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"AI and Technological Innovation: Patents as Indicators of Progress"

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Abstract

This thesis investigates the evolving interplay between Artificial Intelligence (AI) and the patent system, emphasizing AI's dual role as a subject of intellectual property protection and a transformative force in patent practices. Through a comprehensive analysis encompassing AI’s definition, historical evolution, and its core components—including Machine Learning, Neural Networks, and Natural Language Processing—the study elucidates AI's significant impact on technological innovation and the patent landscape. It delves into the role of patents in fostering innovation, the growing influence of AI on patent generation and processing, and the challenges surrounding the patentability of AI-generated inventions. Employing a multifaceted methodological approach that combines quantitative data analysis, qualitative assessments, predictive modeling, and socio-economic impact analysis, this thesis offers insights into AI's contribution to competitive advantage and economic growth. The findings highlight AI's potential to enhance patent search, analysis, and classification, presenting implications for technological innovation, and policy formulation. This research contributes to the discourse on integrating emerging technologies within the patent system, navigating the complexities of AI development, and fostering an environment conducive to innovation.

Sources of materials.

The terminologies and keywords central to the discipline of Artificial Intelligence (AI) and its encompassing subsets, such as machine learning, deep learning, and data mining, are universally acknowledged and utilized. These terms are not isolated to a single source; instead, they are interwoven throughout a broad spectrum of scholarly articles, research findings, technical writings, and narratives within the media that explore technological innovations and advancements. The following discourse aims to illuminate the diverse repositories where these terminologies are rigorously examined and discussed.

Academic Contributions and Symposiums: Prestigious gatherings such as the NeurIPS (Conference on Neural Information Processing Systems), ICML (International Conference on Machine Learning), and CVPR (Conference on Computer Vision and Pattern Recognition) consistently contribute to the body of knowledge by presenting research that explores these critical subjects.

Academic Journals: Leading publications like the "Journal of Machine Learning Research", "Artificial Intelligence", and "IEEE Transactions on Neural Networks and Learning Systems" act as cornerstone platforms for the publication of research insights and analytical reviews within the field of AI.

Sectoral Reports and Market Forecasts: Notable organizations such as Gartner, McKinsey, and MIT Technology Review play a crucial role in offering analytical perspectives that examine the current landscape and forecast the future developments of AI, highlighting key terms and concepts.

Pedagogical Materials and Textual Resources: Authoritative texts, including "Artificial Intelligence: A Modern Approach" by Stuart Russell and Peter Norvig, as well as "Deep Learning" by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, are indispensable resources that provide detailed explorations of the numerous concepts identified herein.

Research Initiatives and Theoretical Discussions: Institutes such as DeepMind, OpenAI, and the MIT Media Lab are central to the advancement and dissemination of research outcomes and discussions pertinent to these themes.

Digital Commentary and Technological Insights: Platforms and outlets like TechCrunch, Wired, and Ars Technica are celebrated for their coverage of the latest advancements and the practical deployment of AI, making specific references to concepts and terminologies.

The attribution of each term significantly varies, depending on the context and the evolving nature of the discipline. As the field of AI advances rapidly, with new research being published frequently, the most up-to-date and relevant sources can be found through scholarly databases such as Google Scholar, PubMed for the medical implementations of AI, IEEE Xplore for research in engineering, and the ACM Digital Library, dedicated to computer science and information technology studies.

Introduction

The advent of Artificial Intelligence (AI) has precipitated a paradigm shift across various sectors, redefining the boundaries of innovation and intellectual property (IP). As AI technologies advance, their integration into the patent system presents unique challenges and opportunities for IP law, policy, and management. This thesis aims to explore the nuanced dynamics between AI and the patent system, focusing on AI's influence on and its implications for patenting practices.

Chapter 1 provides a foundational overview of AI, detailing its evolution, key components, and applications, setting the stage for understanding its interaction with the patent system.

Chapter 2 delves deeper into the definition and historical development of AI, highlighting its significance in the current technological landscape and its role within the framework of intellectual property.

The thesis further examines the critical function of patents in technological innovation in Chapter 3, exploring how patents protect inventions while serving as indicators of technological progress and economic growth. This discussion contextualizes the subsequent analysis of AI's impact on the patent landscape, including its role in enhancing patent search, analysis, and the patentability challenges of AI-generated inventions.

In conclusion, this thesis not only investigates AI's transformative impact on patenting practices but also aims to contribute to the ongoing discourse on technology, law, and policy. By examining AI's role within the patent system, this research seeks to provide insights into managing intellectual property in the age of digital transformation.

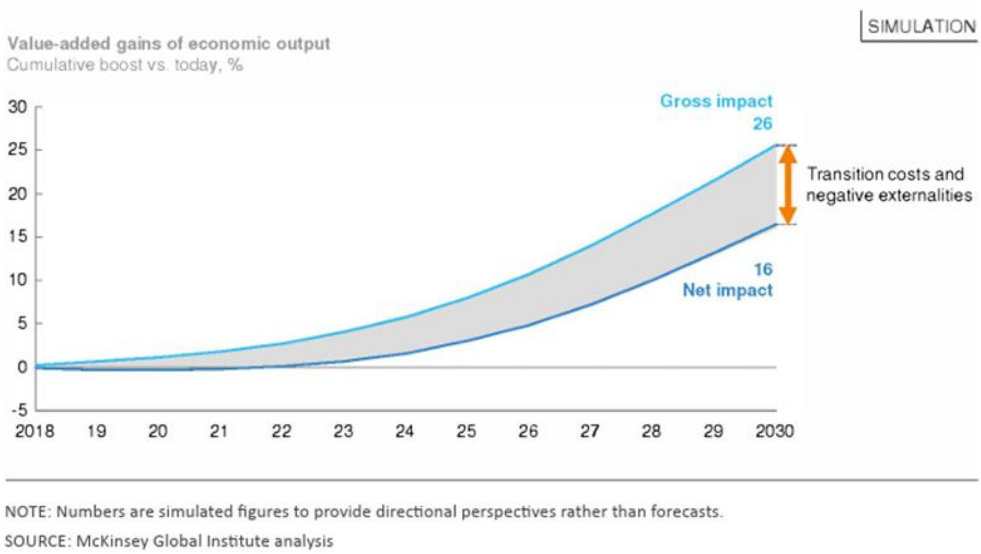
CHAPTER ONE

1. Importance of AI in the Economic Landscape

AI's potential impact on global productivity and economic growth is substantial. According to The McKinsey Global Institute that looked at five broad categories of AI: computer vision, natural language, virtual assistants, robotic process automation, and advanced machine learning, suggests a net addition of $13 trillion to the global GDP by 2030, far outpacing the growth contributions expected in the next five years[i]. This projection is based on the assumption that AI adoption will become more widespread, following a period of gradual implementation costs and slower initial adoption, especially among firms not at the forefront of technology. The adoption curve's shape is more critical than the exact figures year by year, highlighting a potential period of acceleration after the first five to ten years as more companies integrate AI across their operations. This dynamic is reminiscent of the Solow Paradox, where initial underwhelming impacts could lead to a misinterpretation of AI's potential.

The OECD points out AI's applicability across industrial activities, including optimizing systems and enhancing research, indicating that its deployment is expected to increase over time with the advancement of automated learning processes.

GRAPH 1.1



Retrieved from: McKinsey Global Institute analysis

Similarly, McKinsey suggests that AI and automation could lead to a polarized economic structure, with massive organizations and small players dominating, at the expense of mid-sized companies. This "barbell-shaped economy" would result from the competitive advantages and productivity boosts enjoyed by early adopters, leading to a "winner takes all" market scenario.

The technological divide between companies—those that embrace AI early and those that do not—may significantly widen, potentially altering market shares and concentrating profits among the leading firms. This scenario is likely to ignite policy debates concerning the uneven distribution of AI benefits and the challenges of technological diffusion, especially as productivity and innovation gaps widen between top-tier global firms and the rest.

Looking at sectoral impacts, AI is making significant strides in marketing, sales, supply chain management, logistics, and manufacturing[ii]. Early adopters in sectors like transport, logistics, automotive, technology, and even service industries are poised for substantial gains. By contrast, industries like chemicals lag in adoption. PwC predicts a minimum 10% growth across all sectors by 2030, with services, retail, and wholesale trade expecting the highest boosts.

Globally, the disparity in AI adoption could widen the gap between developed and developing nations, as high-wage economies find more incentive to replace labor with AI, potentially reshaping manufacturing, and production landscapes[iii]. This uneven adoption landscape underscores the importance of understanding AI's broad economic impacts and the need for strategic approaches to leverage its potential across different sectors and regions.

1.2 Definition of Absorption and the connection with digitization and competition.

The economic impact of a technology depends on the rate at which it is adopted by economic entities and absorbed throughout their organizations[iv]. Decisions to invest in these technologies do not occur in a vacuum but depend on several important variables that determine the economic and competitive case for adoption and absorption.

Let's delve into the details. According to Venkatesh, Technology adoption refers to the successful integration of new technology into a business or organization[v]. It goes beyond merely using technology; true adoption occurs when the technology is fully embraced and utilized to its fullest potential. The Technology Adoption Lifecycle (also known as the Technology Adoption Curve) is a sociological model that describes how different groups of people adopt or accept an innovation.

On the other hand, technology absorption is about how effectively the organization utilizes and leverages the technology to achieve maximum productivity and innovation[vi]. This concept is crucial for businesses and organizations to derive the full benefits from their investments in technology. However, these processes do not occur in isolation. They are significantly influenced by external factors such as competition and digitalization.

1.3 Technology Adoption Life Cycle.

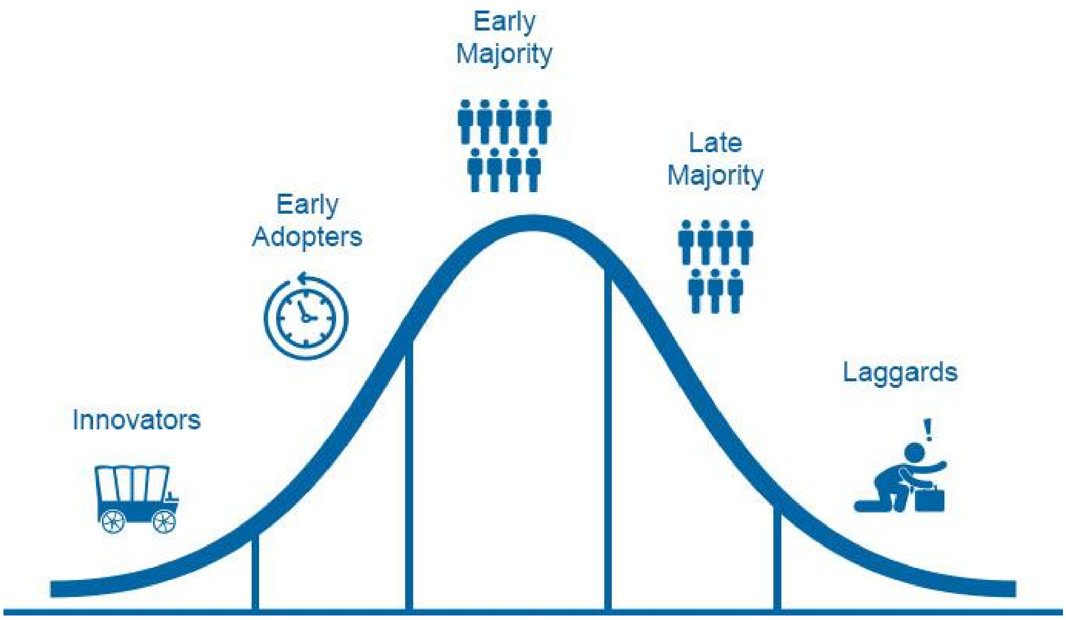
The Technology Adoption Lifecycle (also known as the Technology Adoption Curve) is a sociological model that describes how different groups of people adopt or accept an innovation[vii].

The model identifies five distinct adopter groups:

- **Innovators**: These risk-taking individuals are the first to learn about and embrace new innovations.
- **Early Adopters**: They follow the innovators and are open to trying new technologies.
- **Early Majority**: This group adopts innovations after they've been proven by the early adopters.
- **Late Majority**: The late majority catch on to a new innovation well after the average consumer does usually due to a high level of skepticism about the benefits of a new product or service and having less financial flexibility than earlier adopters. The late majority also commonly only interacts with early majority consumers. This is an indication that a product has reached full maturity in the market.

