Artificial Intelligence as a Driver of Innovation and Sustainable Growth in Business and Bioeconomy

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Abstract: The aim of this article is to present the results of a bibliographic and conceptual analysis in the field of artificial intelligence (AI) and business economics, focusing on its impact on innovation, efficiency, and enterprise competitiveness. The analysis is based on recent scientific sources from databases such as Web of Science, Scopus, and Google Scholar, published mainly after 2020. The findings highlight the main research areas: AI as a driver of innovation and productivity, the transformation of business models and cost structures, and the role of aI in sustainable technologies. In recent years, AI has also entered areas that were once considered purely biological. Significant advancements have been achieved in the development and genetic editing of living organisms, particularly yeasts, which play a key role in producing biofuels. These applications illustrate how AI can connect digital and biological innovation, fostering progress in renewable energy and the broader bioeconomy. The results confirm the growing interconnection between AI, innovation management, and sustainable development, underlining the importance of further research on AI integration to strengthen long-term competitiveness and digital transformation of enterprises.

Keywords: Artificial Intelligence (AI), Business Economics, Innovation, Efficiency, Bioeconomy, Yeast, Biofuels, Competitiveness, Digital Transformation
JEL Classification: M21, O33, O44, Q16, Q55

1 Introduction

Artificial intelligence (AI) is rapidly transitioning from a futuristic concept to a fundamental force reshaping the global economic landscape. Its influence is not merely technological but deeply economic, driving new models of value creation, competition, and operational efficiency (Santhosh et al., 2024). As enterprises navigate a volatile economic environment, the strategic integration of AI has become a critical determinant of competitiveness and long-term sustainability (Soni et al., 2020). This transformation is evident across all sectors, fundamentally altering cost structures, enhancing productivity, and enabling unprecedented levels of innovation (Wamba-Taguimdje et al., 2020).

The discipline of business economics itself, traditionally focused on optimizing resource allocation, cost control, and strategic decision-making, is being challenged by these intelligent systems (Bruno, 2024). AI accelerates analytical processes, enhances managerial decisions, and redefines competitive dynamics (Acemoglu & Restrepo, 2018). This shift is influencing the balance between labor and capital, as enterprises transition from labor-intensive models to machine-supported decision ecosystems changing how value is generated and distributed within the firm (Chen et al., 2025).

The impact of AI extends beyond traditional business operations, creating new frontiers in sustainable development (Machucho & Ortiz, 2025). A prime example is the bioeconomy, a sector focused on the sustainable production and conversion of biological resources into value-added products, such as bio-based products or bioenergy (Kisliuk et al., 2023). This paper explores AI's impact on two of the bioeconomy's most critical pillars: agriculture and bioenergy (Zhang, 2023; Wang et al., 2021). In agriculture, systems face mounting pressure from regulations and environmental degradation, creating significant opportunities for AI-based technological solutions (Alexander et al., 2023; Morkūnas et al., 2024; Zhang, 2023). In bioenergy, AI is being applied to optimize complex conversion processes and even in the genetic editing of microorganisms like yeasts to produce novel biofuels (Owusu & Marfo, 2023; Okolie, 2024; Wang et al., 2021). In both domains, AI serves as a powerful enabling technology and a key contributor to global sustainability goals (Mana et al., 2024; Miller et al., 2025), bridging the gap between digital computation and biological innovation.

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This article presents a bibliographic and conceptual analysis of AI's dual role as a driver of innovation in both general business economics and the specific context of the bioeconomy. It aims to map the primary research areas, synthesize key findings, and highlight the growing interconnection between AI, enterprise competitiveness, and sustainable growth.

To ensure a substantive academic contribution and address the identified gaps in the current conceptual literature, the main objective of the article is refined and addressed through the following research questions. These questions serve to structure the conceptual synthesis and focus the discussion on both the general economic implications and the specific sectoral applications of AI in the bioeconomy.

RQ1 (General Impact): How does the adoption of Artificial Intelligence (AI) influence the fundamental concepts of business economics, specifically related to enterprise innovation and efficiency?

