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ARTIFICIAL INTELLIGENCE AS A DRIVER OF PRODUCTIVITY, GREEN AND CIRCULAR ECONOMIC TRANSFORMATION: A MODEL FOR UZBEKISTAN IN THE ERA OF GLOBALIZATION AND CLIMATE CHANGE

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Abstract

The rapid diffusion of artificial intelligence (AI) is transforming the organization of production, resource allocation, innovation and economic decision-making, while globalization and climate change are simultaneously increasing the need for more productive, resource-efficient and environmentally sustainable growth. For developing economies, the challenge is not only to accelerate digital transformation but also to ensure that AI contributes to green and circular economic development. This study examines the potential of AI to enhance productivity while supporting resource efficiency, environmental sustainability and circular economic transformation in Uzbekistan. The research combines a comparative review of international experience, analysis of Uzbekistan's economic and policy context, indicator-based assessment and conceptual economic modelling. Particular attention is given to the mechanisms through which AI can improve production efficiency, optimize energy and water use, reduce material losses, improve waste management, strengthen forecasting and support climate-resilient economic activities. Based on these relationships, the study develops an **AI-Driven Green Circular Productivity Model (AI-GCPM)** designed for the institutional and economic conditions of Uzbekistan. The proposed model integrates AI adoption, productivity improvement, green efficiency and circularity into a unified framework and provides a basis for evaluating the economic contribution of AI beyond conventional digitalization indicators. The study argues that effective AI deployment requires integration with human capital development, digital infrastructure, environmental policy, data governance and sector-specific innovation. The proposed model provides policy directions for using AI to accelerate sustainable productivity growth and strengthen the long-term competitiveness of Uzbekistan and other developing economies facing simultaneous digital, economic and climate-related transformations.

Keywords: artificial intelligence; productivity growth; green economy; circular economy; digital transformation; sustainable development; climate change; Uzbekistan.

1. Introduction

Artificial intelligence (AI) has moved from being a specialized technological field to becoming a general-purpose technology with potentially significant implications for productivity, innovation,

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resource allocation and economic transformation. Recent developments in computing capacity, data availability and machine-learning technologies have accelerated the diffusion of AI across manufacturing, agriculture, finance, logistics, energy, healthcare and public services. The Organization for Economic Co-operation and Development (OECD) identifies AI as a technology capable of influencing productivity and long-term economic growth, while recent evidence suggests that the magnitude of its economic effects depends strongly on the level of exposure to AI, adoption rates, sectoral structure and the institutional capacity of individual economies.

The productivity dimension of AI is particularly important for developing economies. AI can support productivity through automation of routine activities, improved forecasting, optimization of production processes, predictive maintenance, more efficient allocation of inputs and faster decision-making. However, the potential benefits are not automatically distributed across countries. Recent OECD research indicates that low- and lower-middle-income economies may obtain smaller productivity gains from AI because of limitations in digital infrastructure, skills, financing, organizational capabilities and regulatory frameworks. At the same time, international knowledge transfer, a young workforce and the diffusion of affordable AI applications may create opportunities for developing economies to reduce technological gaps.

The economic importance of AI is therefore closely connected with the broader process of globalization. Global value chains are increasingly influenced by digital technologies, data-intensive production and technology-enabled competition. For developing countries, participation in global markets increasingly requires not only access to physical infrastructure and financial capital but also the capacity to adopt advanced technologies and improve total factor productivity. In the case of Uzbekistan, increasing productivity is particularly important because recent economic assessments identify total factor productivity as a central factor for sustaining growth and achieving higher-income status. The World Bank has also emphasized the importance of private-sector development, technological capacity, trade integration and digital solutions for strengthening Uzbekistan's competitiveness in global markets.

At the same time, the traditional productivity-growth model faces a second major challenge: climate change and increasing pressure on natural resources. Economic expansion can increase demand for energy, water and raw materials, while climate-related risks can negatively affect agricultural productivity, infrastructure, household welfare and long-term investment. Uzbekistan faces particularly important challenges in this area. The World Bank's Country Climate and Development Report identifies water scarcity, drought, extreme heat, rainfall variability, dust storms and the ecological consequences of the Aral Sea crisis among the risks affecting the country's development prospects. It also describes Uzbekistan as having a highly energy and resource-intensive economic structure and emphasizes the need to combine climate action with continued economic development.

These circumstances create a need to move beyond a narrow understanding of digital transformation. AI should not be considered solely as a mechanism for automating existing processes. Properly integrated with environmental and economic policy, AI can also support resource efficiency and the transition toward greener production. AI-based forecasting can improve energy-system management; intelligent monitoring can identify production losses and equipment failures; optimization algorithms can reduce unnecessary energy and material consumption; and data-driven systems can improve waste collection, sorting and resource recovery. The International Energy

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Agency reports that AI is already being applied to optimize energy systems, reduce costs, improve operational performance, increase efficiency and lower emissions. At the same time, AI itself has an environmental footprint because data centers and computational infrastructure require substantial electricity, meaning that the sustainability effects of AI cannot be assumed automatically.