- **Laggards**: Laggards are the last group in the technology adoption stages. Laggards show an aversion to change and are not influenced by opinion leaders. This group tends to focus more on the reliability of products they already use, but also may have very little financial flexibility to take risks when it comes to buying innovative products[viii]. Finally, this group of individuals tends to only be in contact with and trust close friends and family instead of influencers or early adopters.

GRAPH 1.2



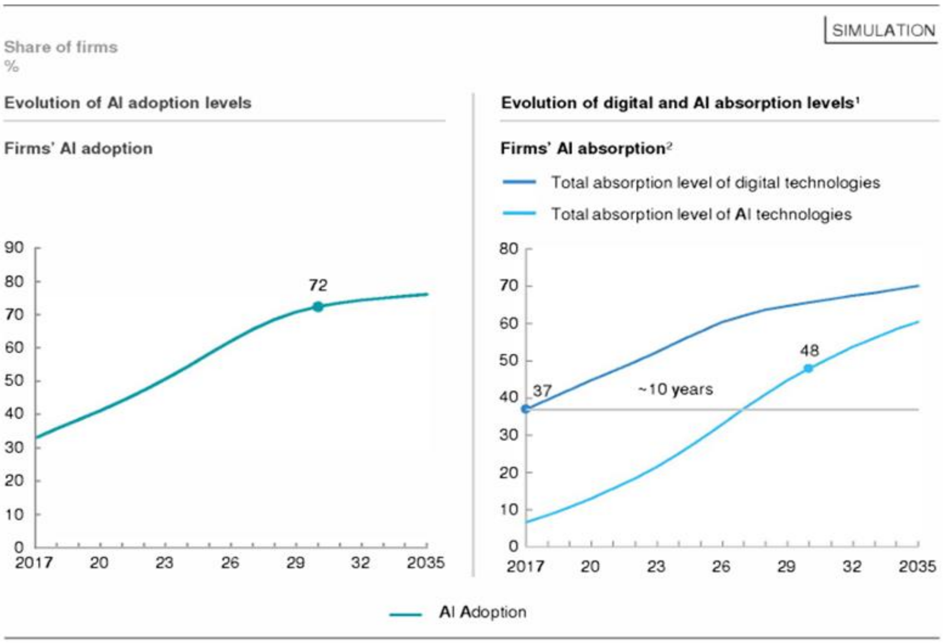
Retrieved from: McKinsey Global Institute report , "No Ordinary Disruption: The Future of Customer Experience".

1.4 Full absorption

In accordance with the McKinsey Global Institute report the total absorption level of AI by companies might reach about 50 percent by 2030[ix].

Performing econometric analysis and proprietary data along with early evidence from surveys on how companies are adopting AI, an estimated 70 percent of companies might adopt some AI technologies by 2030, up from today's 33 percent, and about 35 percent of companies might have fully absorbed AI, compared with 3 percent today. Companies that partially absorb AI technologies are likely to capture partial benefits from AI. One way to put these estimates into context is to compare them to the absorption of digital technologies such as web, mobile, cloud, and big data. Those technologies started to be used about ten to 25 years ago. The average level of absorption of this previous generation of digital technologies was about 37 percent in 2017 and may reach 70 percent by 2035. In comparison, absorption of AI might reach today's level of digital absorption by 2027 in roughly ten years. Early digitization and the competitive race are important determinants of the pace of AI adoption and absorption[x].

GRAPH 1.3



1 Digital technologies for this purpose are big data, cloud, mobile, and web technologies.
2 Total absorption includes the weighted share of firms that have both partially and fully absorbed AI.
NOTE: Numbers are simulated figures to provide directional perspectives rather than forecasts.
SOURCE: McKinsey Global Institute analysis

Retrieved from: McKinsey Global Institute analysis

Full absorption takes time, as seen in the case of the previous generation of digital technologies. AI may be adopted and fully absorbed slightly faster at the high end of benchmarks of the speed at which technologies percolate[xi]. AI adoption and absorption could be more rapid because of the breadth of ways in which it is used, including in domains where digitization is still underpenetrated, such as the automation of services and smart automation of manufacturing processes[xii].

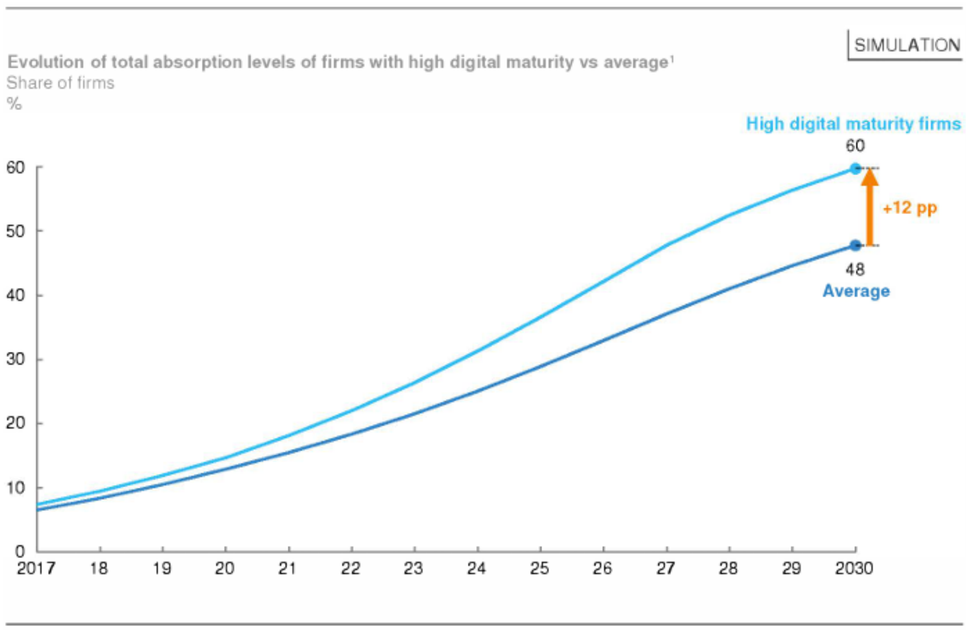
Another reason that AI may be adopted and absorbed more quickly than previous technologies is that its returns tend to be large and to come with significant cannibalization and substitution that create an imperative to respond to, and attempt to move ahead of, the competition. Nevertheless, the adoption and absorption of AI may be bounded by its dependence on the technical infrastructure needed for its effective use.

Two aspects worth highlighting are **digitization and competition**.

- **Digitization**. An important factor in the adoption of AI is whether previous digital technologies are in place, because these are the technical backbone for its effective rollout[xiii]. Machine learning underpins a large share of AI technologies. Most algorithms require big data and a digital architecture. Superior insight from AI does not translate into increases in corporate performance unless many activities change. Even when the technological backbone is present, companies cannot generate value from AI without the skilled labor and experience necessary to tap into its opportunities and mobilize change within organizations[xiv]. The way the absorption of previous generations of digital technologies affects the deployment of AI has been demonstrated. Correlating the absorption of AI with the digital maturity of a firm reveals that companies that are more digitally mature have annual AI adoption and absorption 12 percentage points higher than firms that are less digitally mature.

GRAPH 1.4

Exhibit 5. High digital maturity can accelerate AI adoption and absorption



1 Constitutes companies that have absorbed web, cloud, mobile, and big data technologies.

NOTE: Numbers are simulated figures to provide directional perspectives rather than forecasts.

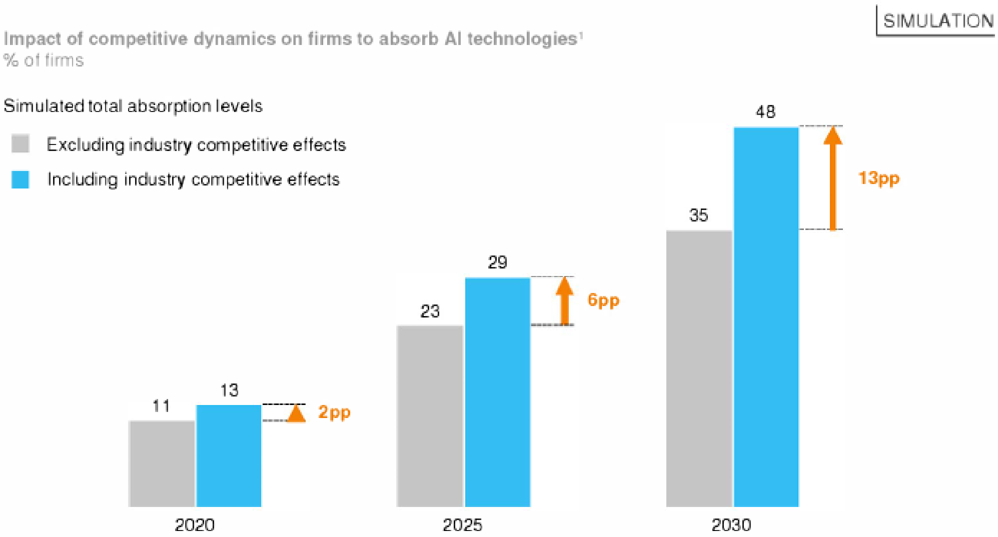
SOURCE: McKinsey Digital Survey; McKinsey Global Institute analysis

Retrieved from: McKinsey Global Institute analysis.

• **Competitive pressure**. Economists have long been interested in how technological innovation and technology interact with competition. According to Schumpeterian and disruptive theory views, the adoption of technology is typically driven by competition and may build a first to-market advantage if the performance of the technology is strong enough to compensate for all the uncertainty surrounding its introduction[xv]. Some companies adopt AI in a preemptive move against perceived fear of disruption from competitors or as a direct response to a new competitor[xvi], while others react more slowly. The econometric analysis and corporate survey conducted by MGI have consistently suggested that, for each type of AI technology analyzed, the presence of rivals investing in AI accounts for a significant share of any decision by a company to invest. Extrapolating from this microeconomic effect, we find that competitive pressure can increase absorption level by about 13 percentage points in 2030.

GRAPH 1.5

Exhibit 6. Competitive pressure can accelerate the pace of AI absorption



1 McKinsey's survey gathered data from C-level executives on whether, and to what extent, they would adopt AI technologies if a competitor or peer did so. MGI used econometrics to study the effect on adoption and absorption levels with and without this effect to understand the degree to which significant competition drives adoption and absorption levels.

NOTE: Numbers are simulated figures to provide directional perspectives rather than forecasts.

SOURCE: McKinsey Digital Survey; McKinsey Global Institute analysis

Retrieved from: McKinsey Global Institute analysis

1.5 Basic Concept of AI

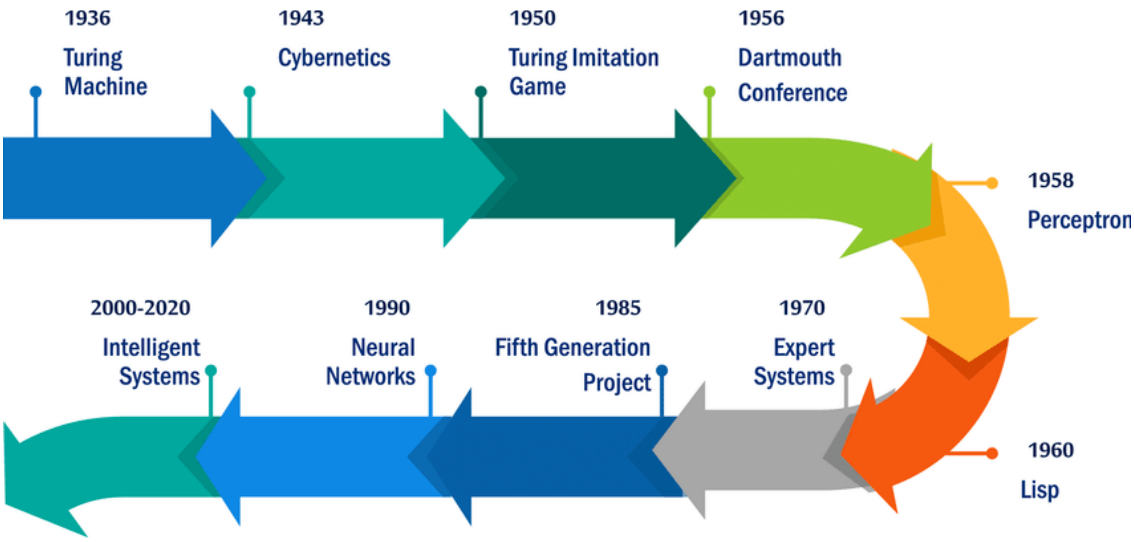
When we talk about artificial intelligence (AI), it often recalls a comprehensive range of techniques and computational methods that emulate human reasoning and are applied to various robotic systems[xvii]. Essentially, AI aims to replicate human intellect in machines by employing algorithms that range from basic to highly intricate architectures. However, Defining Artificial Intelligence is not straightforward, largely because the field is both broad and continuously evolving and because the concept of AI is translated into a variety of different types of application, stages and sorts so that implies the difficulties to explain a single and unique definition always valid. Due to this, many definitions were made to try to better explain AI. Russell, S., & Norvig described it as "a simulation of human intelligence in machines that are programmed to think like humans and mimic their actions"[xviii]. The term can also be applied to any machine that exhibits traits associated with a human mind, such as learning and problem-solving. Another definition was given by Poole, David, and Alan Mackworth: "AI systems are designed to handle tasks that typically require human intelligence, including speech recognition, decision-making, visual perception, and language translation"[xix]. The core aim of AI is to create systems that can perform autonomously, adapt to new inputs, and improve from experience without being explicitly programmed for every contingency.

