key role in organizations by allowing firm partners oroutside entities to accessor use a firm’s data in order to increase its economic benefit.Another technology is Cloud that allows access to data,applications, and servicesby multiple users in realtime and also data storage atreduced technology costs. It has a significant role in optimizing businessperformance and supplychain managementthrough on-demand services and handling bigdata(Vani et al. 2022).

One of the key technologies brought by Industry 4.0 is artificial intelligence which is able to automate the process of sharing real-time data. Also, another feature of this technologies regards transparent advertising which can be realized through personalized content.

Another disruptive technologies from the 4IR spectrum is the Internet of Things or IoT which has utilizations across different industries. The benefits brought by this technology include increased efficiency, reduced costs as well as improved customer services. The instruments that arise from IoT are revolutionizing the production, distribution, and consumption of energy. Real-time energy usage tracking, along with energy grid performance monitoring and optimization, are made possible by this technology, which provides a platform for gathering, analyzing, and sharing data from multiple sources, thus facilitating better decision-making (Mezaal et al., 2024).

One of the fields that implemented IoT is the electric power industry. This sector is in charge of producing, sending, and distributing electricity to residences and commercial buildings. Since its inception, this business has advanced significantly and is still developing, becoming

more dependable and efficient.Additionally, by enhancing insight into possible attacks, IoT is enhancing grid security. In order to help utility operators promptly respond to threats and avoid outages, smart meters and sensors can identify unusual activity and notify them.Lastly, a more dependable and efficient power system is made possible by IoT. Real-time monitoring of energy use and system conditions helps utilities anticipate and control future demand, which reduces outages and boosts customer satisfaction (Abir et al., 2021).

Blockchain helps patent management organizations settle a range of conflicts, such as exchanging private data, proving authorship, transferring intellectual property rights, creating defense publications, etc.This technology stood out through tokens that are divided into two categories, namely fungible and non-fungible (NFT). Within the first type, each token has an equal value, while NFTs are actually digital assets that are kept on a blockchain and have a unique identifier(Regner et al.,2019).

In early 2021, NFTs emerged as one of the most popular uses of blockchain technology, garnering international attention. Real-world objects may be represented digitally. Digital assets (such as images, music, movies, and virtual creations) that have ownership documented in blockchain smart contracts are known as NFTs.The capacity to swap the same type of token from one another represents an important currency aspect which is reffered to as fungibility. The NFT has an unique character and is not exchangeable with the same type of token (Lesavre et al., 2020).

Methodology

Regarding the research methodology, it should be noted that this study employed an exploratory analysis. The primary objective was to identify the recent years technology transfer'and intellectual property rights' evolutionwhile highlighting the obstacles that resulted from the late global crises. In order to achieve the proposed objective, within this paper a series of statistical data were examined with the purpose of depicting the manner in which TT and IP evolved over the period under review. The study was conducted between August and September 2025 and was based on the analysis of secondary data, using relevant and up-to-date sources to support the conclusions drawn.

Results

The study conducted within this research aimed to analyze the degree of digitalization and the level of utilization of modern technologies within the economy and society, with a particular focus on artificial intelligence (AI), electronic commerce (e-commerce), as well as on the sector of ICT.The conducted analysis emphasized the AI trends in what regards enterprise level adoption, patterns of consumer behavior and also the the input of the ICT domain to gross value added. The findings provided an integrated perspective on how the digitalization process is transforming the economic environment and consumer habits at the European Union level and particularly in the case of Romania.

*Figure 1*illustrates the proportion of enterprises using artificial intelligence-based technologies for the analyzed year 2021. It was processed from the 2022 Digital Economy and Society Index (DESI) report. The ''Path to the Digital Decade'' initiative sets the objective that by 2030, over 75% of companies within the European Union will have adopted artificial intelligence-based technologies. However, the current level of AI technology utilization across

the European Union remains relatively low, standing at approximately 8% of all enterprises (Eurostat, 2022).