This dual character of AI creates an important research and policy problem. AI can contribute to economic and environmental efficiency, but its benefits depend on how it is implemented. Digital technologies can support the so-called **twin transition**, in which digital transformation and the green transition reinforce each other. OECD research highlights channels through which digitalization, including AI, can affect energy efficiency and the carbon intensity of economic activity. Digital technologies can also support circular-economy activities through better resource tracking, waste management, product information and more efficient production systems.

For Uzbekistan, this relationship is particularly significant because the country is simultaneously pursuing digital transformation, economic modernization and a transition toward a greener development model. The country's policy agenda includes the development and application of AI in economic and social sectors, while green-development policies emphasize resource efficiency, renewable energy, emissions reduction and climate resilience.

Uzbekistan's policy framework for artificial intelligence is supported by Presidential Resolution No. PP-4996 of February 17, 2021, “On Measures to Create Conditions for the Accelerated Implementation of Artificial Intelligence Technologies.” The resolution establishes priorities for expanding AI applications across economic sectors, improving access to digital data, developing qualified specialists, and supporting AI-based innovation. These priorities provide an institutional foundation for integrating AI adoption with productivity improvement, technological modernization, and sustainable economic transformation in Uzbekistan (President of the Republic of Uzbekistan, 2021). International development assessments likewise identify digital infrastructure, AI capabilities, energy efficiency and environmental sustainability as interconnected components of Uzbekistan's long-term development.

Nevertheless, a substantial research gap remains. Existing studies frequently examine AI and productivity, digitalization and environmental sustainability, or circular economy and resource efficiency as separate research areas. Other studies examine the technological opportunities created by AI without developing an integrated economic mechanism connecting AI adoption with productivity, green efficiency and circularity. Recent international research increasingly recognizes the relationship between digital and green transformation, but there remains a need for practical models adapted to the institutional, technological and resource conditions of developing economies.

This study addresses this gap by developing an **AI-Driven Green Circular Productivity Model (AI-GCPM)** for Uzbekistan. The model conceptualizes AI not as an isolated digital technology but as an economic transformation instrument operating through four interconnected dimensions: **AI adoption, productivity growth, green efficiency and circular economic performance**. The model is designed to explain how AI can improve the efficiency of labor, capital, energy, water and material resources while simultaneously supporting environmental sustainability and climate resilience.

The main objective of the study is therefore to develop and substantiate an economic model for the integration of AI into productivity-oriented green and circular transformation in Uzbekistan. The study pursues the following research questions:

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RQ1. Through which economic mechanisms can AI contribute to productivity growth in Uzbekistan?

RQ2. How can AI adoption support energy, water and material efficiency and the transition toward a green and circular economy?

RQ3. What lessons from developed and emerging economies can be adapted to the economic conditions of Uzbekistan?

RQ4. What institutional, technological and human-capital conditions are necessary for AI-driven green and circular productivity growth?

RQ5. How can an integrated AI-GCPM framework support Uzbekistan's sustainable competitiveness under globalization and increasing climate-related pressures?

The scientific contribution of the study is the development of an integrated **AI-Driven Green Circular Productivity Model (AI-GCPM)** that connects technological adoption with measurable economic and environmental dimensions. In contrast to approaches that evaluate AI primarily through digitalization or automation indicators, the proposed framework considers whether AI contributes simultaneously to productivity improvement, resource efficiency and circular economic transformation. The model is intended to provide a basis for evaluating AI policy not only by the number of digital services or AI applications introduced, but also by their contribution to economic value creation and resource efficiency.

The practical contribution of the research is directed toward policymakers, businesses, researchers and development institutions in Uzbekistan and other developing economies. The proposed framework can support the identification of priority sectors for AI deployment, including manufacturing, agriculture, energy, transport, logistics and waste management, while providing a conceptual basis for linking AI policy with green-growth and circular-economy objectives. Such integration is increasingly important because the environmental consequences of AI itself must be managed alongside its potential efficiency gains.

The remainder of the article is organized as follows. The next section reviews the theoretical and empirical literature on AI and productivity, AI-enabled green transformation, circular economy, climate resilience and international experience. The methodology section then presents the analytical framework, indicators and mathematical formulation of the proposed AI-GCPM. The analysis and results section applies the framework to the economic conditions and priority sectors of Uzbekistan and examines relevant international experiences. Finally, the study presents conclusions and policy recommendations for implementing AI as an instrument of sustainable productivity and green circular transformation.

6.1. AI and Productivity

Artificial intelligence (AI) has increasingly been identified as a general-purpose technology with the potential to transform production processes, improve resource allocation, and increase labor and firm-level productivity. By supporting data analysis, process automation, forecasting, decision-making, and innovation, AI can enable firms to perform existing tasks more efficiently while also creating new forms of production and business organization. Recent empirical evidence provides support for a positive relationship between AI adoption and firm productivity. For example, evidence from German firms indicates that both AI adoption and the intensity of AI use are positively associated with firm-level productivity, while research using European firm-level data also links AI innovation with improvements in productivity and resource utilization.

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The productivity effects of AI, however, are not necessarily immediate or uniform across economies. OECD research emphasizes that the aggregate productivity impact depends on complementary investments in digital infrastructure, human capital, management capabilities, and organizational transformation. AI adoption also remains uneven across firms and sectors, with larger and more productive firms generally adopting AI more rapidly than smaller firms. Similarly, global evidence based on AI patents and publications has identified a productivity paradox: despite the rapid development of AI technologies, their contribution to officially measured macroeconomic productivity has remained relatively limited in many countries.