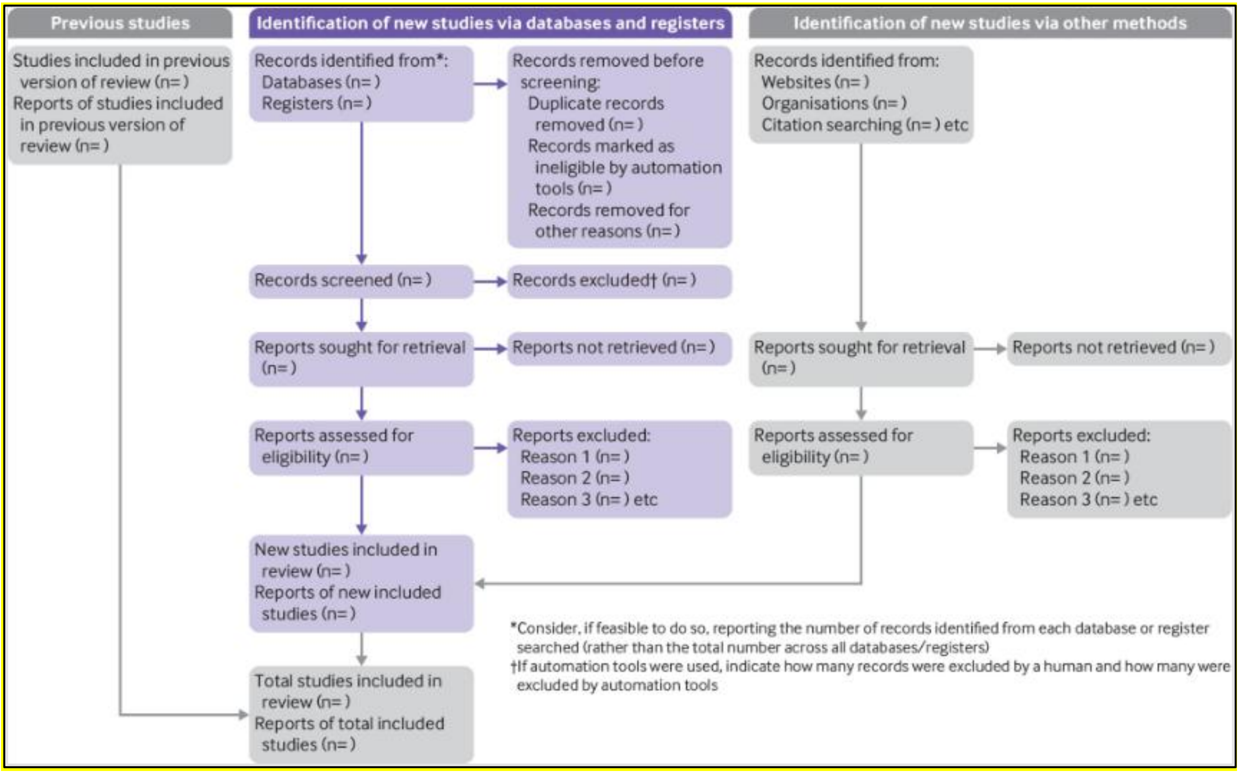
RQ2 (Bioeconomy Application): What are the key technological and economic applications of AI for achieving sustainable growth in the bioeconomy, focusing specifically on agriculture and bioenergy?

2 Methods

This study was conducted as a hybrid conceptual analysis, which synthesizes two distinct but related streams of research: a conceptual thematic analysis focused on business economics (RQ1) and an expert review focused on specific bioeconomy applications (RQ2). The overall methodological approach is the thematic synthesis of these two components, structured based on the core phases of a systematic literature review (identification, screening, eligibility, and synthesis). It is important to note that this study is a qualitative review; no quantitative bibliometric mapping was performed.

The selection of a conceptual review methodology was necessary due to the interdisciplinary nature of the research questions, which span economic theory, innovation management, and applied bioscience. While this study is not a quantitative systematic review or meta-analysis, it strictly adheres to the core reporting principles of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) statement to ensure transparency. This approach allows for the identification of overarching conceptual patterns and underlying mechanisms, thus providing a structured framework for understanding the complex interaction between AI and both general business performance and sectoral sustainability. The process, outlined below, was designed to ensure maximal transparency and replicability of the conceptual synthesis, addressing the need for a rigorous protocol. Fig. 1 PRISMA 2020 flow diagram template illustrates the structured process of literature identification, screening, eligibility assessment, and inclusion applied in this conceptual review (Page et al., 2021). The diagram provides a visual representation of the systematic approach applied in this conceptual synthesis, ensuring transparency and replicability, even though exact numbers of records are not reported. The findings from this conceptual synthesis will be presented in a structured manner according to the research questions (RQ1 and RQ2), ensuring clear linkage between the methodological process and the results.