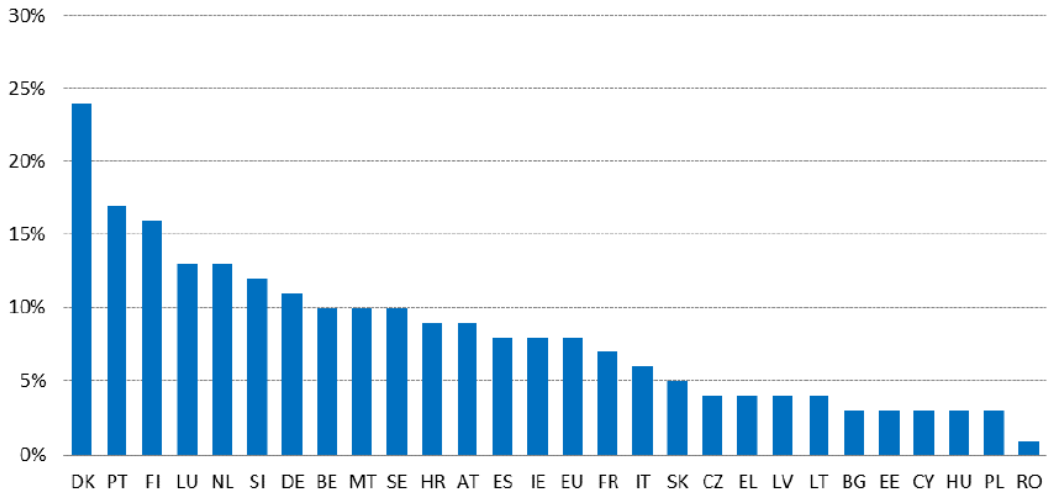

Figure 1. Proportion of enterprises using artificial intelligence-based technologies (% of total enterprises), 2021
Source: Processed from Eurostat, 2022

Following the analysis of statistical data from the DESI 2021 report shown in *Figure 1*, significant differences were observed among European Union member states regarding the degree of adoption of artificial intelligence (AI)-based technologies. Ten countries exceeded the 10% threshold of enterprises using AI technologies, with the highest values recorded in Denmark (24%), Portugal (17%), and Finland (16%). Another seven countries, including Croatia, Austria, Spain, Ireland, France, Italy, and Slovakia, reported adoption rates between 5% and 10%. Conversely, ten member states exhibited very low levels of AI technology utilization, below 5%, among which Bulgaria, Estonia, Cyprus, Hungary, and Poland each registered a share of 3%.

Romania recorded the lowest AI adoption rate among all EU member states, at only 1%, significantly below the European average. This modest performance correlates with the generally low level of digitalization among Romanian enterprises, where even basic digital technologies are not yet widely implemented.

Table 1 illustrates trends in internet use for purchasing goods and services across the European Union during the 2020–2024 period, through a comparative presentation of the five countries with the highest and the five with the lowest usage rates, including Romania.

The indicator is expressed as a percentage of total internet users, and the data reveal that Romania remains under the EU average; although it marked the second rapid growth rate from the analyzed countries, being the number of individuals using the internet to purchase goods or services that increased by 48% in 2024 compared to 2022. Over the 2020–2024 period, Romania shows an average value of 45.7%, in comparison with the EU average of 68.2%. Romania's growth rate of 48%, which is significantlygreater than the EU average of 11%, suggests that the country is gradually narrowing the gap in terms of digitalization and online consumer behavior.

Countries such as Ireland, the Netherlands, and Denmark exhibit very high levels of e-commerce use, between 85-95%. Opposingly, Romania and Bulgaria, that started from the lowest e-commerce levels of adoption within the European Union, show significant progress, reflected in their rapid growth rates, a result of increased technological investment, innovation adoption, and the expansion of digitalization across both society and the economy (Eurostat (a), 2025).