More recent OECD estimates nevertheless suggest substantial potential long-term productivity gains if AI adoption becomes sufficiently widespread and complementary conditions are established. Estimated annual aggregate total-factor productivity gains attributable to AI range from approximately 0.25 to 0.6 percentage points, although these estimates remain sensitive to adoption patterns and technological development.

Therefore, the literature suggests that AI should not be considered simply as an independent source of productivity growth. Its economic effect depends on the interaction between technological adoption, skills, infrastructure, organizational capabilities, and institutional conditions. This perspective is particularly relevant for developing economies such as Uzbekistan, where increasing AI adoption needs to be connected with broader productivity-enhancing and sustainable economic transformation.

6.2. AI and Green Economic Transformation

Artificial intelligence is increasingly considered an important technological instrument for supporting the transition toward greener economic systems. AI-based technologies can improve energy management, optimize industrial processes, reduce material and energy consumption, and support more accurate environmental monitoring. Through predictive analytics and intelligent control systems, firms and public institutions can identify inefficiencies and improve the allocation of energy and other productive resources. Consequently, AI has the potential to contribute to economic growth while reducing the environmental intensity of production.

Recent studies indicate that digital technologies, including AI, can contribute to green innovation by improving firms' ability to monitor environmental performance, develop cleaner production processes, and optimize resource use. AI-supported energy forecasting and intelligent management systems can also facilitate the integration of renewable energy by improving demand prediction and system efficiency. At the macroeconomic level, the environmental benefits of AI may therefore emerge through several channels, including technological innovation, energy efficiency, resource optimization, and the development of environmentally oriented products and services.

However, the relationship between AI and green transformation is not automatically positive. AI systems require substantial computing capacity and data infrastructure, which can increase electricity consumption and generate additional environmental pressures. The overall environmental effect therefore depends on how AI is designed, powered, deployed, and governed. This suggests that AI should be evaluated not only according to its technological or productivity benefits but also according to its contribution to resource efficiency and environmental sustainability.

For developing economies, this issue is particularly important. Countries seeking rapid industrial modernization need to avoid a technological pathway in which digitalization increases productivity while simultaneously intensifying energy and environmental pressures. Integrating AI

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adoption with renewable energy, energy efficiency, green innovation, and environmental regulation can therefore provide a more sustainable pathway for economic transformation. This provides an important conceptual link between AI-driven productivity improvement and the circular and climate-oriented dimensions considered in the present study.

6.3. AI and Circular Economy

The circular economy (CE) extends the sustainability agenda beyond reducing environmental damage by seeking to maintain the value of materials, products, and resources for as long as possible. Artificial intelligence can strengthen this transition by providing data-driven capabilities for monitoring material flows, predicting demand and waste generation, optimizing collection and production processes, and identifying opportunities for reuse, repair, recycling, and resource recovery. Recent literature increasingly identifies AI as an enabling technology for moving waste-management systems from disposal-oriented approaches toward more integrated circular value chains.

AI applications can contribute to circularity at several stages. Computer-vision systems can improve automated waste identification and sorting, predictive models can support maintenance and extend equipment or product lifetimes, while optimization algorithms can improve collection routes, material recovery, and resource allocation. Such applications can simultaneously reduce operational costs and improve the quality and quantity of recovered materials. Research on AI-enabled waste systems has also demonstrated potential benefits through improved routing, monitoring, sorting, and resource-recovery processes.

Nevertheless, existing research remains concentrated in individual technological applications, while the integration of AI across the complete circular value chain is less developed. Recent systematic evidence emphasizes that technical optimization does not necessarily translate into circular outcomes unless it is connected with infrastructure, markets for recovered materials, institutional coordination, reliable data, and appropriate policy mechanisms.

This issue is particularly relevant for Uzbekistan, where the transition toward a greener economy increasingly emphasizes resource conservation, environmental protection, and modernization of waste-management systems.

The institutional basis for this transition is reinforced by Presidential Resolution No. PP-4477 of October 4, 2019, “On Approval of the Strategy for the Transition of the Republic of Uzbekistan to a Green Economy for 2019–2030.” The strategy identifies energy efficiency, renewable energy development, climate adaptation, and the efficient use of natural resources as key priorities. These policy objectives are closely aligned with the proposed AI-GCPM framework, particularly its emphasis on improving resource productivity, reducing material and energy losses, and supporting green and circular economic transformation (President of the Republic of Uzbekistan, 2019). An AI-enabled circular approach could therefore connect industrial productivity with material efficiency by using data and intelligent optimization to reduce resource losses, improve waste recovery, and create secondary-resource value. Rather than treating waste management as a separate environmental activity, such an approach positions circularity as a component of industrial competitiveness and sustainable economic transformation.

6.4. AI and Climate Resilience

Artificial intelligence can also strengthen climate resilience by improving the capacity of economies and institutions to anticipate, monitor, and respond to climate-related risks. Machine-learning models can process large volumes of meteorological, agricultural, satellite, infrastructure, and

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economic data to improve forecasting of extreme weather events, water availability, crop conditions, energy demand, and other climate-sensitive variables. The literature indicates that AI applications are particularly relevant to water management, agriculture, disaster preparedness, energy systems, and climate-risk assessment, where improved prediction can support more timely and targeted adaptation decisions.