1.6 Brief History and Evolution of AI

The concept of artificial intelligence has been a subject of fascination and speculation for centuries, but its formal inception is typically traced back to a workshop held at Dartmouth College in 1956, where the term "Artificial Intelligence" was first coined by John McCarthy. This event marked the beginning of AI as an academic field. The early years of AI were characterized by significant optimism and the development of the first AI programs, such as ELIZA and Perceptron, which demonstrated basic natural language processing and pattern recognition capabilities.

However, AI research faced periods of stagnation and reduced funding, called “AI Winter”, primarily due to inflated expectations and technical limitations. The late 20th and early 21st centuries saw a resurgence of interest and progress in AI, fueled by advances in computational power, the availability of large datasets (big data), and breakthroughs in machine learning algorithms. The introduction of deep learning architectures and neural networks has particularly accelerated AI capabilities and the development of sophisticated AI models capable of complex tasks like driving autonomous vehicles and providing personalized recommendations.

GRAPH 1.6



Retrieved from: https://www.researchgate.net/figure/Timeline-of-Milestones-of-AI-Development-at-Tec_fig3_344274748

1.7 Key Components of AI

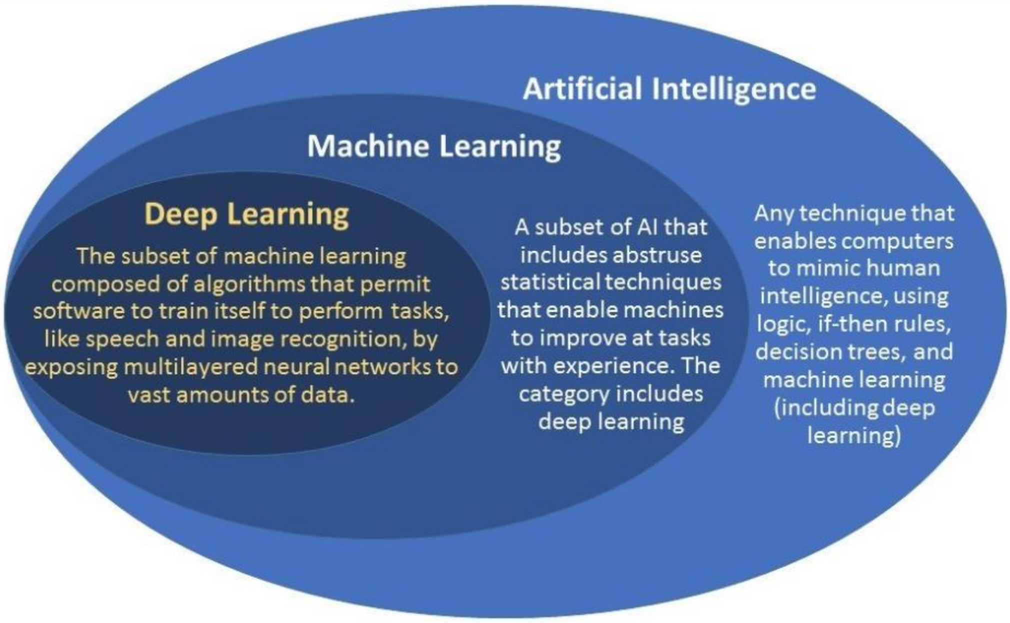
As previously stated, throughout the 21st century, artificial intelligence-based neural networks with Machine Learning (ML) capabilities have enabled systems to learn and improve automatically from experience without being explicitly programmed. This involves the development of algorithms capable of analyzing and learning from data, making decisions, and predicting outcomes. ML is at the heart of many AI systems, providing the foundation for tasks ranging from email filtering and speech recognition to complex decision-making processes[xx].

The natural evolution of this paradigm is manifested with the emergence of Deep Learning (DL), a specialization within Machine Learning that uses deep neural networks to handle previously unimaginable volumes of data[xxi]. These deep neural networks, inspired by the structure and functioning of the human brain, are composed of overlapping layers that transform input data in increasingly complex ways, allowing the system to autonomously identify features and patterns in the data.

This approach has revolutionized areas where traditional ML faced limitations, such as image recognition, automatic translation, and natural language processing, offering significantly superior performance. Deep Learning, with its ability to work with unstructured data and learn directly from the "features" of the data without the need for explicit programming or human intervention, has enabled the development of AI applications that are closer to human intelligence, such as assistance in medical diagnosis, advanced facial recognition, and autonomous vehicle systems[xxii].

Through the use of Deep Learning, AI systems can now handle tasks of a complexity and variety that were considered beyond reach just a few years ago, pushing the boundaries of what technology can achieve and promising revolutions in multiple sectors[xxiii].

GRAPH 1.7

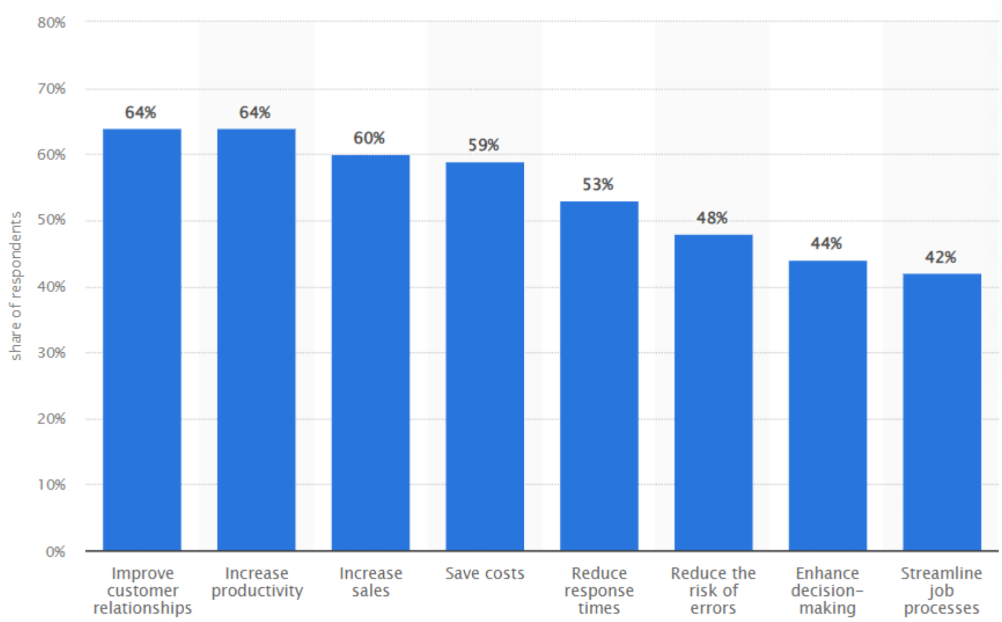


Retrieved from: https://medium.com /deep-learning-demystified

1.8 AI impact on Business

According to an article published by ZDNet, since 2019, the number of businesses adopting artificial intelligence has grown by 270%[xxiv]. By introducing AI and its quick learning capabilities, businesses can create super-powered data processing machines that can generate information, extrapolate large amounts of data, and even take care of tasks that free up time and budget for organizations to focus on more face-to-face tasks. Beyond merely automating repetitive tasks, AI is unlocking new possibilities previously considered beyond reach, industries such as finance, healthcare, and manufacturing have already seen benefits from AI integration. The potential for AI to revolutionize the way businesses operate and compete is immense. It is reshaping industries and redefining business operations across various dimensions[xxv].

GRAPH 1.8

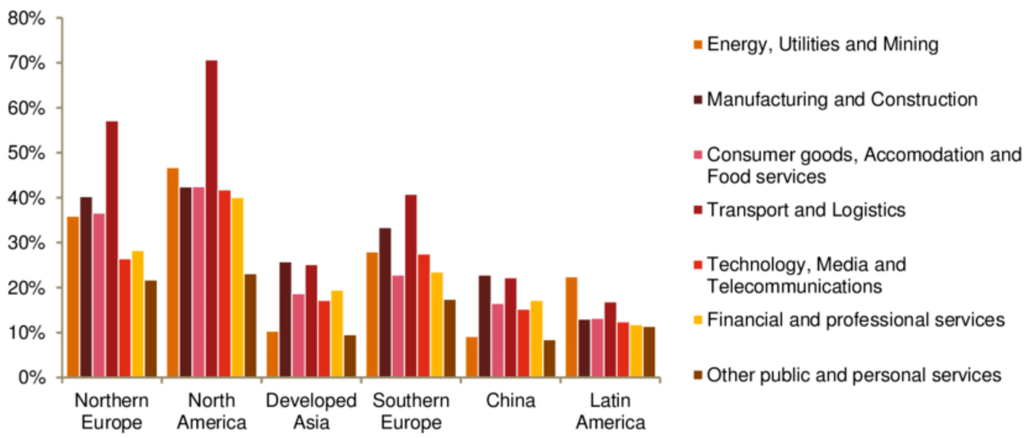


The positive impact business owners in the U.S. expect from artificial intelligence (AI) in 2023.

Retrieved from: Published by Bergur Thormundsson, Dec 6, 2023

One of the transformative powers of AI lies in its ability to sift through and analyze vast amounts of data, revealing deep insights into consumer behavior, market trends, and internal performance[xxvi]. This predictive analysis has become indispensable for strategic planning, uncovering growth opportunities that were once invisible. Companies are now capable not only of gathering but also interpreting huge datasets in ways that inform smarter, quicker business decisions. Cognitive technologies provide actionable insights in real-time, allowing for more informed and faster decision-making processes that can significantly impact a company's direction and success[xxvii].

GRAPH 1.9



Retrieved from: PricewaterhouseCoopers (PwC) analysis, "Work in 2030: The Impact of Automation, Technology and Demographics".

Moreover, AI significantly enhances the customer experience. Sophisticated virtual assistants and chatbots, capable of handling a wide array of customer requests with precision and personalization, are making customer interactions smoother and more satisfying. A *Harvard Business Review study* found that companies that incorporated artificial intelligence into their sales and marketing saw an increase in lead generation by more than 50%, a reduction in their call times of 60% to 70% and overall cost reductions of up to 40% to 60%[xxviii]. This shift not only enhances customer satisfaction but also allows companies to reallocate valuable resources toward areas requiring a human touch, thereby optimizing the balance between automated efficiency and human creativity.

In the realm of cybersecurity, AI introduces innovative methods to safeguard business data. AI-driven security systems can predict and neutralize threats in real-time, learning from each attack attempt to become increasingly efficient. This proactive defense mechanism is crucial in an era where data is one of the most valuable assets a company can possess[xxix].

AI also revolutionizes supply chain management by enabling companies to better predict demand, adjust production, and optimize logistics. This leads to more efficient inventory management, reduced costs, and a heightened ability to quickly adapt to market changes. In marketing, real-time analysis of advertising campaign effectiveness allows for instant adjustments, maximizing investment returns and enhancing consumer engagement in previously unimaginable ways.

Furthermore, AI is reshaping talent management. From recruitment to selection, AI-based systems help identify the most promising candidates and predict their future success within the organization. This makes the hiring process more efficient and less susceptible to biases, enhancing the overall talent pool and contributing to organizational growth.

As Daugherty and Wilson highlight, the value of AI lies not in replacing humans but in augmenting human capabilities and enhancing productivity through human-machine collaboration allowing employees to focus on tasks that require higher cognitive skills, such as strategic planning and creative problem-solving[xxx]. This collaboration between humans and machines not only boosts productivity but also job satisfaction, as employees engage in more meaningful work. By leveraging AI, businesses can unlock new levels of efficiency, creativity, and innovation, paving the way for unprecedented growth and transformation.