Table 1
Percentage of individuals using the internet for purchasing goods or services

Country	2020	2021	2022	2023	2024	Period Average	Growth Rate 2020–2024
Ireland	74.38	87.41	82	87.12	94.7	85.12	27%
Netherlands	86.6	89.47	88.21	92.41	94.06	90.15	9%
Denmark	89.31	90.82	88.3	89.01	90.86	89.66	2%
Sweden	84.15	86.74	85.96	88.75	88.39	86.80	5%
Czech Republic	71.64	75.48	77	77.68	81.24	76.61	13%
EU average	64.74	67.11	67.95	69.6	71.76	68.23	11%
Croatia	55.01	57.35	56.15	59.14	59.3	57.39	8%
Portugal	44.5	51.59	53.53	54.75	59.3	52.73	33%
Romania	37.86	38.49	45.73	50.3	56.12	45.70	48%
Italy	43.93	51.45	49.3	51.11	53.6	49.88	22%
Bulgaria	30.95	33.04	40.54	45.19	49.78	39.90	61%

Source: Processed from Eurostat (a), 2025

Another indicator analyzed in this study focused on identifying the proportion of internet users who purchased financial products or services online. This category includes insurance services (regardless of the policy type or associated package, such as travel insurance purchased together with airline tickets), loans (of any kind), and/or financial investments, such as bonds, stocks, mutual funds, or private pensions.

The analysis of the data in *Table 2* revealed a significant digital gap in the use of the internet for acquiring financial services, while also highlighting a positive evolution for Romania in recent years. During the 2020–2024 period, the national average stood at approximately 4.16%, whereas the European Union average was 16.9%, positioning Romania among the countries with the lowest share of active users in the field of digital financial services. Nevertheless, the growth dynamics were remarkable: 91% for Romania, compared to 56% at the EU level. This outcome reflects a positive trend toward strengthening public confidence in online financial services and advancing the process of digitalization.

The increase from 3.36% in 2020 to 6.43% in 2024 indicates a steady expansion in the use of digital banking services, fintech solutions, and electronic payment methods. However, the penetration level of such services remains lower than that recorded in Western European countries. At the EU level, the average rose from 13.83% in 2020 to 21.61% in 2024, corresponding to a 56% increase, which illustrates an accelerated adoption of digital financial services. Nordic countries (such as Finland and Sweden) and those characterized by advanced digital infrastructures (the Netherlands, Ireland, Estonia) significantly exceed the European average, reaching values between 40% and 50%.

Although Romania records a share almost four times lower than the EU average, the rapid growth rate suggests an intensification of public interest and access to online banking services. This evolution is supported by the expansion of digital infrastructure, the increase in financial literacy, and the development of fintech applications. Therefore, while Romania remains below the European average in terms of digital financial service usage, the sustained growth rate of 91% reflects a clear convergence trend. In the medium term, maintaining this momentum could lead to a considerable digital financial gap mitigation between Romania and the other European Union member states (Eurostat (b), 2025).

Table 2
Share of individuals using the internet for purchasing financial products and services

Country	2020	2021	2022	2023	2024	Period average	Growth rate 2020–2024
Finland	38.18	42.33	47.75	46.64	48.97	44.77	28%
Estonia	37.08	36.6	46.64	48.42	50.86	43.92	37%
Netherlands	34.71	38.78	48.55	45.97	49.51	43.50	43%
Ireland	25.1	25.62	41.5	48.48	56.52	39.44	125%
Sweden	35	36.44	39.3	40.3	43.22	38.85	23%
EU average	13.83	14.37	16.53	18.16	21.61	16.90	56%
Greece	6.32	12.11	11.32	12.43	12.9	11.02	104%
Croatia	14.95	6.44	7.57	8.69	13.72	10.27	-8%
Poland	6.31	6.26	7.1	7.19	9.52	7.28	51%
Bulgaria	5.92	3.25	4.57	5.99	7.37	5.42	24%
Romania	3.36	2.17	4.22	4.63	6.43	4.16	91%

Source: Processed from Eurostat (b), 2025

Another objective established within this study was to identify the distribution shares for Romania, Bulgaria, and the European Union average, based on the categories of online purchased financial products and serviceswhich can be observed in *Table 3*.The data reveal a distinct consumption pattern, markedly different from broader European trends, with Romania exhibiting a strong concentration of online activity in the insurance segment, which accounts for approximately 88% of total financial service purchases, compared to 54% at the EU level. This discrepancy suggests that Romanian users primarily rely on online channels for purchasing insurance policies, particularly travel, automobile, and health insurance.