For Uzbekistan, this dimension has particular economic significance. The country faces climate-related pressures including water scarcity, drought, extreme heat, rainfall variability, and dust storms, while its resource-intensive economic structure increases the importance of efficient adaptation and resource management. The World Bank's Country Climate and Development Report identifies climate adaptation, energy efficiency, renewable energy, and resource management as important components of Uzbekistan's long-term development pathway.

AI can contribute to this process by connecting climate information with economic decision-making. For example, predictive systems could support more efficient irrigation and water allocation, early identification of agricultural risks, climate-sensitive infrastructure planning, and optimization of energy demand. Importantly, AI-based resilience should not be understood only as forecasting hazards. Effective resilience requires the integration of predictive information with institutional capacity, infrastructure investment, human expertise, and adaptive policy responses. Recent research similarly identifies a gap between AI-based climate-risk assessment and the more difficult tasks of evaluating vulnerability, prioritizing adaptation measures, and implementing them effectively.

Thus, climate resilience represents a further dimension through which AI can connect productivity and environmental sustainability. In the proposed framework, AI is viewed not simply as a forecasting technology but as an enabling mechanism that can help coordinate productive efficiency, resource conservation, circularity, and adaptation to climate risks. This integrated perspective is particularly relevant for Uzbekistan, where economic modernization and climate resilience need to develop simultaneously.

6.5. Evidence from Developed Economies

Evidence from developed economies provides important insights into how AI can contribute to productivity growth, environmental efficiency, and more sustainable industrial systems. Countries with advanced digital infrastructure, strong research and development capacity, and relatively high levels of AI adoption have increasingly integrated AI into manufacturing, energy management, logistics, environmental monitoring, and resource optimization. Firm-level studies from European economies, for example, generally associate AI adoption with improvements in productivity, although the magnitude of these effects varies across firms and sectors. (sciencedirect.com)

The experience of advanced economies also demonstrates that technological adoption alone does not guarantee sustainable transformation. Complementary investments in digital infrastructure, workforce skills, organizational capabilities, research and development, and effective institutions influence the extent to which AI generates economic and environmental benefits. OECD analysis similarly emphasizes differences in AI adoption across firms and the importance of complementary factors for realizing productivity gains. (oecd.org)

Developed economies have also provided important examples of AI-supported energy optimization, smart manufacturing, predictive maintenance, intelligent transport, and circular-resource management. These applications demonstrate how digital intelligence can be incorporated into broader sustainability strategies rather than being treated as an isolated technological intervention. At the same

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time, the relatively strong infrastructure and institutional capacity of these economies limits the direct transferability of their experience to countries with different development conditions.

For Uzbekistan, therefore, the developed-economy evidence is most useful as a source of technological and organizational principles rather than as a direct policy template. The key implication is that AI-driven productivity and environmental gains require coordinated development of infrastructure, skills, institutions, data systems, and sustainability-oriented investment. This provides a basis for examining whether similar principles can be adapted to the institutional and resource conditions of a developing economy.

6.6. Evidence from Developing Economies

Evidence from developing and emerging economies suggests that the effects of artificial intelligence depend strongly on the technological, institutional, and human-capital conditions in which adoption occurs. Unlike advanced economies, developing countries often face constraints related to digital infrastructure, access to computing capacity, data availability, skilled labour, financing, and institutional capabilities. Recent international evidence therefore emphasizes that AI adoption should be accompanied by investments in connectivity, digital infrastructure, data systems, and human competencies.

Recent empirical research also demonstrates that the relationship between AI and environmental transformation may differ across developing economies. Evidence from 56 less-developed economies indicates a non-linear relationship between AI development and renewable-energy development, while institutional quality strengthens the ability of AI to support energy transition. This suggests that technological adoption alone is insufficient when regulatory and institutional foundations remain weak. Similarly, research on emerging economies finds that AI adoption is influenced by supply-chain digitalization, green technologies, energy structures, and the capacity of economies to absorb new technologies.

These findings are particularly relevant to Uzbekistan. The country's economy remains relatively energy- and resource-intensive, while its development strategy increasingly emphasizes green transformation, resource efficiency, and private-sector modernization. Consequently, the most relevant pathway is not simply to increase AI adoption, but to connect AI with productivity improvement, energy efficiency, resource conservation, circular production, and climate resilience.

The developing-economy literature therefore supports an important principle for the present study: AI strategies should be adapted to national development conditions rather than directly replicated from advanced economies. For Uzbekistan, this implies combining technological adoption with institutional capacity, skills development, reliable digital and energy infrastructure, and sustainability-oriented investment. Such an integrated approach provides the foundation for the framework proposed in this study.

6.7. Research Gap

The reviewed literature demonstrates that artificial intelligence can contribute to productivity improvement, green transformation, circular resource use, and climate resilience. However, these relationships have largely been examined as separate or partially connected research streams. Studies of AI and productivity primarily emphasize efficiency, innovation, and firm performance; research on AI and green transformation focuses on energy efficiency and environmental performance; circular-economy research emphasizes waste reduction and resource recovery; while climate-oriented studies concentrate mainly on prediction, risk assessment, and adaptation. Although these streams provide

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important evidence, their integration into a coherent economic framework remains comparatively limited.

