European Commission

Quarterly R&I literature review 2023/Q2

The impact of AI on R&I

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LITERATURE REVIEW

Research and Innovation

The impact of AI on R&I

European Commission
Directorate-General for Research and Innovation
Directorate G — Common Policy Centre
Unit G.1 — Common R&I Strategy & Foresight Service

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Literature review

2023 Directorate-General for Research and Innovation EN

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INTRODUCTION

This literature review is developed by the 'Economics of R&I' team of the Chief Economist unit of DG Research and Innovation. It provides a brief summary of a selection of recent publications on R&I economics and policy. Contributors for this edition: Arranz David (guest author for the introduction), Luca Bollinger, Valentina Di Girolamo, Cesar Dro, Alessio Mitra (review coordinator), Elena-Raluca Pancu, Océane Peiffer-Smadja, Julien Ravet (team leader), Jan-Tjibbe Steeman.

Artificial Intelligence (AI) has emerged as a transformative force in recent years. Although the foundations of AI were established decades ago, it is only recently, with the advent of more powerful and suitable processors such as GPUs, that AI seems to be entering a 'golden age'. The technology has experienced cycles of enthusiasm and disillusionment in the past, such as the AI winter, due to unfulfilled expectations. However, there are many signs indicating that this time could be different.

One of the main reasons for this optimism is the diverse applications of AI, particularly in research and innovation. The volume of science produced with the aid of AI is growing at a rapid pace. The promise is that AI will accelerate scientific discovery, fostering economic growth and helping to address significant societal challenges like climate change and deadly diseases such as cancer and Alzheimer's.

At the current stage of the technology, there are remarkable discoveries being made almost on a weekly basis. Given the swift development of the technology, it is reasonable to anticipate that the rate and impact of these discoveries will accelerate in the future.

However, the deployment of this technology also poses questions and challenges for researchers and innovators. These include the risk of misuse of such a powerful technology, threats to research integrity, and the need for researchers to adapt to new tools, to name a few of the main challenges.

This literature review aims to provide a comprehensive overview of the current state of AI applications in research and innovation from various perspectives.

AI IN SCIENCE: OPPORTUNITIES AND CHALLENGES

OECD. (2023). Artificial Intelligence in Science: Challenges, Opportunities and the Future of Research. OECD Publishing. Paris. https://doi.org/10.1787/a8d820bd-en.

Messages	**(1) Science may be getting increasingly complex, entailing slower research productivity. (2) Accelerating the productivity of research could be the most economically and socially valuable of all the uses of artificial intelligence (AI). (3) Broad multidisciplinary programmes are needed to enable scientists, engineers, and industry to collaborate with computer scientists, applied mathematicians and statisticians to solve challenges using a range of AI technologies. (4) Public support for the diffusion of basic AI knowledge, data access and computational infrastructure are needed to allow public research to compete with that of private multinational tech companies.**

The report investigates the importance of accelerating the productivity of research through the use of artificial intelligence (AI) and highlights various ways in which policy makers and research systems can promote the uptake of AI in science.

Firstly, the report showcases the broad set of empirical evidence supporting the fact that technological progress has slowed down compared to the past. Indeed, it is found that achieving growth in many innovation metrics (e.g. number of transistors that can fit on an integrated circuit, agricultural yields, years of life saved, new technologies) requires an increasing amount of research effort (e.g. R&D investments, number of researchers, etc.).

Secondly, the report explains the diverse ways in which artificial intelligence (AI) is helping scientists. It highlights how AI innovations are easily transferable across scientific domains, fostering interdisciplinary approaches. Furthermore, the authors explain that while some machine learning models lack interpretability, they remain useful for hypothesis generation, anomaly detection, formalisation of mathematical proofs, tracking multiple uncertainties, compressing data, analysing unstructured data, making predictions, and precision measurements.

The authors also explain how current statistical AI differs from human intelligence. Humans create abstract models of the world, enabling them to mentally simulate modifications to objects and generalise knowledge to new situations. They don't require extensive experience or countless examples to understand concepts like the importance of not hitting people while driving. Data-driven AI can malfunction if not rigorously validated under different circumstances, cannot distinguish correlation from causality, and inherits the biases of the training data (biases that are not always possible to forcefully remove from the algorithms). Furthermore, the current promises of AI in science are limited by data-related scalability challenges, labelling requirements, black box approaches, and limited symbolic thinking.