Regarding credit services, their share is relatively low, only 6%, nearly three times lower than the European average (16%). This gap can be attributed to several factors, including public reluctance toward online lending, a low level of trust in digital banking platforms, and the limited availability of digital financial products offered by credit institutions. Similarly, online investments account for just 6%, significantly under the EU average of 30%, which depicts an immature investment culture, as well asa low level of financial literacy in Romania.

In the case of Europe, the structure of digital financial service use is more balanced: 54% for insurance, 16% for loans, and 30% for investments. This distribution indicates a higher degree of consumer behavior diversification and a more mature stage of digital financial market development across EU member states. In contrast, Romania is characterized by a

pronounced dependence on insurance products, accompanied by limited engagement in digital lending and investment segments. This unbalanced structure reflects an early stage in the development of financial digitalization at the national level.

To align with broader European trends, Romania needs to strengthen the supply of digital banking and investment products and intensify efforts aimed at increasing public trust and financial literacy (Eurostat (b), 2025).

Table 3
Evolution of internet use for purchasing financial products and services, by category, during the period 2020–2024

Category	Country	2020	2021	2022	2023	2024	Period Average
Insurance	Romania	81%	89%	93%	88%	89%	88%
Loans	Romania	6%	7%	3%	6%	8%	6%
Investments	Romania	13%	4%	4%	5%	4%	6%
Insurance	Bulgaria	64%	73%	62%	65%	72%	67%
Loans	Bulgaria	29%	19%	23%	28%	25%	25%
Investments	Bulgaria	7%	8%	14%	7%	4%	7%
Insurance	EU average	52%	50%	55%	56%	55%	54%
Loans	EU average	16%	17%	16%	16%	15%	16%
Investments	EU average	32%	33%	29%	29%	29%	30%

Source: Processed from Eurostat (b), 2025

*Figure 2*below presentsthe share of online sales (e-commerce) in total business turnover, country average in the European Union member states. In the case of Romania, its digitalization level shows that the state began from a low e-commerce level in the year 2013 with only 6% of enterprises being engaged in online sales. Romania's evolution was not linear, as the 2015-2019 period experienced a compelling stagnation, followed by an acceleration in 2020 driven by the pandemic. By the year 2024 this share doubled marking an optimistic direction on the long-term. In the same period of time, the EU average raised from 13% in 2013 to 19% in 2024.Countriesas Denmark, Finland and Belgiumexceed the EU average, with values between 25-30%.

In comparison, Romania's share of 12% remains below the EU average of 19%. Although, it surpassed other South-European member states like Greece and Bulgaria (8%).The gap between Romania and the leader countries Denmark (30%) and Finland (29%) still remains meaningful (Eurostat (c), 2025).

Romania recorded notable progress in the digitalization of commerce, managing to double the share of online sales in total business turnover. Nevertheless, remaining below the EU average indicates that the domestic business environment has yet to fully capitalize on the opportunities offered by electronic commerce.

To narrow the digital gap, it is essential to strengthen digital competencies among enterprises, increase investment in online sales platforms, and enhance trust in digital transactions.

