



Impact of AI on R&D performance of enterprises

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Abstract: Artificial Intelligence (AI) is transforming Research and Development (R&D) by enhancing productivity, reducing costs, and reshaping workforce dynamics. This study explores AI's impact on R&D, focusing on automation, data-driven decision-making, and innovation acceleration. The research employs a mixed-method approach, utilizing secondary data from surveys and industry reports to analyze AI's influence on productivity and cost efficiency, particularly in the biopharmaceutical sector. Findings indicate that AI-driven automation streamlines repetitive tasks, accelerates data analysis, and optimizes resource allocation, leading to a 30–50% increase in productivity and significant cost reductions. However, AI also disrupts workforce structures, reducing demand for traditional roles while creating new opportunities in AI-related fields. To maximize AI's benefits, businesses should invest in AI integration, workforce upskilling, and ethical AI governance. As AI continues to evolve, future research should explore its interdisciplinary applications and long-term implications for sustainable innovation in R&D.

Keywords: AI, R&D, Innovation Performance, Business Process Modernization.

1. Introduction

In today's rapidly evolving business landscape, Artificial Intelligence (AI) and Research & Development (R&D) have emerged as crucial elements driving innovation, competitiveness, and sustainable growth. AI, with its capacity to process vast amounts of data, recognize patterns, and automate complex operations, has significantly transformed the way businesses function. At the same time, R&D serves as the foundation for innovation, enabling organizations to create new products, services, and processes to meet the ever-changing demands of the market. The combination of AI and R&D is revolutionizing industries such as healthcare, manufacturing, finance, and information technology, optimizing decision-making, reducing operational costs, and accelerating time-to-market for innovative solutions.



AI integration in R&D unlocks new possibilities for innovation, enabling data analysis, trend prediction, and workflow optimization. In pharmaceuticals, AI accelerates drug discovery by simulating molecular interactions, while predictive analytics enhance supply chain efficiency. By harnessing AI, businesses can strengthen their competitive edge in an increasingly technology-driven market.

Despite the growing application of AI in R&D, challenges remain. Its implementation demands substantial investment in technology, infrastructure, and expertise. Businesses also face hurdles related to data privacy, algorithmic biases, and regulatory compliance, raising concerns about the accessibility and scalability of AI-driven R&D. While AI has the potential to transform innovation, productivity, and cost efficiency, a clearer understanding of its true impact is essential.

Despite AI's growing role in R&D, its precise impact on enterprise performance remains insufficiently understood. While case studies and empirical research indicate AI's potential to enhance innovation, systematic analyses quantifying its effects on productivity, cost-efficiency, and innovation quality are still lacking. Furthermore, challenges such as high implementation costs, data security concerns, and the need for specialized talent raise critical questions about the feasibility and scalability of AI-driven research across industries.

This article aims to bridge these gaps by assessing the impact of AI on R&D performance in businesses and identifying the factors that determine the success or failure of AI-powered R&D initiatives. By conducting an in-depth analysis of how AI influences R&D efficiency, cost management, and innovation speed, this research seeks to provide valuable insights for managers, policymakers, and industry leaders. The findings will help businesses make informed decisions about leveraging AI to enhance their R&D capabilities, ultimately driving technological advancements and business growth in an increasingly digital and AI-driven world.

2. Literature review

2.1. Theoretical framework

Artificial Intelligence (AI) and Research & Development (R&D) are closely interconnected, driving innovation across various industries and enterprises. AI accelerates data analysis, automates tasks, and enhances decision-making, while R&D advances AI by developing algorithms, refining models, and expanding its applications.

In the market, the synergy between AI and R&D fosters competitive advantages, enabling companies to optimize operations, enhance product development, and create cutting-edge technologies. Industries such as healthcare, finance, manufacturing, and technology increasingly rely on AI-powered R&D to innovate and stay ahead in the digital era. Enterprises investing in AI-driven R&D gain significant benefits, including improved efficiency, cost reduction, and the ability to anticipate market trends.

Understanding the dynamic relationship between AI and R&D is essential for businesses seeking sustainable growth and technological leadership in today's fast-evolving landscape.