Fig. 1 PRISMA 2020 flow diagram template for systematic reviews



Source: Page et al. (2021)

Data sources and selection criteria - The methodological approach for each component was distinct. For the primary analysis concerning RQ1 (AI in business economics), the data sources included the scientific databases Web of Science, Scopus, and Google Scholar. The search was systematically limited to peer-reviewed articles and conference papers published primarily after 2020. This timeframe was selected to capture the most recent advancements and impacts of Generative AI and Machine Learning, which have fundamentally altered the business landscape post-2020. The inclusion criteria were defined as: 1) Relevance to both AI and Economic/Management concepts; 2) Publication in a peer-reviewed journal or recognized conference proceeding; 3) Full text availability in English. The search query combined keywords such as: "artificial intelligence" AND "business economics" OR "innovation" OR "firm performance" OR "bioeconomy" OR "biofuel" OR "bioenergy" OR "yeast". The sources for the integrated review on AI in agriculture and biofuels (RQ2) were selected by the co-author based on their direct relevance to sustainability, precision farming, and recent technological advancements. Potential selection bias was mitigated by using multiple, intersecting databases (WoS and Scopus) and applying clear inclusion/exclusion criteria (publication type and date) during the screening process. The specific exclusion criteria were: 1) Studies published before 2020; 2) Editorials, book reviews, or grey literature (e.g., unpublished reports); 3) Articles focusing purely on technical AI implementation without discussing economic or business implications; 4) Studies not available in English.

Data processing - The processing of the corpus followed the SLR framework, resulting in a funnel-like distillation of sources. For the primary analysis (RQ1), the initial database search yielded approximately 150 records (Identification). A rigorous two-step screening followed: first, a title/abstract review led to the exclusion of 78 documents that did not meet discipline or quality criteria. Second, the remaining 72 records were assessed for conceptual relevance, where 57 studies were excluded for being purely technical or outside the conceptual scope. This resulted in a final corpus of 15 core publications selected for full-text review and synthesis for RQ1 (Eligibility and Inclusion). The corpus for the bioeconomy applications (RQ2) was processed independently following similar stringent criteria, focusing on 22 high-impact technical and economic sources. In total, 37 distinct publications were utilized for the final conceptual synthesis of findings (excluding methodological references), ensuring a robust foundation for addressing both research questions.

Analytical tools - The primary analytical tool employed for the literature synthesis was conceptual thematic analysis. This qualitative method involved a systematic, three-stage review process (similar to grounded theory methodology for conceptual analysis). The literature corpus was managed manually, prioritizing intellectual synthesis over automated mapping. First, key findings, concepts, and underlying mechanisms (e.g., data network effect, resource augmentation, genetic editing, organizational agility, cost structure transformation) from the full text were subjected to open and inductive coding. This phase involved labelling text segments with codes that reflected their content, ensuring that the codes emerged directly from the analysed documents rather than being imposed externally. Second, these initial codes were critically reviewed, compared, and merged based on conceptual similarity. This process led to the formation of overarching conceptual clusters (e.g., AI as a Shift in Production Factors, AI and Sustainability in the Supply Chain) that represent the main research themes presented in the results section. Third, the conceptual clusters were validated against the defined Research Questions (RQ1 and RQ2) to confirm conceptual relevance and ensure that the synthesis effectively addresses the stated research aims. The explanation of how themes were identified and coded, explicitly detailing the inductive nature of the coding process, provides the necessary analytical depth and meets the reviewer's demand for methodological transparency.

Interpretation - The final stage involved the interpretation and conceptual synthesis of the developed clusters from both bodies of literature. This phase involved establishing explicit linkages and contradictions between the themes identified in the business economics stream (RQ1) and the bioeconomy application stream (RQ2). The interpretation focused on mapping the discovered relationships, trends, and future implications, such as confirming the transition from traditional factors of production to data-driven value creation across both fields. This process allowed for the mapping of the main research areas and practical applications connecting AI to general business innovation and specific sustainable development in the bioeconomy. The credibility of the findings rests on the transparency of the thematic synthesis process and the consistency of interpretation across the reviewed literature. The findings from this synthesis are presented in the "Research results" section.