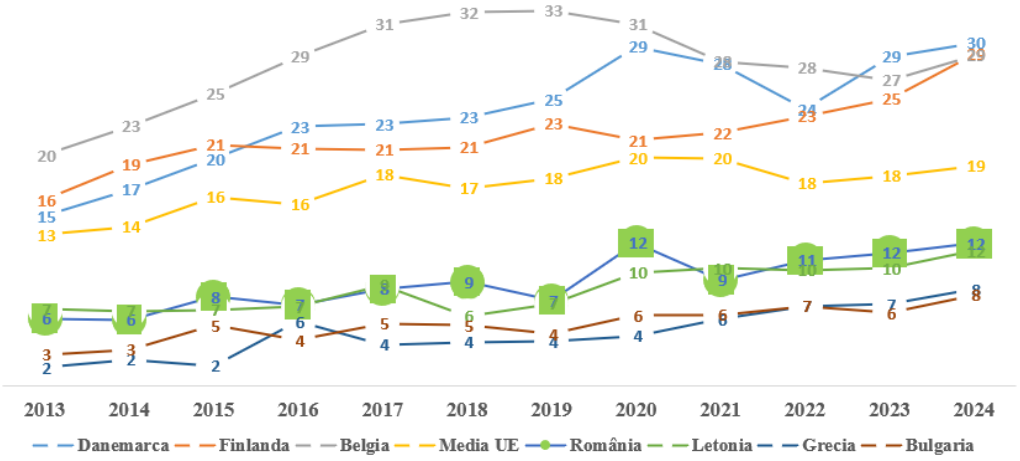

Figure 2. Share of online sales (e-commerce) in total business turnover, country average in the European Union member states
Source: Processed from Eurostat (c), 2025

Figure 3 below illustrates the forthright input of the ICT domain to the development of Gross Domestic Product (GDP) as well as pointing out digitalization's role within Romania's economic structure, in comparison with other member states and the EU average.

The figure presents Romania's position compared to the EU average, the top three EU member states with the highest ICT sector contributions to gross value added, as well as the bottom three countries with the lowest shares. In 2024, Romania is situated below the European Union average, but not at the lower end of the ranking, indicating an intermediate position with room for improvement.

Over the past decade, Romania has recorded a steady increase in the ICT sector's contribution, from 2.93% in 2011 to 4.44% in 2022, representing nearly a doubling of this sector's share in the national economic structure. The growth trajectory has been sustainable and upward, particularly after 2015, a period marked by the intensification of digitalization processes, the expansion of IT service exports, and the increase in investments in software development and digital infrastructure (Eurostat (d), 2025).

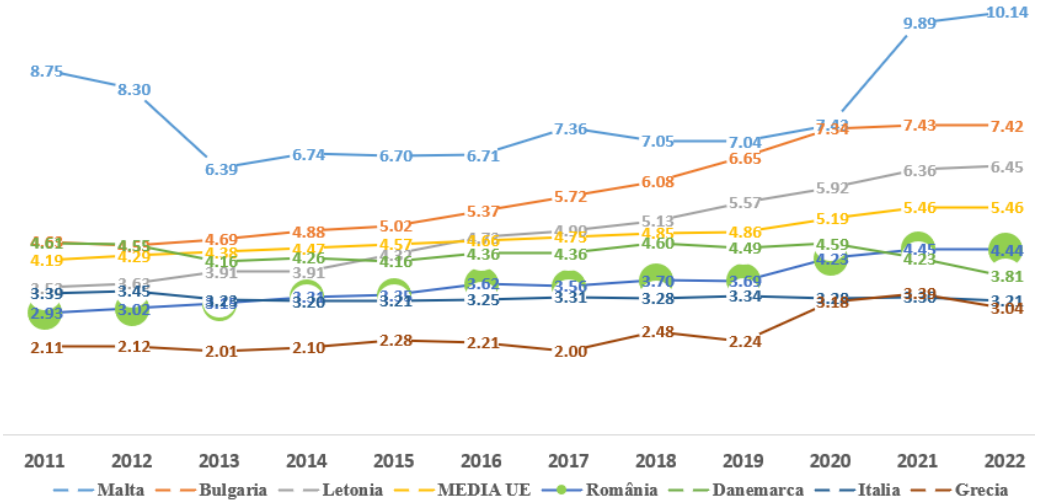

Figure 3. Contribution of the information and communications technology (ICT) sector to the total gross value added of the economy
Source: Processed from Eurostat (d), 2025

According to *Figure 4* at the global level patent applications in the field of information technologies, both hardware and software, serve as a key indicator of a country's ability to convert scientific knowledge into economic value. They reflect not only the intensity of innovation activity but also the capacity of national economies to foster the development of emerging industries, to advance digital transformation, and to support the transition toward technology-driven and AI-based economic models.