2.2. AI and R&D

AI is a transformative field of computer science that mimics human cognition such as learning, adaptation, and decision-making—through technologies like machine learning, deep learning, and natural language processing. Its data-processing capabilities enable automation, cost reduction, and personalized experiences across industries. However, challenges such as reliance on high-quality data and ethical concerns like algorithmic bias affect its real-world applicability. When effectively integrated into business models, AI can optimize processes and drive innovation.

R&D serves as the foundation of innovation, driving knowledge creation and product advancement, particularly in high-risk industries like biotechnology and semiconductors. It ensures competitive advantage and long-term value but is resource-intensive, posing challenges for smaller firms. Additionally, the resource-intensive nature of R&D can pose significant challenges, particularly for smaller firms with limited budgets.

2.3. AI impact on businesses

To evaluate AI's impact on small businesses, Hossain M. used a mixed-methods approach, combining quantitative surveys and qualitative interviews. Data from 100 small enterprises across various sectors were analyzed, focusing on AI adoption in customer service, supply chain management, and data analysis. Performance metrics, cost savings, and revenue changes were examined using linear and logistic regression models to assess the relationship between AI integration and productivity innovation factors. In addition, in-depth interviews with 12 business owners provided deeper insights into AI's transformative effects on business models and implementation challenges. The qualitative data was analyzed using thematic coding. Hossain's research revealed significant productivity gains from AI adoption in small enterprises, with 85% of surveyed businesses reporting reduced operational costs, especially in customer service and inventory management. Regression analysis showed a strong correlation between AI adoption and operational efficiency, with an R^2 value of 0.72. Furthermore, 72% of enterprises reported significantly improved decision-making through AI-powered analytics, reducing operational errors. These findings reinforce the idea that AI not only drives cost savings but also enhances the quality of managerial decisions.

Hossain's research found that 45% of businesses developed new products or services through AI applications. Interviews highlighted AI's role in transforming business models, notably the shift to subscription-based services. However, 30% of enterprises struggled with a shortage of AI-skilled personnel, emphasizing the crucial role of human capital. This underscores the need for targeted training programs and technical support to help small businesses navigate digital transformation successfully.

Irnozarov D. and Puzyrova P. from Kyiv National University of Technology and Design (Ukraine) used a comprehensive approach to assess AI's potential and impact. Their study analyzed machine learning, neural networks, and expert systems based on accuracy, processing speed, and adaptability. The algorithms were tested on sample data sets to measure their effectiveness in tasks such as forecasting market demand or optimizing supply chains. The authors used both primary data sources: Secondary data compiled from



research reports, academic papers: In-depth interviews with AI experts and business leaders to collect qualitative insights. Second, Primary data collected through surveys of businesses that have deployed AI: Delphi method to reach consensus on trends and challenges when deploying AI. Finally, statistical analysis was applied to the collected data using techniques such as multivariate regression, clustering and hypothesis testing, and the quantitative results were compared with expert judgment to clarify the gaps between the theory and practice of AI implementation and management practices in the modern context.

The impact of AI on business process modernization is significant. Quantitative analysis reveals AI improves operational efficiency by 35-45%, cuts labor costs by 20-25%, and enhances market forecasting accuracy up to 90%. Machine learning and neural networks excel in big data processing and supply chain optimization. However, businesses face challenges in system integration (60%) and a skilled workforce shortage (45%), particularly in roles requiring creativity and complex decisions. AI effectiveness also varies by industry, with finance-insurance and retail leading in success.

Thus, the argument that AI is indeed a strategic tool to help businesses improve their competitiveness has been strongly reinforced, although policymakers and business leaders must be careful in building an appropriate digital transformation roadmap.

2.4. R&D Impact on enterprise performance

Dong Y. based on the panel data of 164 listed automotive enterprises in the field of artificial intelligence concept of China's A-share stock market, then integrated panel fixed effect regression to analyze the impact of R&D intensity on innovation performance and considered the moderating effect of three dimensions of patent portfolio on the two factors. Their hypothesis is that when the intensity of R&D (RD) continues to increase, innovation performance of the enterprise (TB) first increases and then decreases. Finally, it was concluded that the impact of R&D intensity on innovation performance is in an inverted U-shaped curve relationship (Figure 1).