Finally, the report recommends substantial public effort to guarantee AI education and adequate infrastructure to allow widespread and fair use of the newest cutting-edge technologies in science, avoiding the loss of human capital related to non-menial scientific tasks.

AI IN SCIENCE: WORDWIDE TRENDS

Arranz, D., Bianchini, S., Di Girolamo, V., Ravet, J. (2023). Trends in the use of AI in science: a bibliometric analysis. R&I Paper Series, WP 2023/04, EU Publication Office.

Messages	1. AI as applied to science and research has been growing at a significant pace in recent years, with China leading the way, followed by the EU and the US. 2. EU's performance is found to be highly heterogeneous across its Member States. 3. Failure to keep pace with the development and uptake of AI in science poses important challenges for the EU.

The paper looks at the global trends of AI in science, with a focus on the EU's performance, and maps the diffusion of AI technology in science and its application in different domains within the EU's research landscape.

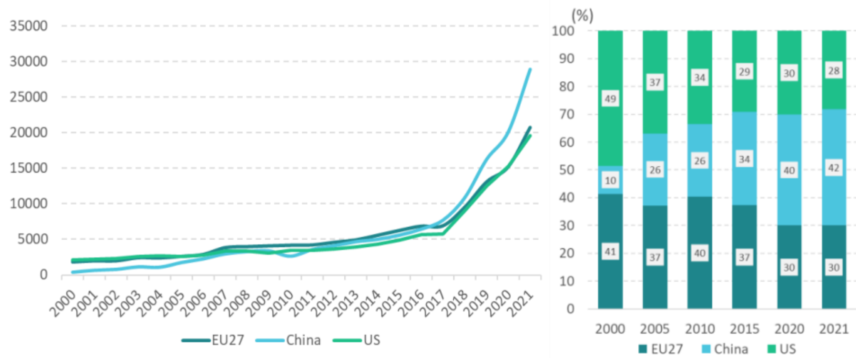
The authors use publication data from the Web of Science (WoS) Core Collection between 2000 and 2021. Publications are identified using AI-related keywords and classified into different fields. The field classification allows to distinguish between application of AI in science, which is the focus of the paper, from development of AI.

Results show that the applications of AI in science have been growing significantly in recent years, with China in the lead, although the Chinese advantage is mitigated when considering quality indicators. The gap between the EU and China is expected to increase in the future. The EU is at a similar level as the US.

Germany, Italy, Spain and France are the top producers of publications related to AI applied in science, and also report a yearly growth rate slightly above the EU average (with the exception of Spain). Other countries reporting both a high absolute number of publications and a good growth performance are Sweden and the Netherlands.

From a policy perspective, the results have important implications. First, they call for actions aiming at strengthening the EU's position in relation to the uptake of AI in research and scientific activities. Given its multifield applications, AI is among those digital technologies with the highest potential to boost the EU's productivity, and complement and reinvigorate the green transition, thereby increasing the EU's competitiveness. Furthermore, if future scientific discoveries will be mostly driven by AI applications and tools, lagging in the development and uptake of AI in science poses important challenges for the EU's strategic autonomy, increasing the risks of developing dependencies in strategic scientific fields.

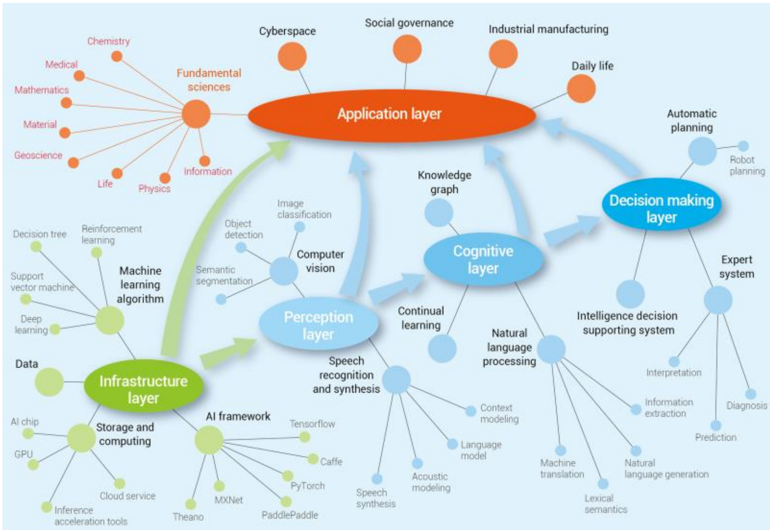
Figure 4. Number of publications (left), and relative share of publications of the EU, US, and China (right), on AI applications in science