An analysis of this indicator reveals a significant concentration of patenting activity in the United States and in major Asian economies such as South Korea, China, and Japan. These nations have established themselves as global hubs of innovation and technological production. In comparison, Europe registers a lower overall volume of patent applications but continues to maintain strategic relevance through notable contributions in specialized domains and high-performance industrial technologies.

The analyzed data emphasized three technological innovation hubs, being: the United States of America, East Asia and Europe (European Patent Office, 2025).

The United States holds a dominant position, accounting for 34.4% of all IT-related patent applications worldwide. On the second place comes China (14.2%), followed by South Korea (8.7%) and Japan (7.8%), illustrating the important role of the Asian region hen it comes to technology and IT-related innovation. In the case of Europe, Germany stands out with 9.3%, followed by France (4.7%), the United Kingdom (3.4%), Switzerland (2.8%)and the Netherlands (2.3%).

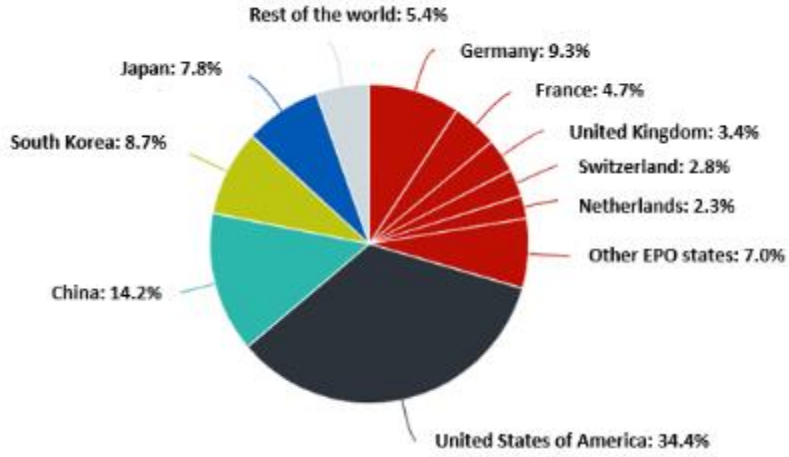

Figure 4. Distribution of patent applications in the field of information technologies (software and hardware) by country of origin, 2024
Source: Processed fromEuropean Patent Office, 2025

*Figure 5*shows the evolution of the number of patents in the field of information technologies (IT) at the global level on the analyzed period 2015–2024. The upward trend observed in recent years is closely associated with the intesified innovation pace driven by the economic effects of the COVID-19 pandemic and the rapid advancement of artificial intelligence.

Overall, the fields of information technology and artificial intelligence remain among the most dynamic and influential sectors of the global economy, playing a pivotal role in enhancing productivity, driving competitiveness, and steering economic development toward sustainable and knowledge-based models. An analysis of the evolution of patent registrations in information technologies (IT) between 2015 and 2024 reveals a clear and sustained upward trajectory. During this period, the total number of patents increased from 10,359 in 2015 to 16,815 in 2024, representing an overall growth of approximately 62%. This expansion reflects not only the intensification of global technological innovation but also the progressive maturation of the IT sector.

The 2015–2018 interval is characterized by a moderate yet steady rate of growth, indicative of a phase of consolidation of earlier digital innovations and a gradual increase in research and development (R&D) investments. Between 2019 and 2021, patenting activity accelerated markedly, driven by the rapid digital transformation, as well as the post-pandemic economic effects, which prompted widespread adoption of digital technologies. Beginning in 2022, the upward trend persists, though at a more balanced pace, with annual increases ranging between approximately +624 and +729 patents. This stabilization suggests a stage of market maturity and the consolidation of key emerging technologies, particularly in the domains of artificial intelligence, cloud computing, and industrial automation.

The overall positive global trend reaffirms the central role of the IT sector as a fundamental driver of technological and economic progress. The industry continues to attract substantial R&D investments and contributes significantly to the competitiveness of advanced economies. Since 2022, a new phase of technological sophistication has become evident,

largely fueled by the rapid expansion of artificial intelligence and machine learning–based solutions (European Patent Office, 2025).