CHAPTER TWO

The chapter aims to provide a comprehensive exploration of the multifaceted role of patents in the advancement and dissemination of technological innovation. It is designed to elucidate the following key points:

Fundamentals of Patent Classification: Offering insight into the two primary types of patent Invention. The chapter will clarify the distinctions between them, focusing on their complexity, novelty requirements, and the duration of protection they offer. It will shed light on the specific criteria that innovations must meet to qualify for patent protection, underscoring the importance of novelty, inventive step, and industrial applicability.

Economic Impact of Patents: Discussing the essential role patents play in the economy, the chapter will highlight how they foster a culture of innovation and contribute to economic growth. The analysis will delve into the rise in patent filings over the years and what it signals about the relationship between patents, innovation, and economic performance.

Patents and Knowledge Dissemination: The requirement for detailed public disclosure in patent applications is crucial for the spread of knowledge. The chapter will examine how this aspect of the patent system enables subsequent innovations and drives technological progress.

Challenges Within the Patent System: Recognizing that the patent system is not without its difficulties, the chapter will address issues such as low-quality patents, patent thickets, and potential barriers to technology diffusion that can arise from overly broad or weak patents.

Patent Strategy in Technological Competition: An in-depth analysis will cover how firms adapt their patent strategies in response to competitive pressures. The discussion will pivot around the use of patents not just as defensive tools to block competitors, but also as offensive weapons to preempt rival innovations and as strategic assets in negotiations and litigation.

Strategic Choices in Patenting: Expanding on the concept of patent strategies, the chapter will contrast traditional imitation-blocking strategies with more nuanced approaches like the fence strategy and play strategy. It will explain the circumstances under which firms might opt for one strategy over another and how these strategic choices can impact a firm's competitive advantage and market freedom.

Case Studies and Current Trends: The chapter will draw upon recent data and case studies to illustrate the practical application of these strategies in the current patent landscape, demonstrating the effects of technological competition on firms' patenting behavior.

2.1 CLASSIFICATION AND AIM OF PATENT.

A patent is an intellectual property right that grants the assignee the exclusive right to an invention for a set period. The assignee is typically the inventor, but not always. If the inventor assigns the rights to another person or entity, that assignee holds the exclusive rights [xxxi]. It prohibits others from making, using, selling, or importing the invention without permission. Issued by governments, patents are enforceable in courts to protect inventors' solutions to technical problems.

Patents fall into two categories: Invention Patents and Utility Model Patents. Both require novelty and aim to solve a technical issue but differ in complexity, requirements, and the duration of protection they offer.

Invention Patents are granted for innovations that represent a significant technical advance and require considerable intellectual and possibly financial investment. For an innovation to qualify, it must be entirely novel worldwide, as per Decision 486's article 16, which states, "An invention will be considered new when it is not included in the state of the art."[xxxii] The protection lasts for 20 years from the application date, after which the invention enters the public domain. The criteria for an invention patent include:

- **Novelty:** The invention must not be part of the existing global knowledge base.

- **Inventive Step**: It should not be obvious to someone skilled in the relevant technical field.
- **Industrial Application**: The invention must be applicable in any industry.

Utility Model Patents are awarded to inventions that provide a new technical solution or improvement to an existing product, enhancing its use or incorporating a technological advance. This patent type is less complex than invention patents and has a shorter protection period which depends on the considered patent office.

2.2 Patents and economic growth

Economic growth, especially its long-run sustainability, has long been a focal point of academic researchers and policymakers. Numerous attempts have been made to provide a long list of factors that may have an impact on economic growth. One of these is the relationship between innovation and economic growth, which has been subsequently tested extensively over the years.[xxxiii]. We now know that the engine of long-run economic growth is the process of innovation[xxxiv]. According to Schumpeter, innovation contributes to economic growth through the discovery of new technologies and new products. Along with enhancing economic growth, innovation helps fight social injustices such as poverty, and unequal access to education and healthcare, as well as improving environmental quality. Innovation and economic growth have been proven to have a feedback-type of a relationship, mutually enhancing each other[xxxv].

Indeed, the number of patents is argued as a good indicator to evaluate the success of innovation activities[xxxvi]. However, the patents themselves cannot exert positive impacts on economic growth without the application of these inventions in production[xxxvii]. In other words, an invention needs an application in production or commercialization in order to exert a positive contribution to the development of firms, production systems, and the economy[xxxviii]. For that reason, the contribution of patents to economic growth would not be homogenous across kinds of patents and socio-economic conditions.

For instance, patents in the ICTs sector may have more important roles in leading economic growth in comparison to overall patents exerting a unidirectional causality due to their nature of general-purpose technology and strong networking and spillover effects.

Moreover, the contribution of patents to economic growth may differ across economies with different development stages.

According to Jones and Williams (1998), whose study focuses on the impact of patents on growth, especially ICTs patents, patents are the results of R&D investments or inventions, which can be considered as new ideas[xxxix]. More importantly, patents can only have knowledge spillovers into production if they are applied to production through commercialization. As such, patents are properly not always a capital source or an input of production.

On the one hand, if the commercialization of the inventions protected by patents may lead to new products, new ways of productions, or new models of business, which would properly contribute significantly to productivity as explained in several studies. Importantly, the applications of ICT inventions (even patent or not patent) would bring not only benefits for the ICT sector, but they would also bring enormous benefits for other sectors as the nature of general-purpose technologies[xl].

As the result, patents, especially ICTs patents, can contribute to output growth through productivity growth following the standing on shoulders effect.

On the one hand, the commercialization of inventions protected by patents can lead to new products or a new ways of production, which would significantly contribute to productivity, as explained in several studies. Importantly, the applications of ICT inventions (whether patented or not) bring benefits not only to the ICT sector but also to other sectors, due to the nature of general-purpose technologies. As a result, patents, especially ICT patents, can contribute to output growth through productivity growth, following the "standing on shoulders" effect.

On the other hand, if patents cannot be commercialized into production, it can lead to situations such as the "fishing out" effect and congestion externality. The "fishing out" effect refers to the diminishing returns in research and innovation activities over time. As more patents are filed and the most straightforward innovations are commercialized, it becomes increasingly difficult to find new, groundbreaking innovations, requiring significantly more effort and resources. This can lead to wasted efforts and resources if the resulting patents cannot be applied or utilized in the market.

Congestion externality occurs when an increase in the number of users of a resource leads to negative effects for all users. In the context of patents, this means that a crowded research environment can create legal disputes and barriers to entry due to overlapping intellectual property rights. This stifles innovation rather than promoting it, as the complexities and costs associated with navigating existing patents discourage new entrants and hinder the development of new technologies.

In this case, if patents cannot be commercialized, they cannot contribute to economic growth, following the "stepping on toes" effect. This effect refers to the negative impact on innovation when too many researchers or entities work on overlapping projects, leading to congestion and reduced overall productivity. Therefore, the inability to commercialize patents prevents them from driving economic expansion and contributing to productivity growth.

Another study made by Jamel Trabelsi, published in the Economics Bulletin (2024), examined the effects of patents on economic growth across 43 countries from 1998 to 2016. It specifically investigated the impacts of both total patents and those in Information and Communication Technology (ICT) industries on real GDP growth and per capita GDP growth, as well as on the growth rates of the manufacturing and services sectors[xli].

The findings reveal three significant insights. Firstly, there exists a mutual bi-directional causal relationship between total patents and economic growth, whereas ICT patents demonstrate a uni-directional causal effect on economic growth. Secondly, total patents positively influence economic growth in both emerging and advanced economies, though the impact is more pronounced in the latter. In contrast, ICT patents primarily drive growth in advanced economies. Thirdly, the study discovered that while ICT patents significantly enhance economic growth over the long term, the same cannot be said for total patents.

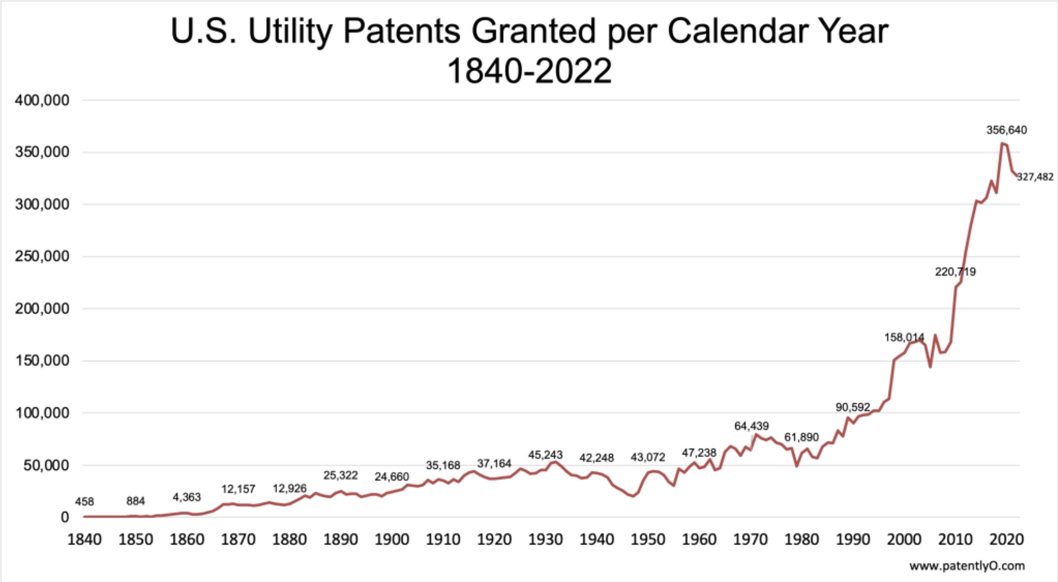
These results underscore the critical role of new knowledge creation, as measured by patent activity, in driving economic growth, particularly in advanced economies. Technological innovations in ICT are deemed vital for the advancement of these economies. However, emerging economies appear less equipped to leverage the benefits of such innovations, possibly due to limited absorptive capacity influenced by institutional, financial, and infrastructural factors[xlii]. Enhancing the development of the ICT sector could greatly benefit economies in the long term. Thus, fostering conditions conducive to both public and private investment in the ICT sector is recommended for all countries, with a particular emphasis on emerging market economies.

Furthermore, the study acknowledges a limitation in its scope due to focusing on a substantial but not globally encompassing sample of 43 economies, excluding some major ones like China due to data constraints. Future research could expand this investigation to include such economies to further elucidate the role of ICT patents in economic growth.

2.3 The Role of Patents in Technological Innovation

Patents stand as foundational pillars in the landscape of technological innovation and economic growth, serving as critical mechanisms for safeguarding inventions while fostering a culture of innovation[xliii]. The surge in patent applications, particularly in fields like information and communications technology (ICT) and biotechnology, reflects the growing role of patents in innovation and economic performance. During the last 20 years, patent filings increased year by year, indicating the increasing reliance of businesses and public research organizations on patents to protect their inventions. This trend is tied to the evolving nature of innovation processes, which have shifted from being centered around individual firms to depending more on global networks of public and private sector actors[xliv]. Such changes are closely linked to scientific advancements and shifts in patent regimes that have expanded the domains of patentable subject matter to include new areas like software and biotechnology, resulting in stronger and more valuable patents.

GRAPH 2.1



Retrieved from: United States Patent and Trademark Office (USPTO).

This chart shows the overall growth of patents filed in the US, which can be a proxy for overall technological innovation.

Patents are crucial for promoting technological advancement and economic growth by enabling a monetization strategy for inventions. Inventors can generate revenue through licensing agreements, thereby securing a competitive edge for companies, and attracting further investment[xlv]. The requirement for inventors to disclose detailed information about their technologies also plays a significant role in knowledge sharing, facilitating subsequent innovation and accelerating technological progress[xlvi].

However, the patent system faces challenges, including the issuance of patents that may lack novelty or are excessively broad, potentially stifling innovation and creating barriers to technology diffusion. Concerns have been raised about patents in emerging technology areas, such as software and genetics, where rapid changes have made it difficult for patent offices to maintain institutional expertise and for courts to establish appropriate standards. The increased patenting activity also raises questions about the system's impact on knowledge diffusion, particularly when patents may restrict access to basic technologies and research tools. For instance, Low-quality patents are those that protect inventions of limited novelty or that provide overly broad protection. Low quality patents can be costly to society. Their proliferation not only swells the number of patents and patent applications that must be reviewed by potential innovators and patent offices, but also creates uncertainty about the validity and enforcement of patents more generally[xlvii]. The societal benefits of such patents are likely to be low, but they can nevertheless be leveraged by their holders for rent-seeking purposes: they may be used as a threat against other companies, especially small ones, or as part of patent thickets for closing market access to potential competitors.

2.4 Technological competition and patent strategy: Protecting innovation, preempting rivals and defending the freedom to operate.