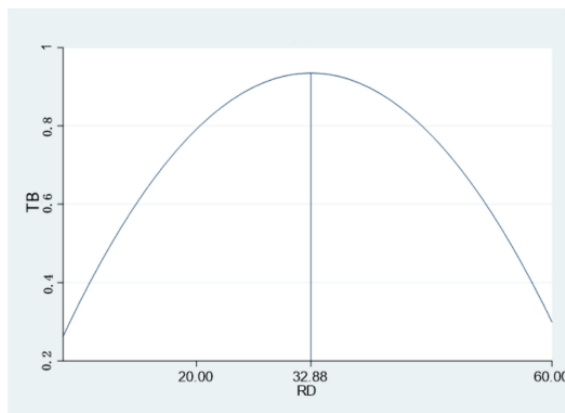


Figure 1. Inverted U-shaped relationship between RD and TB.

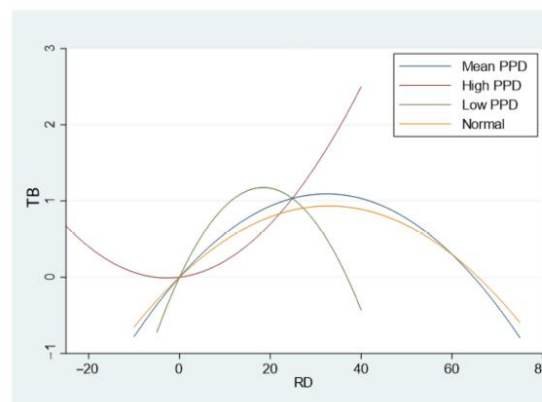


Figure 2. PPD's moderating effect on TD and TB.

According to Figure 2, when the R&D intensity of different enterprises fluctuates sharply, it means that they are adopting different innovation strategies to respond to their environmental conditions and changes.

When a company's patent volume is lower than the industry level, it will often compensate by focusing on core technology areas, which means its R&D investment is seemingly small and precise so that it can easily create synergies. The pressure on the R&D intensity of enterprises has promoted the emergence of many new technologies or new products. This makes them more competitive in the future market, boosting the innovation performance of the industry. When enterprises continuously increase their intensity, they will inevitably encounter difficulties in making innovation decisions. There are too many risks of technological uncertainty and environmental changes. When reaching a certain level (like the turning point of 32.884 according to Dong Y.'s research), the risk created by R&D investment will exceed the expected profit, causing the company to start to decline. The study also found that a diverse patent portfolio weakens the link between R&D intensity and innovation performance. Dong Y.'s data suggests that an abundance of AI enterprises creates an inverted effect on this relationship. In low-diversity scenarios, businesses adopt focused technologies to enhance innovation performance. According to the model, the curve shifts upward and leftward, indicating that lower R&D intensity leads to higher market profits, reflecting technology-specific competition. Greater integration of core technology enhances benefits while reducing the cost of technological diversity. When a strategic and highly diversified patent portfolio is implemented, the model predicts an inverted U-shaped relationship between R&D intensity and innovation performance. As R&D intensity rises, innovation performance improves, reflecting a growing need for technological diversity, ultimately enhancing efficiency.

2.5. Case Study: The Role of AI in Pfizer's R&D for COVID-19 Vaccine Development



The COVID-19 pandemic required rapid vaccine development to tackle the global health crisis. In response, Pfizer, in partnership with BioNTech, leveraged AI to transform its R&D process. AI-driven solutions accelerated research, optimized clinical trials, and streamlined regulatory approvals, enabling the swift delivery of a safe and effective vaccine. Vaccine development has traditionally been a long, complex process, often taking a decade or more. However, the urgency of the pandemic demanded a shift from conventional methods. Pfizer's R&D team leveraged AI to analyze vast biological datasets, identify viable vaccine candidates, and optimize clinical trial protocols. AI played a crucial role across multiple stages of the development process.