A further limitation concerns the uneven geographical distribution of existing evidence. A substantial share of empirical research originates from developed economies with relatively advanced digital infrastructure, high research capacity, and established institutional systems. Evidence from developing economies demonstrates that the effects of AI depend more strongly on infrastructure, human capital, institutional quality, energy systems, and technological absorptive capacity. Consequently, findings from advanced economies cannot be transferred to developing-country contexts without appropriate adaptation.

This gap is particularly relevant to Uzbekistan. National policy is increasingly oriented toward green transformation, resource efficiency, circular economy principles, climate adaptation, and sustainable industrial development. The country's current policy framework explicitly links green transformation with competitiveness, resource conservation, climate adaptation, and the development of circular-economy practices. However, an integrated analytical framework explaining how AI can simultaneously support productivity, green transformation, circular resource use, and climate resilience under Uzbekistan's institutional and economic conditions remains insufficiently developed.

Therefore, the main research gap is not the absence of studies on individual AI-related dimensions, but the limited integration of these dimensions into a single Uzbekistan-oriented framework. Addressing this gap, the present study develops an integrated AI–productivity–green–circular–climate framework that conceptualizes artificial intelligence as an enabling mechanism connecting technological modernization with resource efficiency, environmental sustainability, and climate resilience. The framework is intended to provide a structured basis for identifying policy and managerial pathways through which AI can support Uzbekistan's transition toward a more productive, resource-efficient, and sustainable economy.

7. Research Methodology

7.1. Research Design

This study employs a conceptual and analytical research design to develop an integrated framework for examining the role of artificial intelligence (AI) in sustainable economic transformation in Uzbekistan. The methodology combines a structured review of recent international literature, comparative analysis of developed and developing economies, and contextual adaptation to Uzbekistan's economic, technological, environmental, and institutional conditions.

The study is designed around the assumption that the contribution of AI to sustainable development cannot be adequately evaluated through productivity effects alone. Instead, AI is considered an enabling technology whose economic value depends on its interaction with productivity improvement, green transformation, circular resource use, and climate resilience. On this basis, the study develops an integrated framework linking these dimensions within a single analytical structure.

7.2. Framework Development

The proposed framework is constructed through four interconnected analytical dimensions: **AI-enabled productivity, green economic transformation, circular economy development, and climate resilience**. These dimensions were selected based on the main relationships identified in the literature review and their relevance to Uzbekistan's development priorities.

The first dimension, **AI-enabled productivity**, represents the capacity of AI technologies to improve production efficiency, decision-making, forecasting, innovation, and resource allocation. The

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second dimension, **green economic transformation**, captures the contribution of AI to energy efficiency, cleaner production, renewable-energy integration, and reduction of environmental pressures. The third dimension, **circular economy development**, focuses on material efficiency, waste reduction, recycling, reuse, resource recovery, and the extension of product and equipment lifecycles. The fourth dimension, **climate resilience**, reflects the use of AI-supported forecasting, monitoring, risk assessment, and adaptive planning to reduce vulnerability to climate-related pressures.

These dimensions are not treated as independent components. The framework assumes that improvements in one dimension can reinforce the others. For example, AI-enabled production optimization can reduce energy and material consumption; improved resource efficiency can support circular production; and better environmental and climate information can strengthen long-term investment and adaptation decisions.

7.3. Analytical Logic of the Framework

The analytical structure follows a sequential but interconnected pathway:

AI adoption and digital capabilities → productivity improvement → resource and energy efficiency → green transformation → circular resource use → climate resilience → sustainable economic transformation.

This pathway does not imply that the effects necessarily occur automatically or in a fixed sequence. Rather, it identifies the principal channels through which AI can contribute to sustainable economic development. Institutional quality, human capital, digital infrastructure, energy systems, data availability, and regulatory capacity are considered **enabling conditions** that influence the strength of these relationships.

Accordingly, the framework can be represented conceptually as:

AI Capability + Institutional Enablers → Productive Efficiency + Green Innovation + Circularity + Climate Adaptation → Sustainable Economic Transformation.

This structure allows the study to move beyond a technology-centred interpretation of AI and examine its broader economic and environmental implications.

7.4. Uzbekistan-Oriented Adaptation

The framework is specifically adapted to Uzbekistan rather than directly transferred from advanced economies. The adaptation considers the country's developing digital ecosystem, industrial structure, resource requirements, environmental pressures, infrastructure needs, and increasing emphasis on sustainable economic modernization.

The Uzbekistan application therefore focuses on areas where AI can potentially generate simultaneous economic and environmental benefits. These include intelligent industrial production, energy-demand optimization, predictive maintenance, water and agricultural resource management, waste sorting and recovery, logistics optimization, environmental monitoring, and climate-risk forecasting.

The framework also recognizes potential constraints. Limited data availability, differences in digital readiness between enterprises, shortages of advanced technical skills, infrastructure limitations, financing requirements, and institutional coordination may reduce the effectiveness of AI-based interventions. Consequently, successful implementation requires complementary investment in digital infrastructure, human capital, data governance, institutional capacity, and sustainability-oriented policies.