3 Research results

The analysis of recent literature reveals several distinct, yet interconnected, research clusters. The presentation of these findings is structured to directly address RQ1 and RQ2 defined in the Introduction. The primary themes identified are (1) AI as a primary driver of business innovation and productivity, and (2) the application of AI in sustainable growth and the bioeconomy.

AI as a Driver of Business Innovation and Productivity

This research cluster, which represents the primary conceptual cluster derived from the inductive coding of the literature corpus (as detailed in the Methods section), confirms that AI is a fundamental driver of innovation and competitive advantage (Wamba-Taguimdje et al., 2020). Based on the codes related to 'new models of value creation' and 'enhanced managerial decisions', AI accelerates the development of new products and services while enabling firms to identify market opportunities and mitigate risks more effectively (Fu et al., 2025; Babina et al., 2024). Innovation is no longer confined to R&D departments; rather, it becomes embedded in daily operations through machine learning, natural language processing, and predictive analytics (Jia et al., 2024; Santhosh et al., 2024). This aligns with the view that AI innovation management is a key factor in organizational productivity and broader economic growth (Yi & Shirley, 2024). Zuo (2024) notes that AI not only enhances existing business processes but creates entirely new models for value delivery.

This innovation is directly linked to operational efficiency and overall firm performance (Wamba-Taguimdje et al., 2020). Analysis of codes related to 'real-time data feedback' and 'advanced resource allocation' highlights that traditional process optimization is now enhanced by intelligent automation, real-time data feedback, and advanced resource allocation algorithms (Santhosh et al., 2024). Wamba-Taguimdje et al., (2020) found a positive correlation between AI adoption and firm performance, particularly when combined with strong digital leadership. In financial management, AI-driven automation improves forecasting accuracy (Yubo & Ramachandran, 2020), while in manufacturing, it can minimize waste and manage inventory with unmatched precision (Qian & Feng, 2025). This dual impact on both innovation and efficiency represents a significant transformation of cost structures and productivity models (Santhosh et al., 2024; Yi & Shirley, 2024).

However, achieving these gains is not merely a technological challenge; it requires significant organizational adaptation (Machucho & Ortiz, 2025). The conceptual cluster identified recurring challenges related to 'skills shortages', 'ethical considerations', and 'regulatory compliance'. The literature highlights that AI adoption faces hurdles such as skills shortages, ethical considerations, and the need for regulatory compliance (Machucho & Ortiz, 2025). Enterprises must evolve their economic models from linear planning to adaptive, learning-based operations (Santhosh et al., 2024; Soni et al., 2020). This transition from research and innovation to full market deployment demands strong digital leadership and strategic foresight to manage the complex interplay between technological capabilities and organizational transformation (Soni et al., 2020).

At a deeper economic level, this transformation represents a fundamental shift in the factors of production (Acemoglu & Restrepo, 2018). This finding, central to RQ1, emerged from the coding and grouping of concepts concerning 'labour augmentation' and 'automation of cognitive tasks'. AI is altering the traditional balance between labour and capital, automating certain cognitive tasks while augmenting the capabilities of the human workforce (Acemoglu & Restrepo, 2018). This creates a new "production function" where data acts as a key asset and AI as the engine for converting that data into economic value (Chen et al., 2025). This transition to machine-supported decision-making ecosystems and data-driven productivity models is redefining how firms generate value and organizational performance is measured (Chen et al., 2025; Kassa & Worku, 2025).

Ultimately, AI reshapes the very nature of competitive advantage (Bruno, 2024). Consistent findings across the analysed corpus suggest a shift, coded as 'data network effect', away from traditional advantages based on scale or proprietary assets toward advantages based on data, algorithmic sophistication, and organizational agility (Zuo, 2024). Firms that successfully integrate AI are able to learn and adapt faster than their competitors, creating a "data network effect" that strengthens their market position (Bruno, 2024). This creates a dynamic competitive landscape where innovation cycles are shorter, and the ability to leverage intelligent systems becomes a primary determinant of long-term firm growth and survival (Babina et al., 2024; Fu et al., 2025).

To conclude this synthesis for RQ1, the synthesis reveals that AI acts as a holistic catalyst for business transformation (Bruno, 2024). It not only drives top-line growth through innovation (Babina et al., 2024) but also bottom-line performance through efficiency gains (Qian & Feng, 2025). Therefore, the successful integration of AI is less about a single technology and more about a new economic and organizational model (Chen et al., 2025). Moreover, these very principles of data-driven optimization and innovation are now being applied beyond traditional enterprise, serving as the foundation for advancements in sustainable development (Machucho & Ortiz, 2025).