During preclinical research, AI algorithms processed vast amounts of viral genetic and immunological data, enabling Pfizer to swiftly pinpoint the most promising mRNA-based vaccine candidates. This drastically shortened the time needed for initial testing. In clinical trials, AI enhanced efficiency by predicting patient responses based on genetic and demographic factors, ensuring optimal trial design and participant selection. Additionally, AI-powered predictive analytics optimized supply chain logistics, ensuring seamless material procurement and production scalability. Machine learning models also helped anticipate manufacturing bottlenecks, allowing for proactive adjustments.

Beyond research and production, AI played a crucial role in regulatory compliance. Real-time data analysis tools enabled continuous monitoring of clinical trial results, facilitating rapid adaptations to meet regulatory standards. This agility was critical in securing emergency use authorization (EUA) from health authorities in an expedited timeframe.

The impact of AI on Pfizer's COVID-19 vaccine development was profound. What traditionally took 10–15 years was achieved in under a year, thanks to AI-driven data analysis and predictive modeling. Operational costs were reduced through automation, minimizing manual data processing while improving accuracy in vaccine candidate selection. Furthermore, AI-enhanced production planning allowed Pfizer to scale up global distribution efficiently, ensuring widespread vaccine availability.

Pfizer's breakthrough showcases AI's transformative impact on pharmaceutical R&D, especially in crises. By enabling rapid data analysis, trial optimization, and efficient manufacturing, AI accelerated vaccine delivery and set a new standard for medical innovation. This case highlights AI's potential to revolutionize vaccine development and healthcare, proving technology's crucial role in tackling global challenges.

3. Research method

3.1. Research methodology

Research methodology varies depending on the nature of the study and the type of data required. The three primary approaches—quantitative, qualitative, and mixed-methods—each serve distinct purposes in gathering and analyzing information.

Quantitative Research Methodology

Quantitative research focuses on numerical data, emphasizing measurement, statistical analysis, and objective testing. This approach is particularly effective for



studying large populations efficiently, establishing causal relationships between variables, and making generalized predictions. It follows a deductive process, where hypotheses are formulated early, and data is collected through structured methods for precise analysis.

Quantitative data analysis is divided into two main categories: descriptive and inferential. Descriptive analysis summarizes key features of datasets, making patterns interpretable through measures such as frequency (counts, percentages), central tendency (mean, median, mode), dispersion (range, variance, standard deviation), and position (percentiles, quartiles). Inferential analysis, on the other hand, extrapolates findings from a sample to a broader population, examining relationships between variables. Common techniques include correlation (assessing variable relationships), cross-tabulation (comparing multiple variables), regression analysis (evaluating the effect of independent variables on dependent ones), frequency tables (tracking data occurrence), and analysis of variance (testing differences between variables).

Qualitative Research Methodology

Unlike quantitative research, qualitative methodology explores non-numerical data, focusing on opinions, behaviors, and lived experiences. Though it involves fewer participants, it is often more time-intensive due to in-depth engagement with each subject. This approach is ideal for exploratory studies where the research problem is not yet well-defined, employing an inductive process where hypotheses emerge from collected data rather than being predetermined.

Qualitative analysis encompasses several techniques. Content analysis examines textual or visual data to identify recurring words or themes. Narrative analysis interprets stories and personal accounts from interviews, surveys, or observations to answer research questions. Discourse analysis considers social and environmental contexts to understand interactions, while grounded theory builds explanatory frameworks from collected data to explain phenomena. Thematic analysis identifies and interprets key patterns within qualitative datasets to uncover underlying issues.

Mixed-Methods Research Methodology

Combining the strengths of both quantitative and qualitative approaches, mixed-methods research integrates numerical and textual analysis within a single study. This dual approach enhances the validity of findings by cross-verifying results, uncovering complementary insights, and explaining discrepancies that might arise from using only one method. For instance, unexpected statistical trends from quantitative data can be further explored through qualitative interviews, providing deeper contextual understanding.

By selecting the appropriate methodology—whether quantitative, qualitative, or mixed-methods—researchers can tailor their investigations to the study's objectives, ensuring robust, reliable, and actionable outcomes. Each approach offers unique advantages, and the choice depends on the research questions, available data, and desired depth of analysis.

3.2. Data collection and analysis

The research uses the secondary data from surveys, newspaper, magazine to find out the how AI impact on R&D, or how the company has changed before and after the



support of AI (Productivity, Costs, Work force...). The research accordingly demonstrates the impact of AI on which aspect of R&D.