AI IN FUNDAMENTAL RESEARCH

Xu, Y., Liu, X., Cao, X., Huang, C., Liu, E., Qian, S., ... & Zhang, J. (2021). Artificial intelligence: A powerful paradigm for scientific research. The Innovation, 2(4).

Messages	**1. The development and application of AI have revolutionized fields such as information science, mathematics, medical science, materials science, geoscience, life science, physics, and chemistry.**



This paper provides a comprehensive survey of AI's development and application in a wide range of fundamental sciences, including information science, mathematics, medical science, materials science, geoscience, life science, physics, and chemistry.

In the context of information sciences, AI aims to provide perception, cognition, and decision-making abilities to machines. Its role is to generate basic tools for AI algorithm implementation. AutoML aims to study evolutionary computing and the creation of neural networks according to biological principles.

In medical sciences, AI is rapidly advancing, offering ground-breaking solutions like Internet Hospital and Smart Hospitals. AI aids in providing initial treatment suggestions for vast data sets like electronic medical records. Additionally, it supports image-based medical classification, detection, and early warning systems.

AI, also known as ML, is a crucial tool in modern physics, spanning from subatomic to cosmic scales. It aids in data analysis and image reconstruction, revolutionising particle physics, nuclear physics, condensed matter physics, and cosmic physics. AI algorithms are gaining prominence, enabling deeper insights into the complexities of the universe.

Chemistry, with its complex data, presents a prime opportunity for AI breakthroughs. ML methods are essential for recognising patterns and transforming chemistry research due to the vast chemical space and intricate molecular interactions. ML methods recognise patterns, impacting analytical, computational, organic chemistry, and catalysis.

At the same time the authors stress the significant security risks associated with AI, particularly in terms of data and ML models, that remain a critical concern.

AI PATENTING ACROSS TECH FIELDS

Qiu Y-H., Yang X., Li Z-Z., Zhang C., Chen S-X. (2021). Investigating the impacts of artificial intelligence technology on technological innovation from a patent perspective. Vol.6-Issue1. Applied Mathematics and Non-Linear Sciences.

Messages	**1. AI technology has influenced the technological innovation of the fields of Control, IT Methods for Management, Measurement, Telecommunications (electronic communications techniques) and Medical Technology (technologies for diagnosis, surgery, and identification) significantly.**

This paper analyses the impacts of the latest AI technology on technological innovation in different fields through an analysis of distribution of AI patents in these domains.

The patent data used in this study were collected from the Derwent Patent Database, a subsidiary of Clarivate Analytics. The Derwent Patent Database covers the patent databases of about 60 authorized patent agencies in the world and has collected over 20 million worldwide since 1963.

In this study, AI patents were selected using keywords in the title and abstract ("deep learning," "deep neural network" and "convolutional neural network," which were provided by three researchers and engineers engaged in AI technological research and development. A total of about 25,000 AI-related patents were retrieved and their distribution in 20 different fields defined with the International Patent Classification was analysed.

The results demonstrate that the number of AI patent applications has consistently increased year-by-year since 2014.

Specifically, the number of AI patents in the computer technology field is the highest and is significantly higher than the expected results in other fields. Besides, the quantities of AI patents in the fields of Control (signal device and control adjustment), IT Methods for Management, Measurement (material testing or analysis based on the chemical or physical properties of materials), Telecommunications (electronic communications techniques) and Medical Technology (technologies for diagnosis, surgery and identification) are significantly higher than those in other fields, revealing that AI technology has influenced the technological innovation of these domains significantly.