7.5. Proposed Analytical Indicators

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To facilitate future empirical application, the framework identifies several groups of indicators. AI capability may be represented through AI adoption, digitalization, automation, data-processing capacity, and AI-related investment. Productivity may be assessed through labor productivity, total factor productivity, production efficiency, and innovation performance. Green transformation may include energy intensity, renewable-energy use, emissions intensity, and green innovation. Circularity may be evaluated through material efficiency, waste generation, recycling, reuse, and resource recovery. Climate resilience may include water-use efficiency, climate-risk preparedness, agricultural resilience, infrastructure resilience, and the effectiveness of early-warning systems.

The indicators are intended as an analytical basis rather than a claim that all dimensions must be measured through a single universal index. Their selection can be adjusted according to data availability and the specific sector or region examined.

7.6. Research Contribution

The methodological contribution of the study lies in integrating technological, economic, environmental, circular, and climate dimensions within one Uzbekistan-oriented analytical framework. Rather than examining AI as an isolated determinant of productivity or environmental performance, the framework treats AI as a cross-cutting enabling mechanism whose effectiveness depends on complementary institutional and infrastructural conditions.

This approach provides a foundation for subsequent empirical testing at the national, regional, sectoral, or firm level and offers policymakers and enterprises a structured method for identifying areas in which AI investment can generate combined productivity and sustainability benefits.

8. Analysis and Results

8.1. International Approaches to AI-Enabled Green and Circular Transformation

International experience demonstrates that artificial intelligence can support productivity growth, resource efficiency, and environmental sustainability through different technological and institutional approaches. However, the effectiveness of these applications depends on infrastructure, skills, investment, and the integration of AI into broader economic and environmental policies.

Table 1 summarizes the principal approaches relevant to the development of an AI-Driven Green Circular Productivity Model (AI-GCPM) for Uzbekistan.

Table 1. International approaches to AI-enabled green and circular transformation

Economy / region	Main AI application	Green and circular contribution	Relevance to Uzbekistan
European Union	AI-enabled industrial optimization and resource monitoring	Energy efficiency, sustainable production, circular resource management	Integrate AI with green industrial policy
Germany	Smart manufacturing and predictive maintenance	Reduced production losses and improved resource efficiency	Modernize industrial enterprises
Japan	Intelligent manufacturing and resource optimization	Material efficiency and extended equipment life	Improve industrial productivity
South Korea	Smart factories and intelligent energy	Efficient production and energy management	Develop digitally integrated

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	systems		manufacturing
United States	AI-based forecasting and industrial optimization	Operational efficiency and resource management	Encourage innovation and business adoption

Source: Author's conceptual synthesis of international approaches discussed in the literature review.

The comparison suggests that international experience is most useful for identifying transferable mechanisms rather than directly replicating national strategies. For Uzbekistan, the central implication is to connect AI adoption with measurable productivity and resource-efficiency objectives.

8.2. Comparative Characteristics of Developed and Developing Economies

The economic benefits of AI depend not only on technological availability but also on the capacity of firms and institutions to adopt and effectively use it. Developed and developing economies therefore face different opportunities and implementation constraints.

Table 2. Comparative characteristics of developed and developing economies

Dimension	Developed economies	Developing economies
Digital infrastructure	Generally advanced	Uneven and developing
AI adoption	More established across firms	Often concentrated in selected sectors
Human capital	Greater access to specialized skills	Skills gaps may constrain adoption
Financing	Broader access to innovation capital	Investment constraints may be more significant
Green technology	More established innovation systems	Opportunities for technology transfer and modernization
Circular economy	More developed supporting systems in many cases	Infrastructure and market development remain important
Policy priority	Scale and optimize AI-enabled transformation	Build capabilities and adapt technologies to local needs

Source: Author's comparative conceptual analysis.

For Uzbekistan, the findings support a gradual, sector-specific approach that combines digital infrastructure, workforce development, technological adoption, and resource-efficiency objectives. The main priority is not simply increasing AI use, but ensuring that its application generates tangible economic and environmental benefits.

8.3. Proposed Indicators for the AI-GCPM

To evaluate the contribution of AI to sustainable economic transformation, the proposed model integrates four principal dimensions: AI adoption, productivity, green efficiency, and circularity. Climate resilience is included as a cross-cutting outcome.

Table 3. Proposed indicators for the AI-GCPM

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Dimension	Proposed indicators	Measurement purpose
AI adoption	AI adoption rate; AI-related investment; digital skills	Measure technological integration
Productivity	Labour productivity; production efficiency; total factor productivity	Assess economic performance
Green efficiency	Energy intensity; emissions intensity; water-use efficiency	Evaluate environmental efficiency
Circularity	Material efficiency; recycling rate; waste reduction	Assess resource circulation
Climate resilience	Water-risk preparedness; climate-sensitive forecasting; resource resilience	Evaluate adaptive capacity

Source: Author's proposed analytical framework.

The indicators provide a basis for future empirical evaluation of the AI-GCPM. Their application requires consistent data, sector-specific definitions, and appropriate normalization. The proposed framework does not assume that AI adoption automatically produces improvements in all dimensions.

8.4. AI-Driven Productivity Opportunities in Uzbekistan's Major Economic Sectors

Uzbekistan's economic transformation requires AI applications that address both production efficiency and resource constraints. Agriculture, manufacturing, energy, transport, and waste management offer opportunities to connect technological modernization with green and circular development.