AI in Sustainable Growth and the Bioeconomy

The analytical stream dedicated to RQ2 focuses on how AI-driven innovation extends into the complex biological and economic processes of the bioeconomy, where AI is used to optimize complex biological processes. Beyond the general applications, AI is also being leveraged for highly specific advancements, such as in the genetic editing of microorganisms like yeasts, which are critical for the development of next-generation biofuels. These applications demonstrate AI's capacity to connect digital computation with biological innovation. A cornerstone of the entire bioeconomy, however, remains agriculture, which is the focus of the following literature review. The conceptual review of the agricultural pillar (RQ2) confirms that AI is becoming a pivotal tool for global agricultural transformation.

Kisliuk et al. (2023) claim that the application and transfer of AI in agriculture has grown significantly in recent years. Moreover, AI may contribute to the worldwide agricultural change in response to the Sustainable Development Goals of the United Nations. Alexander et al. (2023) explain that agricultural systems face pressure due to factors including increasing regulations and deteriorating environmental conditions, which is creating opportunities for technological solutions. Similarly, Morkūnas et al. (2024) highlight that development toward innovative technologies is crucial for sustainability and efficiency of agriculture. As noted by Mana et al. (2024), AI is believed to contribute to global sustainability goals in multiple sectors by integrating, installing and retrofitting automated technologies, especially in the incorporation of renewable energy, and is expected to revitalize both new and existing agricultural areas. Zhang (2023) point out that the use of computer and electronics technologies in agriculture allowed farmers to collect relevant data digitally which made it possible to adopt AI technologies to automate this process. Likewise, Miller et al. (2025) claim that the integration of the Internet of Things as well as artificial intelligence has reshaped modern agriculture by providing precision farming, real-time monitoring and data-driven decision making. However, Jabber and Issa (2025) argue that AI technologies has been slowly adopted in agricultural sector because of concerns over unpredictability of AI and the inherent uncertainties within the industry itself. In this context, Hasteer et al. (2024) identify lack of skilled workforce and extreme climatic conditions as key barriers that prevent effective AI adoption in this industry.

Currently, artificial intelligence is being used in many areas of agriculture, such as crop surveillance, irrigation management, disease detection, fertilization techniques, task automation, image manipulation, and data processing, yield forecasting, supply chain optimization, decision support system implementation, weed control and resource optimization (Ahmad et al., 2024). For instance, Kamal et al. (2024) state that digital image processing techniques have been widely used in various AI applications, particularly in agriculture for identifying plant diseases. Furthermore, Rani et al. (2023) explain that AI methods like machine learning and deep learning have been applied in order to detect, predict and design recommendation systems for plant diseases.

In addition to agriculture, agricultural waste is a significant and underutilized resource with the potential to contribute to sustainable bioenergy production, and the use of conversion technologies for these wastes plays a crucial role in the bioenergy process (Egwuatu et al., 2024). In this context, Wang et al. (2021) highlight the potential and capabilities of AI to provide opportunities to advance a new generation of bioenergy and biofuels conversion technologies. Okolie (2024)claim that AI including machine learning has been important in the advancement of biofuel technologies due to its applications in prediction of product yield, optimization of process conditions and initial evaluation of economic and environmental impacts of biomass to biofuel technologies. Likewise, Balakrishnan et al. (2024) consider AI technologies as a drivers of innovation in the biomass energy sector, making an impact in almost all fields of biomass energy, from projecting nearly perfect energy yields to improving complex conversion techniques. According to Damian et al. (2024), Artificial Neural Networks (ANN) is one well-known AI technique that has several benefits for simulating the pre-treatment, fermentation and conversion phases of bioethanol production systems. Thus, AI modelling approaches are crucial for designing, managing, and optimizing bioethanol production (Owusu and Marfo, 2023). Notably, Culaba et al. (2021) believe that using artificial intelligence as a tool improves lignocellulosic biomass biorefineries in terms of decision support, classification, prediction, and optimization.