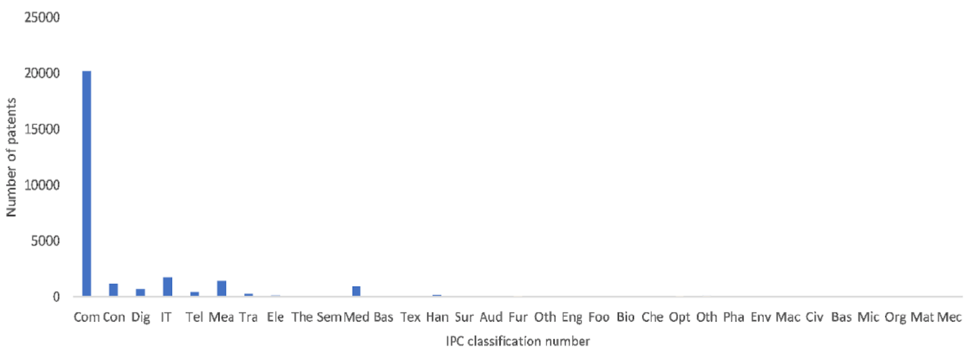


Fig. 4 Quantity of AI patents in different fields.

AI AND SCIENTIFIC DISCOVERY

Bianchini, S., Müller, M., & Pelletier, P. (2022). Artificial intelligence in science: An emerging general method of invention. Research Policy. 51(10), 104604.

Messages	1) AI methods, particularly neural network (NN) research, are widely adopted in science showing exponential growth across disciplines. 2) AI adoption is linked to increased citation impact 3) The adoption of AI methods may reinforce existing knowledge structures rather than promoting novel discoveries.

The article examines AI's diffusion and impact in the scientific system, focusing on neural network (NN) research growth and its implications for discovery and collaboration. Using network analysis and empirical data, the study explores AI adoption trends. The findings underscore AI's potential as a research tool, emphasizing the importance of effective governance, collaboration, and public engagement to maximize benefits.

The authors study NN research diffusion and its impact on scientific discovery. Network analysis uncovers patterns and relationships within the dataset, examining scientific research network structures, AI method adoption, and AI's influence on research outcomes.

Firstly, AI emerges as a pervasive research tool, as the adoption of NN methods results in a reconfiguration of global actors within the scientific system (see figure - The shaded areas are time series intervals defined by minimum and maximum citation shares. The orange profile represents 'theoretical' contributions, and the blue profile represents 'applications').

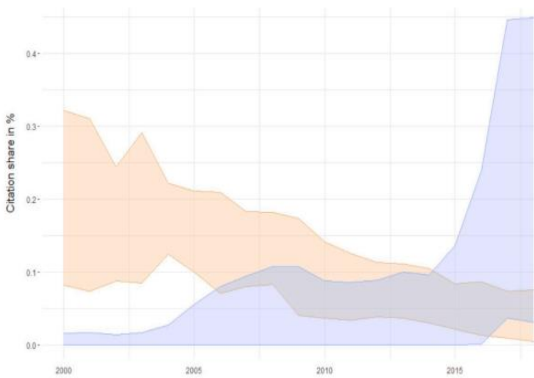


Fig. 3. Trends in annual citations of influential NN publications.

Secondly, the impact of AI adoption on scientific discovery suggests that AI methods tend to reinforce existing knowledge structures rather than generating entirely new knowledge.
Thirdly it appears that AI-assisted research is more likely to achieve high citation impact.

The authors propose that AI should be regarded as an emerging general method of invention. However, they caution against viewing AI as a fully autonomous tool for navigating the knowledge landscape. Instead, AI has the potential to bridge disciplinary boundaries and foster collaboration between scientific communities, enabling the identification of blind spots and opportunities in the knowledge landscape.

The study emphasizes the importance of understanding the tasks performed by scientists and effectively coordinating human-machine interactions to harness the benefits of collaboration.

Finally, the article addresses governance and data ownership challenges, urging the development of institutions and policies to foster collaboration and knowledge exchange.