Table 4. AI-driven productivity opportunities in Uzbekistan's major economic sectors

Sector	AI application	Productivity effect	Green effect	Circular effect
Agriculture	Precision agriculture and irrigation optimization	↑	↑	↑
Manufacturing	Predictive maintenance and process optimization	↑	↑	↑
Energy	Demand forecasting and smart-grid optimization	↑	↑↑	↑
Transport	Route and logistics optimization	↑	↑	—
Waste management	Intelligent sorting and	↑	↑	↑↑

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	resource recovery			

Note: ↑ indicates a potential positive contribution; ↑↑ indicates a potentially stronger contribution; — indicates no direct circular effect identified in the proposed application. These are qualitative expectations, not measured effect sizes.

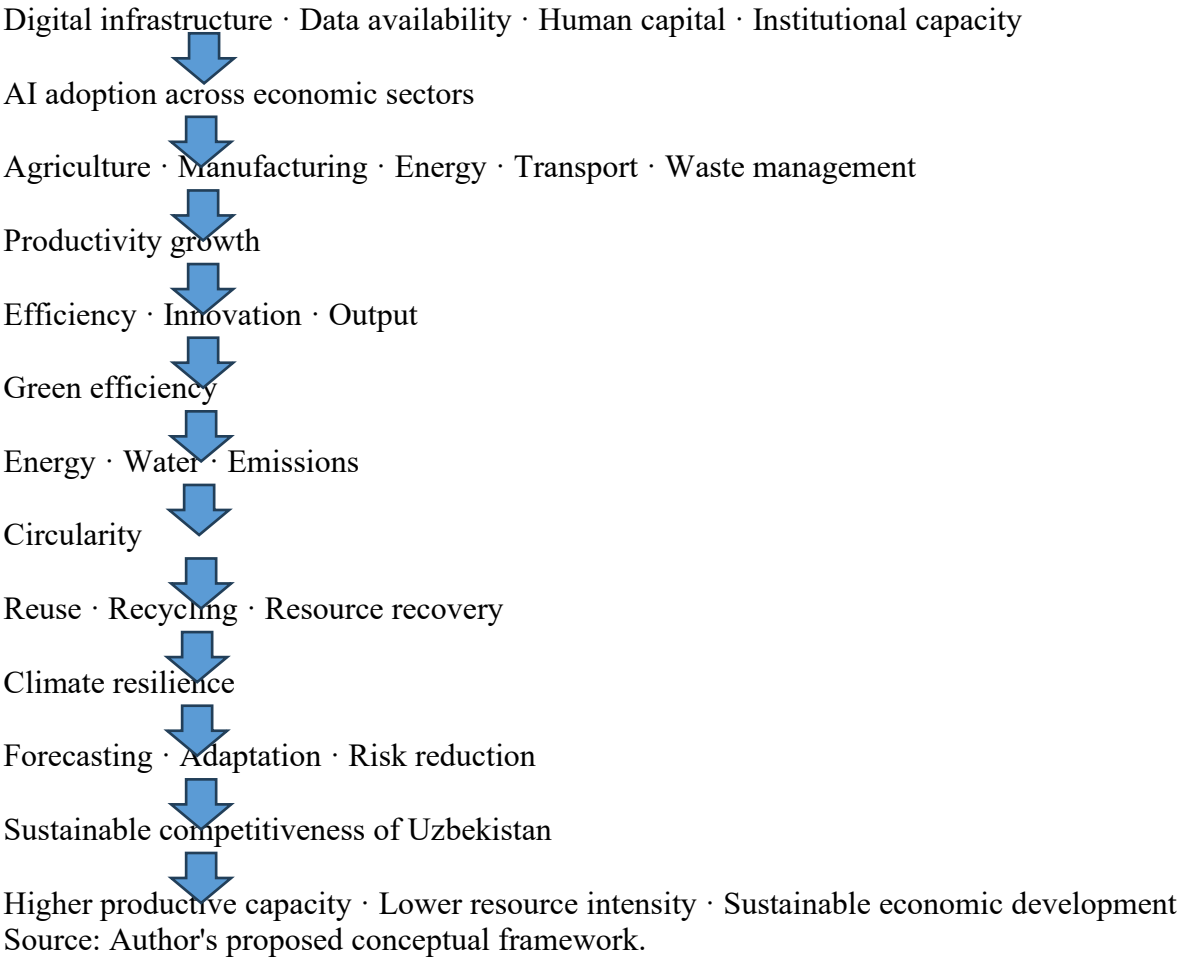
The sectoral analysis highlights the potential for AI to generate combined economic and environmental benefits. Precision irrigation may improve agricultural resource allocation, predictive maintenance may reduce industrial downtime and material losses, and intelligent waste sorting may increase the recovery of reusable materials.

However, the actual effects will depend on implementation quality, infrastructure, skills, investment, and the availability of reliable data.

8.5. The AI-Driven Green Circular Productivity Model for Uzbekistan

The proposed AI-GCPM conceptualizes AI as an enabling mechanism that connects technological capabilities with productive efficiency, green transformation, and circular resource use. Its central principle is that AI adoption should be evaluated by the economic and environmental outcomes it helps generate, rather than by technology adoption alone.