Drawing from the resource-based view of the firm, this analysis explores how technological competition influences a firm’s patenting strategy, particularly focusing on the play and fence strategies in discrete and complex industries. This shift is essential for firms to maintain competitive advantage amidst increasing R&D competition.

The traditional strategy involves using patents to protect innovations from imitation, ensuring the firm can capitalize on its R&D investments. This strategy relies on securing the exclusive rights to exploit proprietary technologies, thereby creating a competitive barrier to market entry for rivals[xlviii].

Technological competition, where multiple firms concurrently develop similar technologies, complicates the landscape. In such environments, merely protecting innovations from imitation becomes insufficient. Instead, firms need to consider additional strategies to safeguard their market positions and R&D investments.

The play strategy involves using patents as bargaining tools rather than solely for protection against imitation. This approach varies between discrete and complex industries. In discrete industries, with clear, standalone products (e.g., pharmaceuticals), the play strategy can help firms secure freedom to operate by avoiding hold-ups from other patent owners[xlix]. Firms in these industries may use their patents to negotiate cross-licensing agreements, ensuring they can access essential technologies without litigation. In complex industries, where products consist of numerous interrelated technologies (e.g., electronics), the play strategy is crucial. Firms use patents as leverage in IP litigation, increasing their bargaining power and reducing the risk of being blocked by other patents[l]. Cross-licensing becomes a strategic necessity to navigate the intricate web of interdependent technologies.

The fence strategy aims to create a patent fence around existing technologies to preempt competition and block substitute inventions[li]. This strategy also varies between discrete and complex industries. In discrete industries, the fence strategy can be particularly effective in blocking direct competitors from developing similar products. By creating a perimeter of patents around a core technology, firms can preempt rivals from introducing substitute products, thereby securing market exclusivity[lii]. In complex industries, the fence strategy is used to cover different technical solutions achieving similar functional outcomes. This approach not only blocks competitors but also increases the transaction costs associated with licensing. Consequently, firms can maintain exclusivity over their technological domain, making it harder for rivals to introduce alternative innovations.

Choosing between these strategies depends on several factors. Technological complexity is a key consideration; complex industries characterized by interdependent technologies might favor play strategies to navigate the dense patent landscape and ensure operational freedom[liii]. The type of industry also plays a role; discrete industries with more straightforward technology applications might lean towards traditional or fence strategies to directly block competitors and secure market share. Additionally, the proximity of competition to a firm's core technology influences strategic choice. When competition targets areas close to a firm's core technology, a fence strategy is more likely to be adopted to preempt substitutes and protect the firm’s technological base[liv].

Understanding the conditions that favor each strategy is crucial for firms to effectively manage their patent portfolios. Different strategies imply varying costs, risks, and potential benefits[lv]. The traditional strategy has lower transaction costs and focuses on direct market protection. The play strategy involves higher litigation and negotiation costs but provides increased flexibility and bargaining power, particularly important in complex industries. The fence strategy incurs higher initial costs due to broad patent coverage but offers significant long-term exclusivity benefits, especially in discrete industries.

In conclusion, technological competition demands a nuanced approach to patenting strategy. Firms must carefully evaluate their industry context, the nature of technological competition, and their core competencies to choose the most suitable patenting strategy. By leveraging the right mix of traditional, play, and fence strategies, tailored to the specific challenges of discrete and complex industries, firms can enhance their competitive advantage and better capture value from their R&D investments.

GRAPH 2.2

Table 1. Definition of patent strategies.

Type of strategy	Reasons for patenting	Use of the patent
Traditional strategy		(In-house Commercial use) & (No other uses)
Fence strategy	(Blocking patents or Preventing imitation by inventing around) & No Licensing or cross-licensing	Unused
Play strategy	(Blocking patents or Preventing imitation by inventing around or Pure defense or Prevention of infringements suits) & Cross-licensing	Cross-Licensing & (No In-house Commercial use & No other uses) or Unused

Retrieved from: https://doi.org/10.1016/j.respol.2023.104785

CHAPTER THREE

3 Research Methodology Introduction

In this chapter, we explore the methodology and data sources underpinning our research on the relationship between Artificial Intelligence (AI) and the patent system.

To systematically analyze patenting trends in AI, we relied on the PATSTAT (Patent Statistical Database) maintained by the European Patent Office (EPO). PATSTAT is a comprehensive global database that enables researchers to track and analyze patent filings across jurisdictions. It contains bibliographic data from over 100 patent offices worldwide and includes information on patent applications, legal status, and citations. PATSTAT gathers its data from multiple sources, including national patent offices and international organizations like the World Intellectual Property Organization (WIPO), to provide a holistic view of global patenting activity.

For our analysis, we focused on key variables within PATSTAT, including:

- **Application Details**:
  - Application ID: Unique identifier for each patent application.

- Application Authority: Country or organization where the patent was filed.
- Application Number: Patent application number.
- Filing Year: Year the patent application was filed.

- **Applicant and Inventor Details**:
  - Person Country Code: Country code representing the applicant's or inventor's location.
  - Person ID: Unique identifier for each applicant or inventor.
  - Person Name: Name of the applicant or inventor.
- **Geographic Information**:
  - NUTS Codes: Regional codes representing geographic locations within Europe.
- **Content Information**:
  - Title: Title of the patent application.
  - Abstract: Summary of the invention.

After extracting relevant data from PATSTAT, we utilized Excel for further analysis. Our data elaboration process involved data cleaning (removing duplicates, handling missing values, and standardizing classifications) and grouping and aggregation (by filing date, technology class, and applicant country).

In the final part of this chapter, there will be a discussion and a conclusion that provide insights into the trends and implications of AI innovation within the patent landscape.

3.1 Data Collection

Each of these columns below serves a specific function in organizing and providing access to detailed information about patent applications, their applicants, and associated geographical data within the context of this SQL database. The SQL query itself is joining several tables to compile a comprehensive view of patent applications, combining titles, abstracts, and person details, which are filtered and shown in the results table.

SQL basic concepts:

- **appln_id**: This appears to be a unique identifier for each application. It's a common practice in databases to have a unique identifier for each record, which in this context seems to be for patent applications.
- **appln_auth**: This column likely represents the authority or the office where the patent application was filed. For example, "EP" stands for the European Patent Office, "US" for the United States Patent and Trademark Office.
- **appln_nr**: This is the application number assigned by the patent office. It uniquely identifies a patent application within a particular authority.
- **appln_filing_year**: The year in which the patent application was filed.

- **person_ctry_code**: The country code for the person associated with the patent application. This could be the inventor or the applicant, depending on the context of the database. (IT: Italy, DE: Germany, FR: France, ES: Spain, GB: United Kingdom, NL: Netherlands, SE: Sweden, FI: Finland, CH: Switzerland, NO: Norway, BE: Belgium, AT: Austria, PL: Poland).
- **person_id**: A unique identifier for the person related to the patent application.
- **person_name**: The name of the person associated with the patent application.
- **nuts**: This typically stands for the Nomenclature of Territorial Units for Statistics, which is a geocode standard for referencing the subdivisions of countries for statistical purposes by the European Union. In this context, it might relate to the geographical area associated with the person or the patent application within Europe.

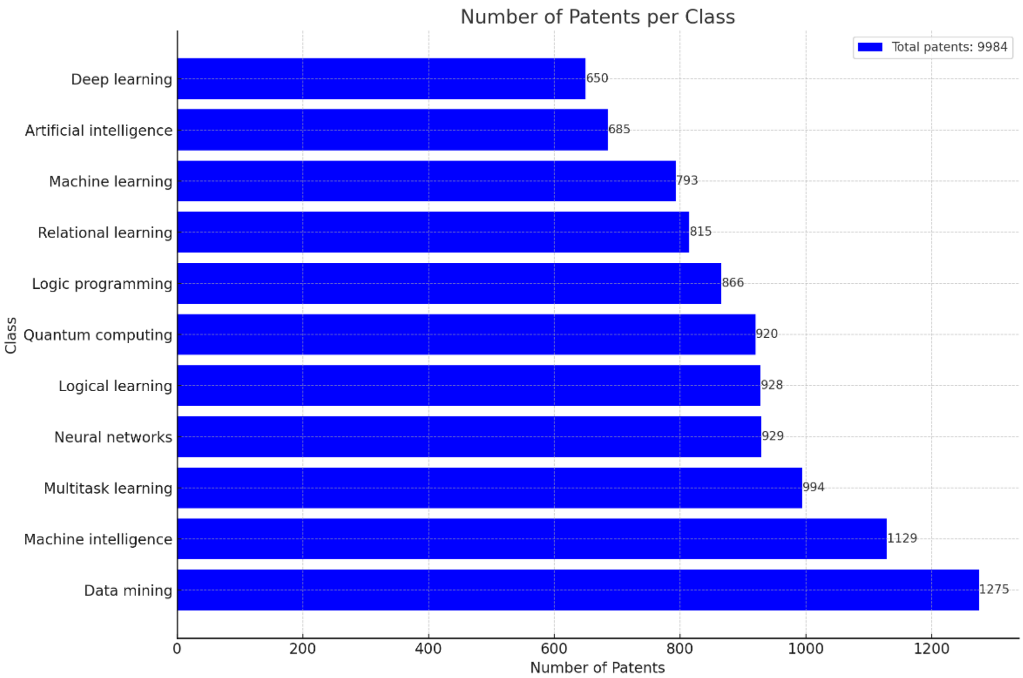
GRAPH 3.1

Row	appln_id	appln_auth	appln_nr	appln_filing_year	appln_title	appln_abstract	person_ctry_c...	person_id	person_name	nuts
1	596293413	US	202217849397	2022	Machine learnin...	Two-dimensiona...	AT	79503382	Presenhuber, M...	AT
2	596293413	US	202217849397	2022	Machine learnin...	Two-dimensiona...	AT	79503248	Habenschuss, S...	AT
3	596293413	US	202217849397	2022	Machine learnin...	Two-dimensiona...	AT	89023924	BAZRAFKAN, S...	AT
4	596287917	US	202217648920	2022	METHODS AN...	Methods and sy...	FI	89137356	Vaananen, Heik...	FI
5	596287222	US	202217581759	2022	Deep Learning ...	A Deep Learnin...	NL	79564283	Zonooz, Bahram	NL
6	596287222	US	202217581759	2022	Deep Learning ...	A Deep Learnin...	NL	89200299	Gowda, Shruthi	NL
7	596287222	US	202217581759	2022	Deep Learning ...	A Deep Learnin...	NL	77862859	Arani, Elahe	NL
8	596287068	US	202318159651	2023	DATA-DRIVEN ...	One embodime...	CH	89053769	ZOSS, Gaspard	CH
9	596287024	US	202217929702	2022	METHOD FOR ...	A computer impl...	GB	79574309	HASLAM, Niall	UK
10	596287024	US	202217929702	2022	METHOD FOR ...	A computer impl...	GB	81808759	COOMBER, Cat...	UK

Retrieved from: https://www.epo.org/en/searching-for-atents/business/patstat

The title and abstract of the patent have not been considered, as they will not be useful for our future processing and research in Excel, However, the keywords used for the search include:

GRAPH 3.2



By using these keywords in our queries, we were able to filter and retrieve patent applications that are relevant to our areas of interest in artificial intelligence.

3.2 Data elaboration.

The dataset includes data from the years 2015 to 2023. We did not consider data from years prior to 2015 because they were not deemed significant for our research. In our research, only European countries were considered, excluding countries such as China, Japan, and the USA due to the overwhelming abundance of data. The sheer volume of information from these countries would have made the data processing and analysis exceedingly complex and resource intensive. Only the total number of patents will be considered to provide a unit of measure comparable to the European countries. As will be demonstrated later, the information we have extracted from the database are sufficient to achieve satisfactory results.

To proceed with the data processing, we utilized Microsoft Excel, following a series of fundamental steps.

First, in the **data preparation** phase, we organized the data in an Excel sheet. Each relevant variable, such as Country, Year, and Number of Patents, was assigned a specific column header. This structured format ensured that our dataset was both organized and easy to navigate.

Next, we moved on to **data cleaning**. This step involved removing any rows and columns that contained irrelevant data or data that fell outside our period of interest, specifically data prior to 2015. Additionally, we conducted a thorough check to ensure that there were no duplicate entries or missing values in our dataset. This step was crucial in maintaining the integrity and accuracy of our analysis.

In the **data filtering** stage, we applied Excel's filtering tools to focus exclusively on European countries, deliberately excluding data from China, Japan, and the USA. The auto-filter feature in Excel, accessible via the Data tab, was instrumental in this process. By doing this, we were able to streamline our dataset and make it more manageable for analysis.