The research was collected from Global Data, it is a survey of 128 participants about the voting rates of respondents on the level of productivity increase and cost reduction when applying AI to R&D activities like productivity increases and lower costs.

4. Research result

4.1. AI impact on increasing productivity of R&D generally.

The integration of Artificial Intelligence into Research and Development (R&D) processes is having a transformative impact on productivity. Numerous studies and industry estimates suggest that AI can enhance research workflow productivity by 30–50%, product performance by up to 60%, time-to-market by up to 40%.

Automation of Repetitive and Time-Consuming Tasks

One of the primary ways AI improves productivity in R&D is by automating repetitive and time-consuming tasks. Traditionally, research involves several routine processes, such as data entry, preliminary analysis, experimental setup, and documentation, which can take up a large portion of a researcher's time. AI tools can handle these tasks with greater speed and accuracy, allowing R&D teams to focus on higher-level activities like hypothesis generation, strategic decision-making, and generative creative problem-solving. For example:

- **Data Processing:** In industries like genomics or materials science, researchers often work with massive datasets. AI algorithms can quickly process and clean this data, eliminating the need for manual intervention. This frees up researchers to concentrate on interpreting results and deriving insights.
- **Automated Experimentation:** AI-driven platforms are now capable of automating entire experimental processes, from setting up and conducting experiments to analyzing results and optimizing future iterations. In synthetic biology or drug discovery, this can reduce the time needed to conduct hundreds or even thousands of experiments, significantly boosting throughput.

This automation of routine tasks can easily lead to a 30% increase in productivity by reducing time wasted on manual labor and minimizing errors that require rework.

Faster Data Analysis and Insights Generation

AI's ability to rapidly analyze complex data is another critical factor in boosting productivity. Many R&D fields, particularly those focused on biological, chemical, and physical sciences, generate enormous amounts of experimental and observational data. Manually analyzing this data can take weeks or even months. However, AI-powered data analytics tools, especially those using machine learning (ML) and deep learning (DL), can dramatically speed up this process.

For instance, in drug discovery, AI systems are used to identify potential drug candidates by analyzing chemical structures and biological data at a pace that would be impossible for human researchers to match. AI can sift through large datasets to uncover patterns, relationships, and correlations that researchers may not have anticipated. Similarly,



in material science, AI algorithms can analyze millions of potential chemical compounds to predict which ones are most likely to have desirable properties for specific applications. By dramatically accelerating data analysis, AI allows researchers to move from the data collection phase to actionable insights faster, leading to more efficient use of time and resources. This could contribute to the higher end of the 30–50% productivity boost.

Improved Decision-Making Through AI

One of AI's greatest strengths is its ability to provide actionable insights that support better decision-making. In the R&D context, this means AI can help teams prioritize the most promising research paths, allocate resources more efficiently, and avoid dead-end projects.

AI algorithms can analyze past research data, market trends, and current industry needs to guide R&D teams toward high-value opportunities. For example, AI can predict which technologies or products are most likely to succeed in the market, allowing companies to focus their R&D efforts on the most promising innovations. In drug discovery, AI can predict the likelihood that a drug candidate will pass clinical trials, enabling companies to focus their resources on the compounds with the highest potential for success. By enabling more data-driven decisions, AI reduces the risk of pursuing unprofitable or unsuccessful research paths. This optimizes the use of resources and time, directly contributing to an increase in productivity. Teams spend less time revisiting failed projects and more time developing successful ones.

Collaborative AI Systems for Enhanced Knowledge Sharing

AI tools designed to facilitate collaboration are also enhancing productivity in R&D environments. Research and development are often team-based efforts, involving specialists from different fields and even different organizations. Knowledge sharing, however, can be challenging when working across disciplines and geographies.

AI-powered platforms are emerging to enable seamless collaboration by organizing, sharing, and interpreting research data. These platforms can recommend relevant papers, summarize findings, and even translate technical jargon between disciplines. Natural Language Processing (NLP) tools can also analyze large bodies of text, such as academic papers and patents, to ensure that researchers have access to all relevant knowledge without spending weeks reading and analyzing.