GPT-4 AND ASSOCIATED RISKS

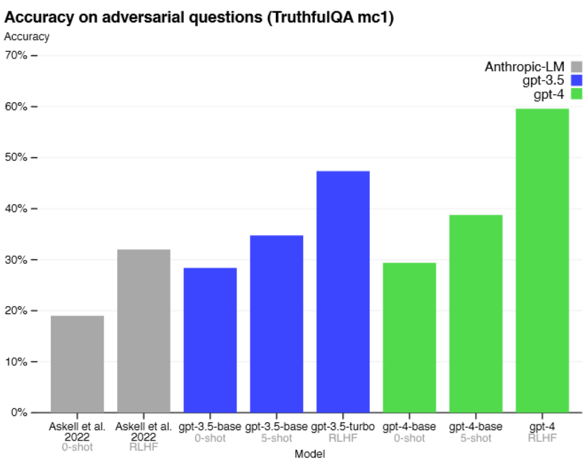
OpenAI. (2023). GPT-4 system card. https://cdn.openai.com/papers/gpt-4-system-card.pdf

Messages	1. A system card is a type of report on a computer system focusing on its capabilities and limitations. 2. The GPT4 system cards highlights known risks such as hallucinations, harmful content, harms of representation and allocation of service, disinformation and influence, weapon proliferation, privacy invasion and cybersecurity. 3. The GPT4 system card identifies potential risks such as power seeking and overreliance. 4. OpenAI has taken steps to mitigate these risks in its model and recommends these to other developers of LLMs.

A system card is a type of report on a computer system focusing on its capabilities and limitations. This system card (report) is dedicated to both known risks and emergent safety challenges that arise from the GPT-4 Large Language Model (LLM). The report also compares GPT-4 and previous versions of the model as well as other models to evaluate the degree of improvement in risk mitigation.

Firstly, the authors document the “known risks” exhibited by LLMs. These include hallucinations, harmful content, harms of representation and allocation of service, disinformation and influence, weapon proliferation, privacy invasion and cybersecurity.

Secondly, new vulnerabilities that may emerge from GPT-4 capabilities, named



“risky emergent behaviour”, are investigated. Indeed, as models increase in size, they also increase in capabilities (“scaling laws”). At certain thresholds, new capabilities are likely to emerge. Emergent behaviours that could potentially appear in GPT-4 include:

- Agency, eventually “power seeking” (autonomous replication, “paperclip maximiser”)
- Interactions with other systems (change of capabilities and risks of systems coupled with GPT-4)
- Economic impacts (increasing inequality by inequal access, targeted harm to social groups)
- Acceleration of the race to economic competition leading to a decline in safety standards and controls
- Overreliance (excessive trust and dependence on the model, lock-in and unnoticed mistakes)

Thirdly, the system card (report) outlines that GPT-4 has seen marked improvements over its earlier versions and the state-of-the-art LLMs (see figure).

Finally, the system card concludes that extensive testing of risky behaviours is useful for policymakers to anticipate potential issues, while informing further investigation and regulation.

GPT IMPACT ON SCIENTIFIC PUBLISHING

Lund, B. D., Wang, T., Mannuru, N. R., Nie, B., Shimray, S., & Wang, Z. (2023). ChatGPT and a new academic reality: Artificial Intelligence-written research papers and the ethics of the large language models in scholarly publishing. Journal of the Association for Information Science and Technology, 74(5), 570-581.

Messages	**1. AI-driven language models like ChatGPT-3 can be valuable for research, via tasks like translation, summarization, and question answering. 2. ChatGPT can enhance research productivity and publication quality by handling repetitive tasks such as formatting citations and editing. 3. ChatGPT raises concerns about disseminating research biases, copyright, citation practices, and the potential impact on scholarly publishing's "Matthew Effect" (cumulative advantage for well-known researchers). 4. Collaboration among researchers, publishers, and developers is essential to establish ethical and transparent guidelines and protocols for AI language model use.**

This paper investigates how the advanced language model ChatGPT-3 (generative pre-trained transformer) developed by OpenAI can be used in academia to create and write research and scholarly articles, as well as the associated issues.

Firstly, the authors highlight the benefits of ChatGPT and similar models in research. In short, ChatGPT can save time and increase quality when used correctly. It aids editors in tasks like grammar correction, structuring of papers to various journal style guidelines, consolidating peer review comments, and offering author recommendations. It enhances research dissemination through improved metadata, indexing, and summaries. In interdisciplinary topics, it helps identify relevant studies despite varied terminologies. It assists researchers in structuring papers, summarizing findings, and providing language support.