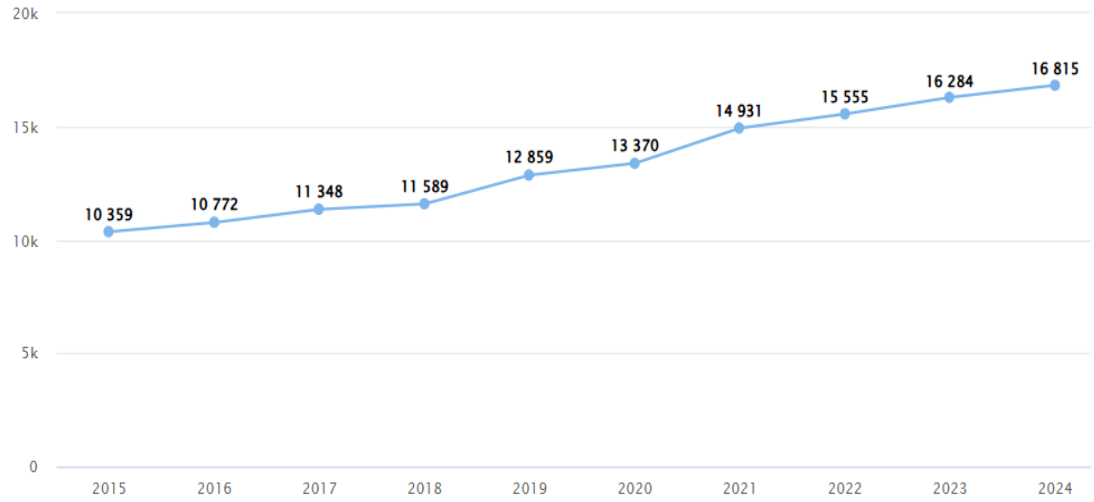

Figure 5. Evolution of the number of patents in the field of information technologies (IT) at the global level, 2015–2024
Source: Processed fromEuropean Patent Office, 2025

As illustrated in *Figure 6*, the increase in IT-related patents is closely linked to the substantial investments made by major global industry players such as Samsung, Huawei, Microsoft, and Alphabet. The dynamics of patenting activity reflect the intensification of international competition for technological leadership, the rapid expansion of applications based on generative artificial intelligence, and the deepening integration of digital technologies across diverse economic sectors, from healthcare and education to transportation, industry, and services.

The sustained upward trajectory of IT patenting thus stands as evidence of the growing global commitment to innovation and of the consolidation of this sector's position as a cornerstone of the knowledge-based economy. The following figure illustrates the hierarchy of leading IT companies, ranked according to the number of patents obtained in 2024. The global ranking of companies with the highest number of patents in the field of information technologies is dominated by Asian and American corporations such as Samsung, Huawei, Microsoft, Alphabet, Qualcomm, and Apple. This distribution reflects a broader pattern within the global innovation landscape: organizations originating from economies with substantial investments in research and development (R&D), particularly South Korea, China, and the United States, tend to exhibit superior capacities for generating and protecting technological innovations.

In contrast, the representation of European companies among global leaders is more limited, although firms such as Siemens and Royal Philips maintain a consistent presence in patenting activities. With approximately 430 and 190 patents respectively, these companies remain at a notable distance from the global frontrunners. The gap suggests that, while Europe hosts competitive industrial actors, its innovation profile in the strictly IT-oriented domain is less pronounced compared to that of major players from Asia and North America.

A closer look at the American companies reveals a relatively narrow difference between Microsoft (690 patents) and Alphabet (670 patents), indicating comparable capacities in technological innovation and intellectual property protection. In the case of Apple, the comparatively smaller number of patents (around 250) does not necessarily imply reduced research activity, rather, it reflects a distinct strategic orientation toward the protection of design and hardware-related innovations.

According to data published by the European Patent Office (EPO) in its Patent Index, leading European applicants include companies such as Royal Philips, Siemens, BASF, and Ericsson. The EPO's annual reports confirm the dominance of firms from the United States, Japan, South Korea, and China in the number of patent filings within Europe, while European companies appear less frequently in the global rankings of major IT innovators (European Patent Office, 2025).