Such collaboration tools allow for faster knowledge dissemination, ensuring that R&D teams can quickly build on existing research rather than duplicating efforts. This increased speed in sharing and collaboration could result in faster project completion and greater overall productivity.

Reducing Time to Market and Product Development Cycles

AI's impact on productivity can be clearly seen in the reduction of time-to-market for new products. In industries like pharmaceuticals, automotive, and consumer electronics, shortening the product development cycle can be the difference between success and failure. AI helps accelerate every stage of the development cycle, from ideation and research to prototyping and production.



For example, AI-driven design tools can suggest optimal configurations for new products based on performance data, allowing for quicker iterations. In manufacturing, AI can optimize production processes by predicting potential bottlenecks or equipment failures before they occur, ensuring that products are delivered on time.

With AI streamlining multiple stages of development, companies can bring products to market faster than ever before, which directly translates into higher productivity and a competitive edge.

4.2. Specific example: AI increase productivity and lower cost of R&D in Biopharmaceutical industry.

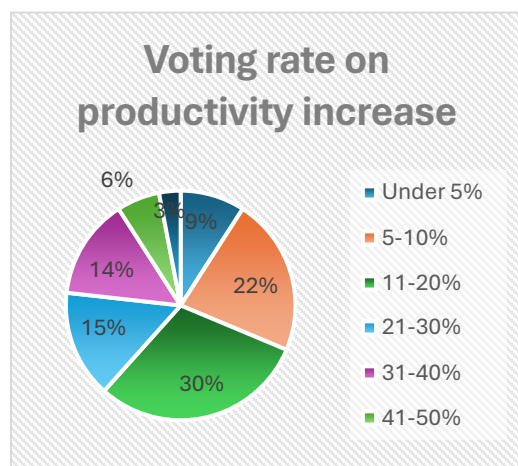


Figure 3: Voting rate on productivity increase.

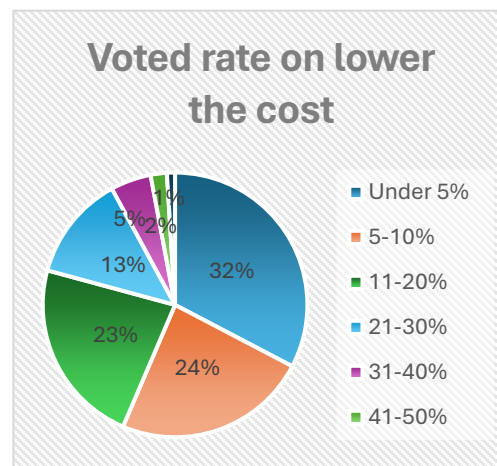


Figure 4: Voting rate on cost reduction.

Based on research from Global Data, the survey was conducted with 128 participants. The report presents the voting rates of respondents on the level of productivity increase and cost reduction when applying AI to R&D activities. Figure 3 illustrates that 30% of surveyed participants believe AI will enhance R&D productivity in the industry by approximately 11% to 20%. Meanwhile, the proportion of votes for the highest increase rate (41% or more) and the lowest increase rate (5% or less) remains relatively low, at around 3% to 6% and 9%, respectively. Figure 4 shows that 24% of surveyed participants believe AI can help reduce costs by up to 10%, while 23% think the reduction could reach up to 20%. In contrast, only 1% of respondents believe AI will lower costs by more than 50%.

4.3. AI impact on workforce of R&D field

Risk of Job Loss

The integration of artificial intelligence into research and development processes brings significant concerns about workforce displacement. One major consequence is the potential reduction in required human labor, as AI systems increasingly take over tasks such as data analysis, simulation testing, and report generation. Routine and repetitive jobs, particularly those involving basic data processing, face the highest risk of automation, which could lead to decreased demand for traditional R&D personnel.



This technological shift is also transforming job structures across industries. Many conventional roles, including laboratory technicians and junior data analysts, may see declining demand as their functions become automated. Meanwhile, the growing reliance on AI is creating new opportunities for specialized professionals such as AI experts, data scientists, and machine learning engineers. This transition will require substantial workforce retraining initiatives to help employees adapt to evolving job requirements.