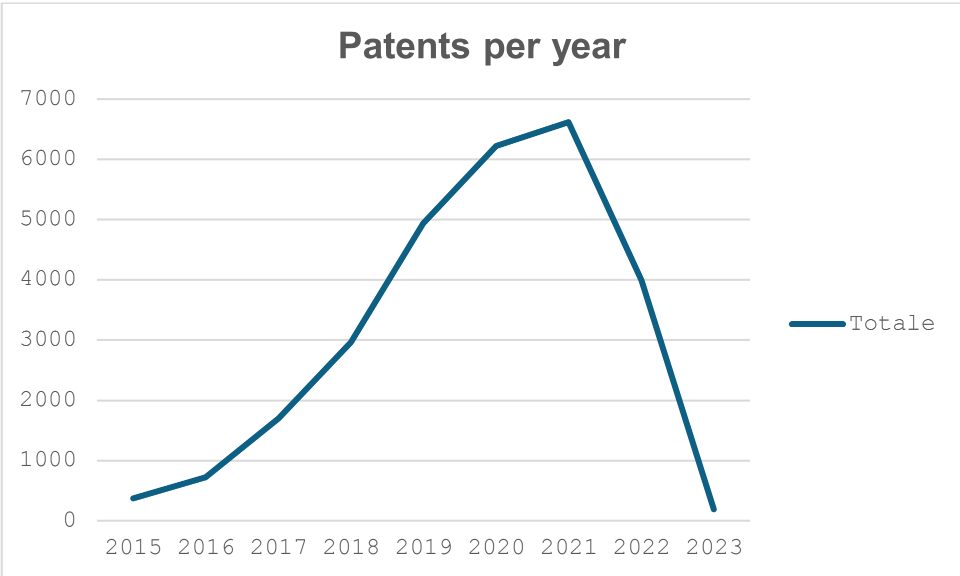
With the filtered data, we proceeded to the **data analysis** phase. Several key analyses were conducted at this stage using bar charts to compare the data between various European countries, allowing us to visualize how different countries stood in relation to one another.

Creating **pivot tables** was another important step in our process. These tables allowed us to summarize and analyze the data efficiently. We configured the pivot tables to display the data organized by Country and Year, with the number of patents as the main value. This configuration enabled us to extract meaningful insights from the dataset with ease.

Finally, we focused on **visualizations**. Various charts were created to illustrate the results of our analyses. These visual aids were included in the document to help convey the trends and comparisons more effectively. By presenting the data visually, we aimed to make the information more accessible and understandable for our audience.

3.2.1 PATENTS PER YEAR

GRAPH 3.3



The chart shows the number of patent applications filed each year from 2015 to 2023. Initially, the number of patent applications grows steadily. In 2015, there are 368 applications, and the number continues to increase over the next five years, peaking in 2020 with 6,224 applications. After 2020, a downward trend is observed, with the number of applications decreasing progressively: in 2021, it drops to 6,617, in 2022 to 3,996, and finally, in 2023, there is a drastic drop to only 189 applications.

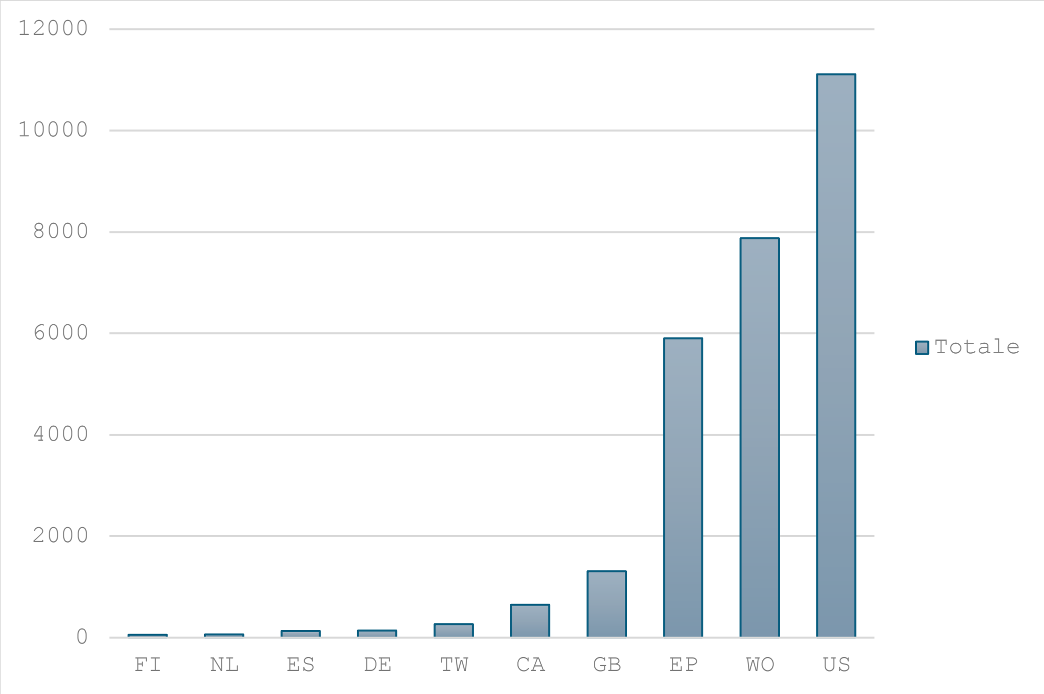
This significant decrease in recent years can be partially explained by the increase in the number of patents granted. Since we are considering granted patents and the time it takes for a patent application to become granted is on average 4 years, the number decreases because the elapsed time is not sufficiently long (less than 4 years). A granted patent is the result of the patent application process, which includes the following stages: filing the application, examination of the application by the patent office, and finally, granting the patent if the invention meets all legal and technical requirements[lvi]. A granted patent gives the holder exclusive rights to the invention, including the ability to produce, use, and sell the invention for a certain period, usually 20 years from the application filing date.

The increase in the number of patents granted has several implications that can affect the number of new patent applications. Firstly, with more patents already granted, the market can become more saturated, reducing opportunities for new patentable inventions. Companies, seeing that the areas for patentable innovation are decreasing, may choose to focus their efforts on protecting and utilizing existing patents rather than investing in new patent applications.

Moreover, business strategies can change accordingly. Instead of aiming for new patent applications, companies may focus on optimizing and innovating within the patents they already own. This strategic shift can further contribute to the reduction in the number of new patent applications[lvii].

3.2.2 The distribution of patent applications based on the authority.

GRAPH 3.4



The chart shows the number of AI patents filed by European inventors at various patent authorities around the world, highlighting the distribution of patent applications based on the authority to which they were submitted. Patent authorities are entities that examine patent applications and, if approved, grant patents, giving inventors exclusive rights to their inventions.

The graph highlights some interesting trends. For instance, during the period considered, the United States received the highest number of patent applications from European inventors, with a total of 11,110 applications. This is followed by the World Intellectual Property Organization (WIPO) with 7,876 applications and the European Patent Office (EPO) with 5,902 applications. Other countries, such as the United Kingdom (1,310 applications), Canada (648 applications), and Germany (141 applications), received fewer applications but still a significant number. Furthermore, it clearly reflects how European inventors file a substantial number of patent applications in the United States and at international organizations like WIPO and EPO. This indicates a strategy aimed at obtaining global protection for their inventions, maximizing commercial potential and legal protection. The process of filing a patent varies slightly from one authority to another, but generally requires a detailed description of the invention, the claims, technical drawings, and payment of the relevant fees.

Process Overview

The process of obtaining a patent involves several critical steps that ensure the invention is worthy of legal protection. Patent authorities rigorously examine each application to verify that it meets specific criteria before granting a patent. Here is an overview of the key stages involved in this process:

- **Filing the Application**: The inventor submits a patent application to the relevant authority. This application must contain a detailed description of the invention, a claim of what is intended to be protected, and often technical drawings.
- **Examination**: The patent authority examines the application to ensure that the invention meets legal and technical requirements, such as novelty, originality, and usefulness.
- **Granting the Patent**: If the invention is approved, the authority grants the patent, giving the inventor exclusive rights for a certain period, usually 20 years from the application filing date.

3.2.3 How to File a Patent with Different Authorities

❖ **United States (US)**

To file a patent application in the United States, you need to contact the United States Patent and Trademark Office (USPTO). The application can be submitted online via the USPTO's electronic filing system (EFS-Web). It is important to include a detailed description of the invention, the claims, technical drawings, and pay the filing fees.

❖ **World Intellectual Property Organization (WO)**

WIPO manages the Patent Cooperation Treaty (PCT), which allows you to file a single application valid in many countries. To file a PCT application, you can use WIPO's ePCT system. This process simplifies international patent filing, allowing inventors to obtain protection in multiple countries with one application.

❖ **European Patent Office (EP)**

The European Patent Office (EPO) allows you to obtain patents valid in multiple European countries with a single application. The application can be filed online through the EPO's electronic filing system. The procedure requires a detailed description of the invention, the claims, technical drawings, and payment of the filing fees.

❖ United Kingdom (GB)

To file a patent application in the United Kingdom, you need to contact the UK Intellectual Property Office (IPO). The application can be submitted online via the IPO's electronic filing service. As with other authorities, it is necessary to include a detailed description of the invention, the claims, technical drawings, and pay the filing fees.

❖ Canada (CA)

In Canada, the relevant authority is the Canadian Intellectual Property Office (CIPO). Applications can be submitted online via CIPO's electronic filing system. The application must also include a detailed description of the invention, the claims, technical drawings, and payment of the filing fees.

❖ Germany (DE), Spain (ES), Netherlands (NL), and Finland (FI)

The patent authorities in these countries follow similar procedures. Applications can be submitted online via their respective electronic filing systems and must include a detailed description of the invention, the claims, technical drawings, and payment of the filing fees.

3.3 The Strategic Importance of Registering Patents with Various Patent Authorities.

Registering a patent with various patent authorities is a strategic move for inventors and companies. This practice offers numerous benefits beyond the simple legal protection of the invention. A patent grants the holder exclusive rights to the invention, preventing others from making, using, selling, or importing the invention without permission. This helps protect investments in research and development and maintain a competitive[lviii].

In an increasingly competitive global market, obtaining a temporary monopoly on the invention can translate into a significant commercial advantage. This monopoly allows the holder to exclusively capitalize on the patented product or process, thereby increasing sales and profits[lix]. Extending the protection of the invention internationally is crucial for companies operating in multiple markets or planning to expand globally. Filing a patent in different jurisdictions allows covering more territories, protecting the invention from imitations and illegal copies in those countries.

Patent protection not only attracts investors and commercial partners but can also generate revenue through licenses and royalties. A strong patent portfolio demonstrates innovation and a solid technological foundation, making the company more attractive to investors[lx]. Additionally, licensing a patent to other companies can be a significant source of passive income, allowing the economic exploitation of the invention without the need for direct production. This type of protection also facilitates the creation of partnerships and joint ventures, as companies are more willing to collaborate if the invention is legally protected, reducing the risks of misappropriation.

The main reason a European inventor might want to file a patent with different authorities is to obtain global legal protection for their invention[lxi]. For example, the United States represents one of the largest markets in the world, so obtaining a patent with the USPTO can be crucial for protecting the invention in this influential market.

The PCT system of WIPO allows filing a single patent application valid in many countries, simplifying the international protection process, and reducing initial costs. The European Patent Office (EPO) allows obtaining a patent valid in multiple European countries with a single application, which is particularly useful for companies operating in the unified European market[lxii]. Obtaining a patent in the United Kingdom is important for protecting the invention in one of the major European markets, especially after Brexit.