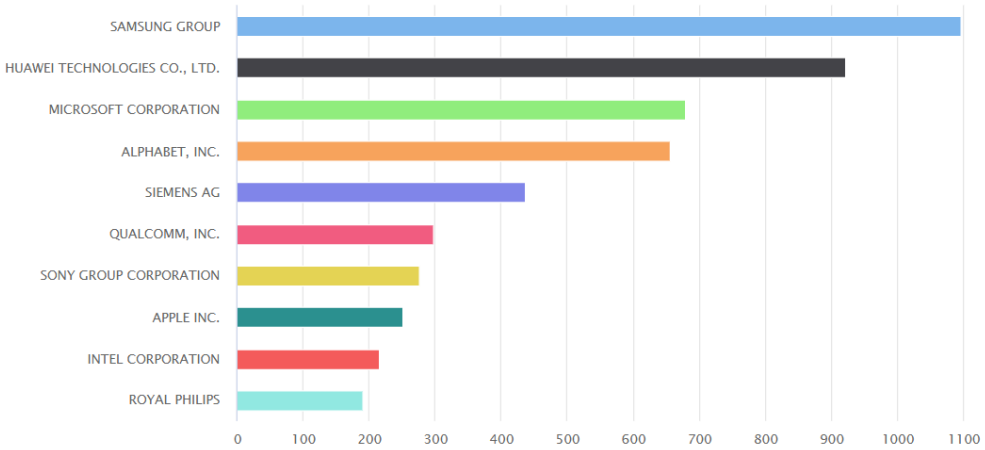

Figure 6. Top 10 global companies by number of patents registered in the field of information technologies (IT), 2024
Source: Processed fromEuropean Patent Office, 2025

The analysis conducted within this study highlighted significant progress in the digitalization of Romania's economy, reflected in the increasing use of electronic commerce, online financial services, and the growing contribution of the ICT sector. Although Romania remains below the European Union average for most of the indicators analyzed, the accelerated pace of development confirms a clear trend of digital convergence. The results indicate a positive dynamic, supported by the expansion of digital infrastructure and the rising interest in technological innovation.

To further enhance Romania's digital performance, it is essential to strengthen digital competencies across the population and the business sector, alongside increased investments in research, development, and innovation (RDI). Moreover, public policies should aim to support the integration of emerging technologies and the adoption of artificial intelligence within economic sectors. Building trust in the digital environment and fostering a strong digital culture will be key determinants in reducing the gap between Romania and the European average.

Conclusions

The recent global crises (economic, energy-related, and pandemic, among others) have transformed sustainable digital transformation from a simple technological trend into a macroeconomic instrument of major importance, playing a critical role in strengthening economic resilience. In this context, the turbulence of recent years has demonstrated that emerging digital technologies are key drivers of economic development, with the capacity to foster both growth and adaptability. Countries capable of rapidly integrating these technologies across multiple sectors are better positioned to withstand external crises, manage resources more efficiently, and maintain long-term competitiveness.

Within this framework, technology transfer and intellectual property (IP) play an essential role. In all states, technological progress, regardless of sector, must be rigorously regulated to ensure that creators receive continuous protection for the products and ideas they develop. Intellectual property represents a strategic component of digital transformation, contributing significantly to both stimulating market demand and translating innovative ideas into practice. Research in the field has shown that, at both the national and European levels, there is a pressing need for more flexible procedures and processes for registering intellectual property rights.

Establishing an efficient and adaptable legal framework, recognized both domestically and internationally, can stimulate innovation and accelerate economic development. At the same time, technology transfer must be regarded as a powerful catalyst for innovation. For this process to be effective at both national and European levels, close collaboration between academic research, industry, and the business sector is required, ensuring that scientific findings are quickly translated into production and real-world applications.

In light of these considerations, sustainable digital transformation associated with the propagation of technology transfer and intellectual property processes is able to create a robust economic growth strategy on the long-term. In the case of Romania, the above-mentionedhave a crucial role in reinforcingnational economic resilience and competitiveness as well asencouraging sustainable development.

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