Figure 1. AI-GCPM conceptual framework



Source: Author's proposed conceptual framework.

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The framework illustrates how AI capabilities, when supported by appropriate enabling conditions, can contribute to productivity, environmental efficiency, circularity, and climate resilience. These dimensions jointly support the transition toward a more competitive and sustainable economy.

Figure 2. AI → Productivity → Green and Circular Transformation Mechanism

1. AI adoption



Automation, forecasting, intelligent monitoring, and optimization.

2. Productivity improvement



Higher output efficiency, reduced downtime, and better resource allocation.

3. Green transformation



Lower energy, water, and material intensity.

4. Circular transformation



Waste prevention, reuse, recycling, and resource recovery.

5. Sustainable economic value



Improved competitiveness, resource efficiency, and resilience.

Source: Author's proposed mechanism.

The mechanism suggests that AI can generate broader economic value when productivity improvements are accompanied by resource conservation and circular production practices. The relationship is conditional: efficiency gains must exceed the additional resource consumption associated with AI deployment.

Figure 3. Proposed Uzbekistan Implementation Roadmap

Stage 1

Digital foundations



Develop data infrastructure, connectivity, and digital skills.

Stage 2

Sector-specific AI adoption



Introduce targeted applications in priority economic sectors.

Stage 3

Productivity transformation



Improve forecasting, production processes, and resource allocation.

Stage 4

Green and circular integration



Connect AI applications with energy efficiency, water conservation, and waste recovery.

Stage 5

Sustainable competitiveness



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Evaluate outcomes through productivity, environmental, and resilience indicators.

Source: Author's proposed implementation roadmap.

The roadmap proposes a gradual transition from digital readiness to sector-specific AI adoption and, ultimately, measurable sustainable economic outcomes. Implementation should be supported by workforce development, institutional coordination, responsible data governance, and continuous performance monitoring.

8.6. Key Analytical Findings

The analysis leads to three principal findings:

1. Integrated productivity: AI can support productivity growth while improving resource efficiency when technological adoption is connected with organizational and environmental objectives.

2. Sector-specific transformation: Agriculture, manufacturing, energy, transport, and waste management offer distinct opportunities for combining AI-enabled efficiency with green and circular practices.

3. Adaptation to Uzbekistan: Successful implementation requires a phased approach that accounts for infrastructure, human capital, investment, institutional capacity, and climate-related pressures.

Overall, the proposed AI-GCPM provides a conceptual basis for integrating AI adoption, productivity growth, green efficiency, circularity, and climate resilience into a unified economic transformation framework for Uzbekistan.

9. Conclusion and Recommendations

9.1. Conclusion

This study examined the potential of artificial intelligence (AI) to support productivity growth and green and circular economic transformation in Uzbekistan under the combined pressures of globalization and climate change. Based on a comparative review of international experience, an analysis of Uzbekistan's economic context, and the development of the AI-Driven Green Circular Productivity Model (AI-GCPM), the study presents an integrated framework connecting AI adoption with productivity, green efficiency, circularity, and climate resilience.

The proposed model conceptualizes AI as an enabling instrument for improving the efficiency of production and resource allocation while supporting environmental sustainability. Its central contribution is the integration of technological adoption, economic performance, and resource efficiency within a unified framework adapted to the development conditions of Uzbekistan.

The analysis identifies agriculture, manufacturing, energy, transport, and waste management as priority sectors in which AI applications may generate combined productivity and sustainability benefits. However, the realization of these benefits depends on digital infrastructure, human capital, institutional capacity, investment, and the integration of AI with environmental objectives.

The study therefore proposes that Uzbekistan's AI strategy should move beyond technology adoption alone and emphasize measurable productivity gains, efficient resource use, circular production, and sustainable competitiveness. The AI-GCPM provides a conceptual foundation for future empirical research and the development of sector-specific policies for sustainable economic transformation.

9.2. Policy Recommendations

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To translate the proposed framework into practice, the following recommendations are presented:

1. Integrate AI with productivity and green-economy policies. Establish sector-specific programs linking AI adoption with measurable economic and environmental objectives.

2. Prioritize resource-intensive sectors. Promote AI applications in agriculture, manufacturing, and energy to improve water management, production efficiency, and energy utilization.

3. Accelerate circular-economy innovation. Support intelligent waste sorting, material recovery, predictive maintenance, and resource-efficient production.

4. Strengthen digital infrastructure and human capital. Expand access to reliable data systems, digital technologies, and practical AI skills for enterprises and workers.

5. Develop an AI-GCPM monitoring framework. Introduce indicators for productivity, energy and water efficiency, material use, recycling, and climate resilience to evaluate the outcomes of AI-related investments.

6. Encourage public–private innovation partnerships. Facilitate cooperation among universities, businesses, research institutions, and public authorities to develop and test sector-specific AI solutions.

9.3. Limitations and Future Research

This study develops a conceptual and analytical framework rather than an empirically validated econometric model. The proposed relationships and indicators require further testing using reliable sectoral, regional, and enterprise-level data.

Future research should examine the measurable effects of AI adoption on productivity, energy and water efficiency, circularity, and climate resilience in Uzbekistan. Particular attention should be given to regional differences, implementation costs, institutional conditions, and the long-term sustainability of AI-enabled economic transformation.

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