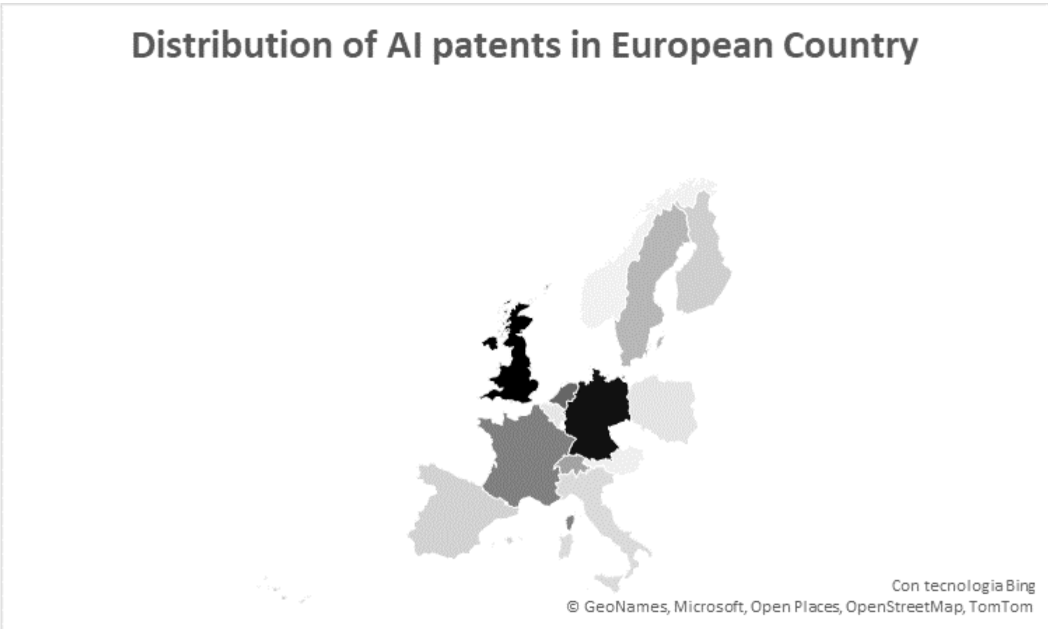
The Canadian market can be significant, especially for companies also operating in the United States, given the geographical proximity and close commercial relationships between the two countries.

Protecting an invention in countries like Germany, Spain, the Netherlands, and Finland, which have advanced economies and strong industrial sectors, is crucial for companies operating in Europe and wishing to safeguard their interests in technologically advanced markets.

To sum up, registering a patent with various patent authorities offers a wide range of benefits, from legal protection to revenue generation and the strengthening of collaborations. Extending protection internationally is a key strategy to maximize the value of an invention and ensure that it is protected in all relevant markets[lxiii]. This strategy not only protects the invention but also promotes innovation, attracts investments, and allows companies to maintain a competitive advantage in a global market.

3.3.1 The Distribution of Patents in European Countries

GRAPH 3.4



The chart shows the number of AI patents registered in various countries, indicated by the country code, such as DE for Germany, GB for the United Kingdom, FR for France, and so on, visually illustrated with darker shades of red indicating a higher number of patents.

Germany stands out with 7002 patents, represented by the darkest shade of red on the map, followed by the United Kingdom with 6863 patents. France, with 2927 patents, and the Netherlands, with 2716 patents, follow at a distance, while Switzerland, Sweden, Finland, Spain, Italy, Poland, Belgium, Austria, and Norway register progressively fewer patents.

There are multiple reasons why some countries register fewer patents than others. Investments in research and development (R&D) are a crucial factor: countries like Germany and the United Kingdom invest heavily in this sector, leading to a higher number of innovations and thus patents[lxiv]. Conversely, countries with lower investments in R&D see a correspondingly lower number of patents. The size of the economy and the population also play a significant role. Larger economies and populations tend to produce more patents, while countries with smaller economies and populations, like Norway or Austria, have fewer patents.

The support infrastructure for innovation is fundamental. The presence of universities, research centers, startup incubators, and technology hubs contributes to the number of patents. Countries with well-developed infrastructures in this area register more patents[lxv]. Government policies and incentives are another determining factor. Government policies and incentives that promote innovation, such as research grants and tax breaks for innovative companies, positively influence the number of patents. For example, countries like Germany and the United Kingdom offer generous research and development grant programs and tax breaks for innovative companies. In Germany, there is the "ZIM" program (Zentrales Innovationsprogramm Mittelstand), which provides significant funding to small and medium-sized enterprises (SMEs) for research and development projects[lxvi]. Similarly, the United Kingdom has the "Patent Box," a tax scheme that allows companies to pay a reduced tax rate on profits derived from patents, thus encouraging companies to invest in innovation and intellectual property protection. In France, the "Crédit d'Impôt Recherche" (CIR) offers tax credits for research and development expenditure, making it more convenient for companies to invest in new technologies and register patents[lxvii]. The Netherlands has introduced the "WBSO" (Wet Bevordering Speur- en Ontwikkelingswerk), a tax incentive program that reduces labor costs for research and development activities.

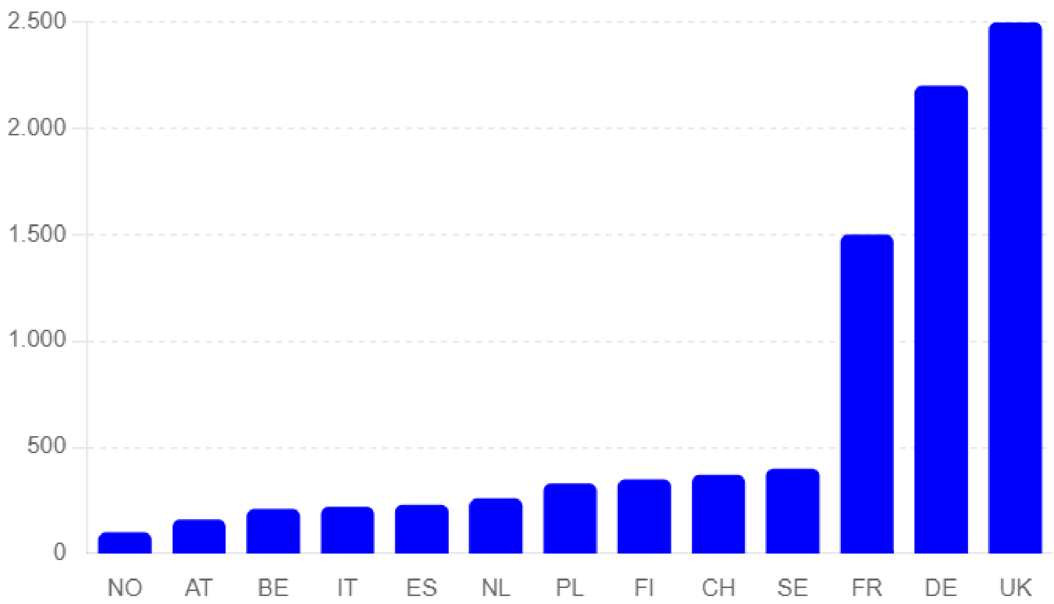
The culture of innovation also plays an important role. A culture that promotes innovation and intellectual property protection encourages people to patent their inventions. For example, countries with a strong entrepreneurial culture, like the United States and Israel, see a high rate of patent registration[lxviii]. This culture is often supported by an educational system that emphasizes creativity and entrepreneurship, as well as a strong network of incubators, accelerators, and venture capital that provide the necessary support to turn innovative ideas into commercial realities. In some countries, awareness of the importance of patents and intellectual property protection is less pronounced. In fact, in some emerging economies, companies might not be as familiar with the patent registration processes or might lack the necessary resources to pursue intellectual property protection. This can lead to a lower number of registered patents, despite the presence of significant innovations.

Finally, the predominant industrial sectors in each country influence the number of patents. Countries with high-tech industries, such as engineering, information technology, and biotechnology, tend to register more patents compared to those with economies based on less innovative sectors[lxix].

3.3.2 Top 20 NUTS By Number Of Patents in Europe

GRAPH 3.5

AI PATENTS BY NUTS



The chart illustrates the number of unique patents registered for different NUTS codes, showing a clear picture of patent distribution across various regions. Notably, the UK stands out with the highest number of patents, boasting over 2,500. Following the UK, Germany (DE) has around 2,200 patents, and France (FR) holds approximately 1,500 patents. Other significant regions include Switzerland (CH), the Netherlands (NL), and Sweden (SE), each contributing substantially to the patent landscape.

What's particularly interesting about this data is that it considers the addresses of the inventors or assignees. This detail provides valuable insight into where the inventions are actually being made, highlighting the key innovation hubs within these regions. By analyzing the origin of these patents, we can better understand the geographical distribution of inventive activity and recognize the areas that are driving technological advancements.

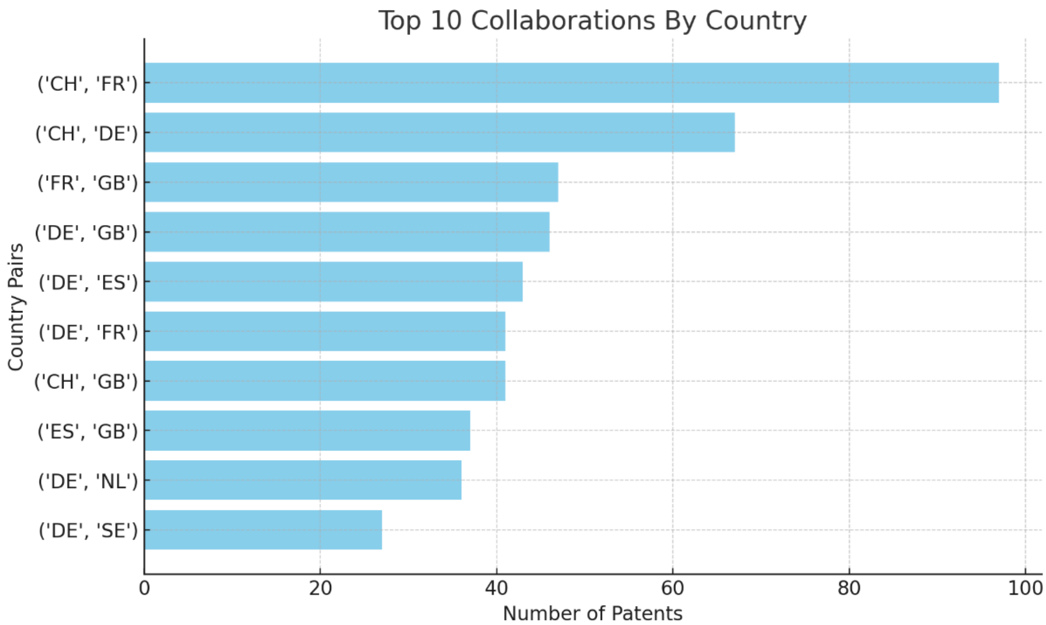
NUTS, an acronym for Nomenclature of Territorial Units for Statistics, is a geographical classification used by the European Union to divide the territories of its member states for statistical purposes[lxx]. This subdivision allows for regional analyses and comparisons between different areas. The NUTS codes are organized into three levels: NUTS 1, representing large socio-economic regions such as entire countries or macro-regions; NUTS 2, corresponding to basic regions for regional policies such as administrative regions; and NUTS 3, identifying small regions for specific diagnoses such as provinces or districts.

For example, DE11 corresponds to Stuttgart in Germany, a region known for its strong automotive and technological industry. FR10 represents Île-de-France in France, including Paris, the country's economic and technological heart

These data reflect how technological innovation and research are concentrated in regions with strong economic foundations, advanced infrastructure, and the presence of academic and research institutions. Regions with a high number of patents tend to be those with high economic and industrial activity, facilitating investment in research and development[lxxi]. According to an article in the Financial Times, metropolitan regions tend to be hotspots of innovation due to the concentration of resources and talent. Additionally, an OECD report highlights how the concentration of research and development activities in these areas is a key factor for their global competitiveness[lxxii].

3.3.3 Top 10 Patent Collaborations

GRAPH 3.6



The horizontal bar chart titled "Top 10 Collaborations By Country" visually represents the number of patents where all inventors come from different countries. This chart focuses on the top 10 combinations of countries that collaborate on patents, showing how frequently inventors from these different countries work together.

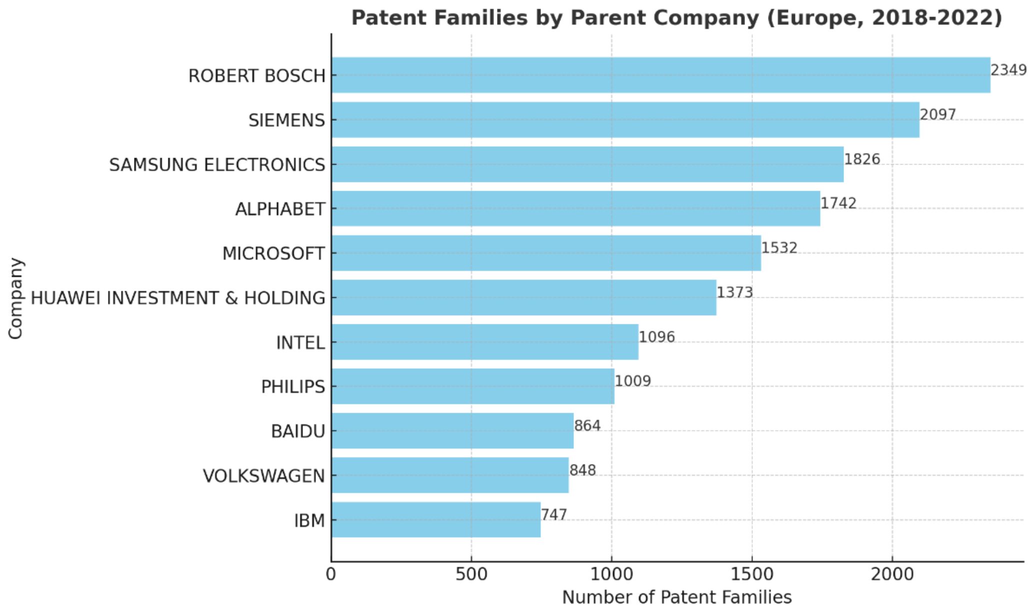
The horizontal axis at the bottom of the chart represents the number of patents. Each bar's length corresponds to the number of patents collaboratively created by inventors from the countries listed on the vertical axis. The vertical axis on the left lists the combinations of countries, showing which countries' inventors collaborated on these patents.