At the same time, the analysis highlights how AI-driven language models can harm research. Indeed, the training data and coding process of language models such as GPT-3, which are usually sourced from large web-based datasets, can contain bias regarding gender, race, ethnicity, and disability status. Such a bias can be inadvertently perpetuated when these models are used to generate academic research.

Citations are vital for giving credit, showcasing knowledge depth, and ensuring validity in scholarly work. ChatGPT can suggest citations, but it's prone to errors, and suffers from favouring highly cited yet outdated papers (Matthew Effect). Copyright and plagiarism concerns arise as models like GPT-3 lack source tracking (as they are trained on a massive corpus of data from across the Internet). Hence, compliance with copyright laws and proper attribution becomes challenging. Because of it, some publishers are considering restricting open-access papers to prevent AI like ChatGPT from accessing them, which leads to 'open science' considerations. Chat GPT generation of text based on existing work coupled with the academic evaluation that emphasizes grants, publications, and citations may hinder creativity and innovation.

The authors emphasise collaboration among researchers, publishers, and developers to create tools and guidelines for AI language model use, such as anti-ChatGPT software.

POTENTIAL RISKS OF GENERATIVE AI FOR SCIENCE

Birhane A., Kasirzadeh A., Leslie D., Wachter S. (2023). Science in the age of large language models. Nature Review Physics. 5, pages 277–280.

Messages	1. If GenAI is used automatically and without critical oversight, it may fundamentally undermine the foundations of ‘good’ science. 2. This paper calls for careful consideration and responsible usage to ensure that good scientific practices and trust in science are not compromised.

This article discusses potential risks of rapid advances in the capabilities of large language models and the broad accessibility of tools powered by this technology.

Four experts in artificial intelligence ethics and policy are interviewed in depth about large language models (LLMs) and deep learning models with a huge number of parameters trained in an unsupervised way, on large volumes of text.

They identify 17 open questions classified in 4 fields (Accuracy, reliability and accountability; explainability, missingness and bias; Scientific ingenuity and discovery; Science assessment and peer review) to ensure that generative AIs are not misused.

Some of the questions are: How can scientists methodically determine when large language models (LLMs) are ‘hallucinating’ or generating inaccurate and fantastical content? Who is responsible for the integrity of scientific research and the content of scientific papers aided by LLMs? How can scientists, who draw on opaque LLMs, clarify the intended meaning or nuances of the texts based on which such models render their outputs? How will LLMs enhance existing and introduce new biases or help remove existing ones? Will outliers (radical new ideas, unconventional views and unusual writing styles) be lost, overlooked or averaged out? Will overreliance on LLMs to produce arguments and text risk diminishing or weakening the writing and critical thinking skills and insight of researchers?

They conclude that:

- Although LLMs seem to provide useful general summaries of some scientific texts, relying solely on LLMs for writing scientific summaries can result in oversimplified texts that overlook crucial value judgements obvious to the human eyes.
- If GenAI is used automatically and without critical oversight, it may fundamentally undermine the foundations of ‘good’ science.
- Until more robust and reliable safeguards are in place, the scientific community should take a timely and firm stance to avoid any overreliance on LLMs and to foster practices of responsible science in the age of LLMs. Otherwise, the risk is to jeopardize the credibility of scientific knowledge.

This paper calls for careful consideration and responsible usage to ensure that good scientific practices and trust in science are not compromised.