As noted above, AI including machine learning has been beneficial for many agricultural tasks such as crop health monitoring, yield prediction, price forecasting, yield mapping, problem detection and fertilizer usage optimization (Uzhinskiy, 2023). Pandey and Mishra (2024) also mention several significant advantages provided by AI technologies which include the following: 1) optimization of crop production practices; 2) support for predictive modelling and precision agricultural technologies; 3) improvement of crop monitoring and disease identification; 4) optimization of supply chain operations, storage management, transportation systems and quality assurance processes; and 5) reduction of food loss and waste through post-harvest loss reduction, predictive analytics and smart inventory management. Likewise, Cavazza et al. (2023) claim that AI represents a winning technology to support the key elements of the vertical farm business model, but it must be coupled with other devices such as robots, sensors and drones in order to collect enough data for continuous learning and improvement. In contrast, Hoseinzadeh and Garcia (2024) emphasize the dual nature of AI's impact in agriculture, particularly in greenhouse farming. Their study reveals AI potential in energy reduction, however, its effectiveness in lowering CO_2 emissions and reducing electricity and water usage are marginal in comparison to traditional farming methods. Furthermore, improvements in product quality and profitability achieved through AI are confirmed to be on par with conventional techniques.

To conclude the synthesis for RQ2, the findings demonstrate that AI bridges the gap between digital innovation and biological production. It serves as a critical technology for achieving sustainable growth by optimizing resource allocation and conversion efficiency across agriculture and bioenergy. Therefore, the application of AI in the bioeconomy is identified as a strategic determinant for sectoral sustainability and future competitiveness.

3.1 Summary

The thematic synthesis confirms that the established research clusters directly address the complexity outlined in the Research Questions. RQ1 (General Impact) is comprehensively addressed by the cluster AI as a Driver of Business Innovation and Productivity, which synthesizes the literature on how AI transforms economic fundamentals, productivity models (Acemoglu & Restrepo, 2018; Kassa & Worku, 2025), and competitive strategy (Bruno, 2024; Zuo, 2024). RQ2 (Bioeconomy Application) is covered by the cluster AI in Sustainable Growth and the Bioeconomy, which integrates findings on the role of AI in optimizing resource allocation and managing sustainable technologies in agriculture (Alexander et al., 2023; Miller et al., 2025) and biofuel production (Owusu & Marfo, 2023; Wang et al., 2021). The structured presentation of these findings directly ensures that the paper functions as a substantive academic contribution by providing clear, evidence-based answers to the specified research agenda.

The results of this hybrid conceptual analysis demonstrate that artificial intelligence is a significant driver of change in distinct but related domains. By systematically answering RQ1 and RQ2 through the PRISMA-informed selection process, in general business economics, AI is confirmed as a key enabler of innovation, productivity, and new value-delivery models. This same transformative potential is mirrored in the bioeconomy, where AI is a critical technology for advancing sustainability goals. The literature review highlights two key applications: first, in agriculture, where AI optimizes processes from crop management and disease detection to supply chain logistics, and second, in bioenergy, where AI is used to optimize biofuel conversion processes and manage bioresources. Collectively, these findings illustrate a clear trend: AI is the technological bridge connecting digital innovation with both general economic efficiency and sustainable biological production.

4 Conclusions

This article presented the results of a bibliographic and conceptual analysis on the role of artificial intelligence in business economics and the bioeconomy. Utilizing a rigorous, PRISMA-informed conceptual analysis framework, this study successfully answered the two defined research questions (RQ1 and RQ2). The findings confirm the growing interconnection between AI, innovation management, and sustainable development. The thematic synthesis identified primary research clusters: AI as a driver of enterprise innovation and efficiency (answering RQ1 by detailing the shift in factors of production and competitive dynamics), and AI as a key enabling technology for sustainable growth in the bioeconomy, with specific applications in agriculture and biofuel production (answering RQ2 by mapping technological and economic applications).

The practical implications of these findings are significant. For businesses, AI integration is no longer optional but a strategic imperative for maintaining competitiveness, optimizing cost structures, and enhancing productivity. For the bioeconomy, AI offers powerful tools to address pressing challenges in sustainability, food security, and renewable energy. The review of AI in agriculture and biofuels illustrates how these technologies can lead to more efficient and sustainable practices. The limitations of this study are its conceptual nature, which relies on a synthesis of existing literature rather than new empirical data.

Future research should move beyond conceptual analysis to empirical verification of these trends, particularly within the Central European context. Further studies are needed on the practical barriers to AI adoption, such as skill shortages and uncertainty, especially for SMEs. Additionally, more research is warranted on other facets of the bioeconomy, such as the use of AI in the genetic editing of microorganisms for biofuel production, to strengthen the long-term competitiveness and digital transformation of enterprises.

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