The bars are colored in a sky-blue shade, making them visually appealing and easy to distinguish against the background. The y-axis is inverted, meaning the combinations with the highest number of patents are at the top, making it easy to quickly identify the most prolific international collaborations.

It shows the top 10 country combinations based on the number of patents they have collaboratively produced. Each bar's length clearly indicates the number of patents for that specific combination. Longer bars represent a higher number of patents, highlighting which country combinations are most active in collaborative patent creation. This visualization helps us see trends in international collaboration among inventors, showcasing which pairs or groups of countries are most frequently working together to innovate and create new patents.

3.3.4 AI Patents by Parent Company in Europe.

GRAPH 3.7



The chart displays the number of AI patent families registered by various companies from 2018 to 2022, reflecting their commitment and involvement in AI-related innovations in Europe.

Among the top 11 companies, Robert Bosch leads with 2349 patent families, demonstrating a strong focus on innovation and intellectual property in AI. Siemens follows with 2097 patent families, highlighting substantial engagement in AI-related R&D across a wide spectrum of applications and technologies. Samsung Electronics, a major player in the electronics industry, has 1826 AI-related patent families, reflecting its involvement in AI technologies across various products and services. Alphabet, the parent company of Google, has 1742 AI-related patent families, aligning with Google's focus on AI-driven technologies including machine learning, natural language processing, and other AI applications. Microsoft, with 1532 patent families, indicates a strong focus on AI R&D, showing a broad range of AI technologies and applications.

Huawei Investment & Holding has 1373 patent families, indicating extensive involvement and a wide scope of AI technologies developed. Intel follows with 1096 patent families, showing its commitment to technological innovation and the development of advanced AI solutions. Philips has registered 1009 patent families, indicating significant engagement in AI technologies, particularly in the healthcare sector. Baidu, with 864 patent families, demonstrates a strong presence in the AI field, especially in internet search and applications. Volkswagen holds 848 patent families, signaling a growing interest in integrating AI technologies in the automotive sector. IBM, with 747 patent families, continues to be an important player in AI innovation, focusing on various technological applications.

In cocnlusion, higher numbers of AI-related patent families suggest extensive involvement and a broader scope of AI-related technologies for each company. These numbers underscore the importance of AI innovation across various industries, from electronics and technology to healthcare and automotive, in Europe.

Technology Domain By Assignee

GRAPH 3.8

Players/Technology domain	Computer technology	Measurement	Digital communication	Telecommunications	Control	Medical technology	IT methods for management	Transport	Electrical machinery, apparatus, energy	Audio-visual technology	Handling
ROBERT BOSCH	1550	453	93	74	512	29	93	442	18	56	92
SIEMENS	1373	341	131	39	471	443	181	104	105	20	58
SAMSUNG ELECTRONICS	1499	116	404	334	120	80	137	65	0	257	24
ALPHABET	1615	130	351	185	121	83	190	24	1	141	67
MICROSOFT	1389	53	400	105	68	34	259	8	395	102	10
HUAWEI INVESTMENT & HOL	910	85	483	422	72	19	55	62	0	106	12
INTEL	980	68	213	141	97	15	39	56	0	84	23
PHILIPS	671	147	36	26	46	547	48	3	114	17	4
BAIDU	837	81	111	29	102	4	110	69	0	37	4
VOLKSWAGEN	416	183	28	60	230	25	59	438	1	23	11

Retrived from: https://questel-website.s3.eu-west-3.amazonaws.com/table_patent_mapping_ai_patent_technology_b752698586.png

The chart provides a comprehensive overview of the technological domains in which various leading companies have concentrated their patent families. It categorizes the patent families into several key technology areas: computer technology, measurement, digital communication, telecommunications, control, medical technology, IT methods for management, transport, electrical machinery, apparatus, and energy, audio-visual technology, and handling, highlighting their contributions to various fields of technology.

3.3.5 Top 10 Assignees of U.S. Patents in 2023 by Number of Patents Granted

GRAPH 3.9

RANK	ORGANIZATION	2023 PATENTS	CHANGE FROM 2022
1	SAMSUNG ELECTRONICS CO., LTD.	9036	5%
2	LG CORPORATION	4170	-9%
3	INTERNATIONAL BUSINESS MACHINES	3953	-15%
4	QUALCOMM	3886	46%
5	TAIWAN SEMICONDUCTOR MFG. CO.	3719	22%
6	CANON K.K.	3199	5%
7	TOYOTA JIDOSHA K.K.	2667	-12%
8	ALPHABET INC.	2579	23%
9	APPLE INC.	2568	11%
10	HUAWEI TECHNOLOGIES CO., LTD.	2290	-24%

Retrieved from: https://www.uspto.gov/.

The patent landscape is undergoing a period of upheaval, with new players emerging and old powers giving way. To compare the data with American patents, it is important to consider some potential differences in the definition and classification of artificial intelligence technologies. In the United States, a different definition of AI might be used, which could include or exclude certain technologies compared to the context analyzed. This can lead to significant variations in the number and type of patents registered, thereby affecting the overall results of comparative analyses. In 2022, Samsung Electronics Co., Ltd. dethroned IBM from the top spot in the ranking of the top 10 patent assignees in the United States, ending IBM's 29-year reign. This shift at the top highlights Samsung's growing innovative strength in areas such as semiconductors and mobile devices.

Qualcomm and TSMC also saw significant growth in the number of patents granted, by 46% and 22%, respectively. Their rise underscores the crucial importance of the semiconductor industry to the US economy.

However, not everyone saw a positive trend. Huawei, in particular, experienced a 24% decline in the number of patents granted in 2022. This decline can be attributed to a number of factors, including increased scrutiny from the US government.

In addition to the changes at the top, the ranking highlights some general trends:

- Competition in the patent industry is intensifying, with new companies emerging as key players.
- The semiconductor industry is playing an increasingly important role in technological innovation.

- The geopolitical landscape can significantly impact companies' patenting strategies.

It is important to note that the ranking is based on the number of patents granted by the USPTO and does not take into account the quality or impact of the patents themselves. Additionally, the ranking may vary slightly depending on the specific data source. Despite these limitations, the data offers valuable insights into the evolving patent landscape and the companies that are driving technological innovation.

Conclusions

In this thesis, we have explored the multifaceted relationship between artificial intelligence (AI) and the patent system. Through a comprehensive analysis of AI's evolution, its principal technologies, and their widespread applications, we laid the groundwork for understanding the intricate dynamics at play between AI innovations and patenting practices.

Summary of Findings

The quantitative analysis of AI patent data revealed several key trends.

Firstly, there has been a significant increase in AI-related patent applications over the past decade, indicating rapid growth in the field. This growth is evident across various subdomains of AI, such as computer vision, machine learning, and natural language processing. The geographic distribution of AI patent filings based on Patent Office, shows a concentration in specific regions, particularly North America, Europe, and Asia, with the United States, China, and European nations leading in the number of applications.

Large technology companies and research institutions dominate AI patent filings. These organizations have the resources and expertise to develop cutting-edge AI technologies and navigate the complexities of the patent system. Additionally, there is a notable trend of increasing collaboration between academia and industry, as evidenced by joint applications involving research institutions and private companies.

The technical landscape of AI patents reveals a focus on emerging technologies. Machine learning algorithms, deep learning architectures, and natural language processing are some of the most frequently patented areas, highlighting their importance in the current AI ecosystem.

Visualizations created during the analysis, such as the horizontal bar chart illustrating the top 10 country combinations of inventor collaborations, provide a clear picture of international cooperation in AI patenting. These visual aids help to understand how inventors from different countries work together on patents, showcasing the global nature of AI innovation.

Critical Perspective

While the findings provide valuable insights into the trends and patterns of AI patenting, it is crucial to consider the broader implications and challenges associated with these developments. The concentration of patent filings in specific regions and by major organizations underscores the importance of fostering international collaboration. However, this also raises concerns about potential monopolies and the equitable distribution of technological advancements.

The rapid expansion of AI technologies and their integration into various sectors necessitate adaptive and forward-thinking policies within the patent system. Policymakers must balance protecting intellectual property with promoting innovation and ensuring access to new technologies. The risk of patent thickets, where overlapping patent claims create barriers to innovation, is a critical issue that requires careful management.

Ethical considerations surrounding AI technologies, such as bias in algorithms and the transparency of AI decision-making processes, also need to be addressed within the patent framework. Ensuring that AI advancements contribute positively to society while safeguarding ethical standards is paramount.

From a critical standpoint, it is evident that the current patent system may not be fully equipped to handle the unique challenges posed by AI technologies. There is a need for more dynamic and flexible approaches to patenting AI innovations, which can accommodate the rapid pace of technological change and the complex nature of AI inventions.

Final Thoughts

In conclusion, this thesis has underscored the transformative role of AI in the patent landscape, highlighting both the opportunities and challenges it presents. The insights gained from this research contribute to the broader discourse on intellectual property law in the digital age. As AI continues to evolve, it is crucial for the patent system to adapt and support innovation while addressing the associated socio-economic and ethical implications.

By fostering international collaboration, implementing adaptive policies, and considering ethical dimensions, we can navigate the complexities of AI and patents to promote a dynamic and inclusive innovation ecosystem. The journey of AI from conceptualization to its current state reflects human ingenuity and the relentless pursuit of extending the capabilities of machines. It is imperative that the patent system evolves in tandem with these advancements to ensure that AI's potential is fully realized for the benefit of all.

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APPENDIX

SQL CODE:

SELECT

a.appln_id,

```
    a.appln_auth,
    a.appln_nr,
    a.appln_filing_year,
    at.appln_title,
    aa.appln_abstract,
    p.person_ctry_code,
    pa.person_id,
    p.person_name,
    n.nuts
FROM
    tls201_appln a
LEFT JOIN tls202_appln_title at ON a.appln_id = at.appln_id
LEFT JOIN tls203_appln_abstr aa ON a.appln_id = aa.appln_id
JOIN tls207_pers_appln pa ON a.appln_id = pa.appln_id
JOIN tls206_person p ON pa.person_id = p.person_id
JOIN tls904_nuts n ON p.nuts = n.nuts
WHERE
    (
```

at.appln_title LIKE '%Artificial intelligence%' OR

aa.appln_abstract LIKE '%machine learn%' OR

at.appln_title LIKE '%data mining%' OR

aa.appln_abstract LIKE '%data mining%' OR

at.appln_title LIKE '%quantum computing%' OR

aa.appln_abstract LIKE '%quantum computing%' OR

at.appln_title LIKE '%neural networks%' OR

aa.appln_abstract LIKE '%neural networks%' OR

at.appln_title LIKE '%logic programming%' OR

aa.appln_abstract LIKE '%logic programming%' OR

at.appln_title LIKE '%deep learn%' OR

aa.appln_abstract LIKE '%deep learn%' OR

at.appln_title LIKE '%logical learn%' OR

aa.appln_abstract LIKE '%logical learn%' OR

at.appln_title LIKE '%relational learn%' OR

aa.appln_abstract LIKE '%relational learn%' OR

at.appln_title LIKE '%machine intelligence%' OR

aa.appln_abstract LIKE '%machine intelligence%' OR

at.appln_title LIKE '%multitask learn%' OR

```
      aa.appln_abstract LIKE '%multitask learn%'
  )
  AND a.appln_filing_year BETWEEN 2015 AND 2023
  AND p.person_ctry_code IN ('IT', 'DE', 'FR', 'ES', 'GB', 'NL', 'SE', 'FI', 'CH', 'NO', 'BE',
'AT', 'PL')
  AND pa.invt_seq_nr > 0
ORDER BY a.appln_id DESC;
```

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Francesco.