AI AND HUMAN COLLABORATION IN R&I TEAMS

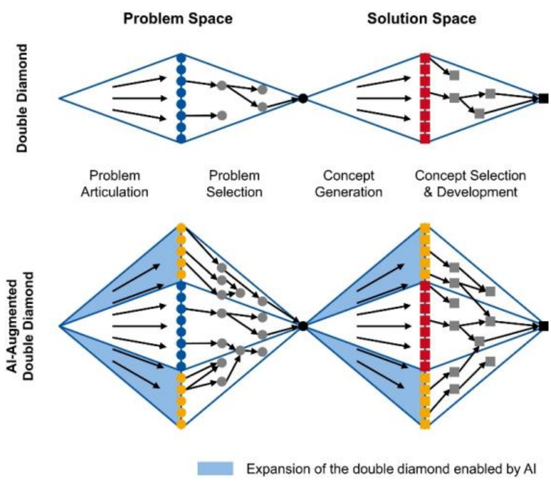
Bouschery, S. G., Blazevic, V., & Piller, F. T. (2023). Augmenting human innovation teams with artificial intelligence: Exploring transformer-based language models. Journal of Product Innovation Management, 40(2), 139-153.

Messages	**1. Transformer-based language models, such as ChatGPT may bear particularly interesting opportunities for an AI-augmented innovation process, performing various tasks such as machine translation and text summarization, insight extraction, or generating creative output. 2. AI and humans will increasingly work together in a form of hybrid intelligence, which calls for a re-evaluation of how we approach and manage innovation.**

This paper explores the implications of companies using advanced language models such as ChatGPT-3 (generative pre-trained transformer) in their innovation processes.

The authors refer to the well-known double diamond framework to structure their exploration of potential use cases of how transformer-based language models can augment human innovation teams in the future. By doing so, the authors present a new model: the AI-augmented double diamond.

To kickstart innovation, collecting vast amounts of knowledge is crucial. However, this process can be labour-intensive and not easily scalable due to unstructured data being difficult to process automatically. Transformer-based language models like GPT-3 offer a promising solution for extracting knowledge. These models excel at summarising text efficiently, conveying the essential aspects and meaning of the original content. Transformer-based language models are also adept at mining sentiment from online communities, offering valuable insights for firms to understand customer needs and identify areas for product and service improvements. The authors elaborate that transformer-based language models can also be valuable to generate (new) ideas based on questions or initial input.



This said, the authors highlights that we currently cannot determine the reliability of an AI-generated response without having the answer ourselves. Indeed, unlike humans, a language model will not admit when it does not know the answer but will provide the most probable response when given a task to generate output. Also, humans are crucial to identify biases in AI, highlighting the necessity of hybrid intelligence for innovation.

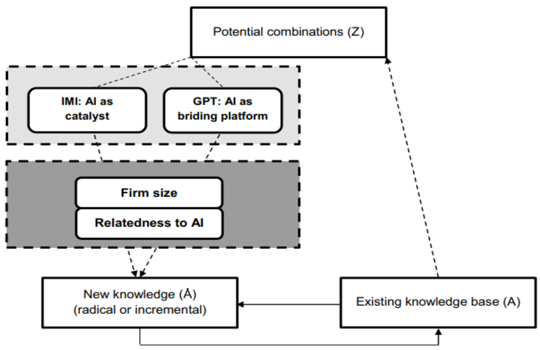
Based on the findings, the authors conclude that language models can act as knowledge brokers by interacting with various knowledge sources, learning from them, and facilitating the sharing and transformation of knowledge. This can enable them to foster knowledge exchange among stakeholders and can promote the creation of new knowledge.

AI AND COMPANIES' INNOVATION

Grashof, N., & Kopka, A. (2022). Artificial intelligence and radical innovation: an opportunity for all companies?. Small Business Economics, 1-27.

Messages	**1. The effect of AI-knowledge on the likelihood of firms to develop radical innovations varies across firms and different type of AI. 2. Overall, AI techniques appear to negatively influence radical innovations, while AI applications have a positive effect. 3. AI techniques appear to be more beneficial for smaller firms, while larger companies benefit more from AI applications.**

The paper investigates the extent to which AI-related knowledge affects the emergence of radical innovations in firms, differentiating between SMEs and large companies to capture the different capacities in seizing the potentials of AI, and identifying what type of firms are better fit to generate radical innovation through AI knowledge.



The empirical analysis builds on two main datasets: ORBIS and PATSTAT. The former is used to retrieve firm-specific characteristics of European companies between 2011 and 2020. The patent database PATSTAT is then used to identify AI knowledge within the companies, as well as radical innovations. Specifically, the emergence of radical innovations is proxied by new technology combinations on a patent, which have not been combined before (since 1981). SMEs are defined as companies having less than 250 employees. The empirical strategy adopted in the paper relies on a quasi-Poisson fixed effects generalized linear model.