Perhaps the most pressing challenge is the widening skill gap in the labor market. Employees who lack AI-related competencies or struggle to keep pace with technological advancements may find themselves at a professional disadvantage. To maintain a competitive workforce, organizations will need to prioritize continuous learning and development programs, ensuring their teams can work effectively alongside AI systems. Without such investments, businesses risk losing valuable talent while struggling to fill emerging high-tech roles.

These workforce disruptions highlight the need for proactive strategies to balance AI adoption with employee retention and retraining. While AI offers efficiency gains, its implementation must be managed carefully to mitigate negative employment consequences and foster a smooth transition toward more technologically advanced workplaces.

New Job Opportunities

AI integration in R&D is reshaping employment, creating new roles rather than just eliminating jobs. Industries now seek AI specialists, machine learning engineers, and data scientists to develop and refine AI systems. This demand has led to roles like AI Research Scientists, Data Engineers, and AI Ethics Officers, ensuring innovation and responsible AI deployment.

Beyond creating new roles, AI is fundamentally enhancing how research professionals work. By automating routine tasks and data processing, AI tools enable R&D teams to operate with unprecedented efficiency, freeing human experts to concentrate on higher-level strategic thinking and creative problem-solving. This powerful synergy between human ingenuity and machine intelligence is already yielding remarkable innovations across multiple scientific disciplines, from materials science to pharmaceutical development. The resulting productivity gains and breakthrough discoveries are expanding the horizons of what's possible in research while simultaneously creating new avenues for professional growth and industry advancement.

This transformation is also reshaping the skills landscape in research professions. The most sought-after professionals will be those who can effectively bridge traditional domain expertise with AI competencies. For instance, pharmaceutical researchers who can leverage machine learning for drug discovery or materials scientists applying neural networks to develop novel compounds will command significant competitive advantages. While some traditional roles may diminish, employment opportunities are not vanishing but rather migrating to new hybrid domains that require both specialized scientific knowledge and AI literacy. This shift underscores the importance of continuous learning and skill adaptation for research professionals seeking to thrive in the AI-augmented workplace of the future.

5. Conclusion



AI has revolutionized R&D by driving productivity gains, reducing costs, and improving the workforce. Studies demonstrate AI's ability to improve efficiency through task automation and faster data analysis, increasing productivity by 30–50% while shortening research and lead cycles and time-to-market. The technology also offers significant cost savings by optimizing operations through predictive analytics and automated processes, reducing costs associated with testing and resource management. Both the unskilled and knowledge workforces are undergoing fundamental change as AI adoption advances. While automation replaces some traditional roles, it simultaneously creates new opportunities in AI-focused sectors. This transformation underscores the growing need for workforce reskilling and adaptation to meet the changing needs of the industry. Together, these changes highlight the dual role of AI as both a disruptor and an enabler in the modern R&D environment.

Implication

The findings of this analysis highlight the need to maximize the benefits of AI while minimizing potential risks in R&D. Companies should prioritize investments in AI integration to improve research efficiency and maintain competitiveness, combined with comprehensive workforce upskilling initiatives to prepare employees for changing job requirements. A balanced approach to human-AI collaboration will be important, assuming that AI augments, not replaces, human expertise. At the same time, the development of robust ethical frameworks and governance standards is essential to ensure responsible AI deployment.

Recommendations

Advancing AI algorithms are transforming R&D, enabling faster discoveries, smarter decision-making, and breakthrough innovations. By leveraging AI, businesses can optimize processes, enhance predictive analytics, and drive sustainable growth.

Limitations

While AI benefits R&D, limitations remain. Data quality impacts accuracy, high costs pose barriers, and legal compliance is challenging. AI cannot replace human creativity, and over-reliance may hinder breakthroughs. Cybersecurity and intellectual property risks also require attention. A balanced strategy integrating technology, people, and regulations is essential for effective and sustainable AI application in R&D.

Future research directions

To optimize AI in R&D, it is necessary to focus on improving data quality, developing transparent algorithms, and reducing bias. Research on models that combine AI and human thinking will help balance automation with creativity. In addition, building a tight legal framework and enhancing data security are necessary to ensure safe and effective AI deployment. These directions will help AI promote sustainable innovation in R&D

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