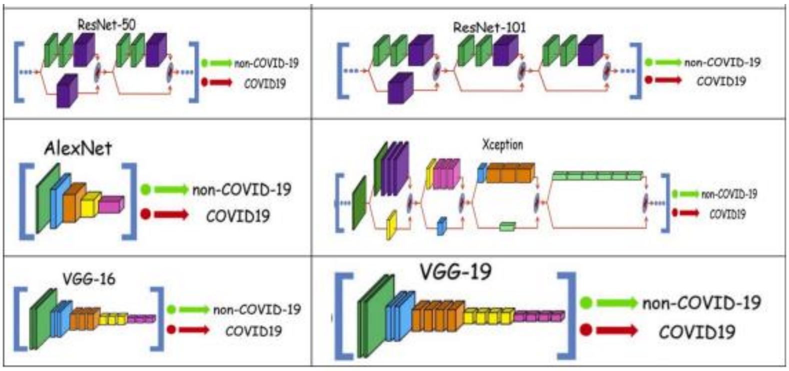
Overall, the analysis provides a broad set of findings. On the one hand, the results suggest that the extent to which AI influences radical knowledge generation highly depends on the specific type of AI considered. Specifically, the paper finds that AI techniques (Invention of a method of inventing, IMI, characteristics) have a negative influence on radical innovation, while AI applications (its general-purpose technology, GPT, characteristics) have a positive one. On the other hand, the effect of AI techniques appears to be higher in smaller firms, while the larger the company the more positive the effect of AI applications. Furthermore, the analysis also accounts for the extent to which a firm's knowledge base is related to AI techniques, finding that the degree of relatedness plays an important role in facilitating radical knowledge, especially in smaller firms.

From a policy perspective, the plurality of these results suggests that target policy approaches able to account for the different features of AI are needed to optimise AI-knowledge contribution to the development of radical innovations across different firms. Furthermore, the paper highlights the particular benefits of AI techniques for SMEs, presenting an opportunity for smaller firms to catch up in the innovation process.

AI AND COVID-19

Peng, Y., Liu, E., Peng, S. et al. (2022). Using artificial intelligence technology to fight COVID-19: a review. Artif Intell Rev 55, 4941–4977.

Messages	**1. The introduction of artificial intelligence technology has provided a contribution to the suppression of the new coronavirus. 2. There are limitations in terms of data accessibility and classification of symptoms, making the role of doctors crucial.**



This paper highlights AI's potential in combating the COVID-19 pandemic. AI's data processing capabilities, efficiency, and wide range of applications in medical imaging, disease tracking, and predictive modeling are emphasised. The literature analysed in the paper identifies three main prediction directions for AI: propagation prediction, drug prediction, and survival prediction.

In terms of spread prediction, AI utilising big data and a long and short-term memory network (LSTM) achieves 93.4% accuracy in predicting disease propagation in real-time. For drug development, AI enables the repurposing of existing medications, offering a quicker and cost-effective approach. AI is also employed to predict and identify drugs for treating COVID-19, leading to promising discoveries. Additionally, AI aids in the rapid identification of effective existing drugs, saving valuable time.

Accurate clinical predictive models for mortality play a crucial role in assessing the severity of COVID-19. Survival prediction models incorporating variables such as age, biomarkers, and comorbidities assist in decision-making and policy development. The paper also discusses AI's implications in symptom recognition through CT and X-ray scanning, mental health maintenance, crowd monitoring, contact tracing, and software development.

The advantages of AI technology include faster processing capacity, deep learning, and neural networks that provide reliable predictions and symptom identification. However, challenges exist in accuracy, data availability, disease classification, and drug development. AI models for symptom recognition still have room for improvement and differentiating COVID-19 from other lung diseases through imaging remains difficult. The role of doctors remains crucial, and time and cost constraints affect AI-based drug development.

The paper identifies future strands of AI technologies in the context of COVID-19, including AI and the Internet of Things, cloud computing, drone technology, and blockchain.

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The aim of the Review is to inform policymakers on the latest findings from the literature that links R&I economics to R&I policy.

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