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Original Article

Exploring the Drivers of Artificial Intelligence's Impact on the Development of Technological Entrepreneurship (Case Study: Rural Areas of Shemiranat County)

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Abstract

Purpose- Technological advancements, particularly Artificial Intelligence (AI), are transforming modern business models and fostering technological entrepreneurship. While AI offers significant potential for sustainable development in rural areas through increased productivity and innovation, these regions often benefit less due to weak digital infrastructure and institutional constraints. This study aims to identify and analyze the key drivers of AI's impact on the development of technological entrepreneurship in the rural areas of Shemiranat County.

Design/methodology/approach- This applied research employs a descriptive-analytical approach and a mixed-methods (qualitative-quantitative) design. Data collection involved documentary studies and fieldwork. In the qualitative phase, data were gathered through semi-structured interviews with 18 experts selected via purposive sampling. Data were analyzed using qualitative content analysis with open, axial, and selective coding. In the quantitative phase, the causal relationships among the identified drivers were analyzed using Interpretive Structural Modeling (ISM) and MICMAC software. The research was conducted in the rural areas of Shemiranat County in 2025.

Finding- The analysis identified 18 key drivers, categorized into five groups: technological, economic, social, policy-related, and environmental. Results indicate that AI can effectively contribute to rural socio-economic sustainability by enhancing productivity, creating innovative employment opportunities, and strengthening environmental resilience. Key challenges include a gap between physical access to technology and commercial utilization, low digital literacy, and a lack of supportive legal frameworks tailored for rural micro-businesses.

Practical Implications- To leverage AI for rural technological entrepreneurship, policymakers should prioritize: 1) expanding high-speed internet and digital infrastructure; 2) establishing rural-focused innovation centers and accelerators; 3) developing supportive policies including low-interest loans and tax exemptions for AI-based ventures; and 4) implementing targeted training programs to enhance digital literacy and practical AI skills among local communities. These actions will help bridge the existing digital divide and translate infrastructure into productive economic outcomes.

Originality/value– This research is novel in its comprehensive and systemic analysis of drivers for AI-based technological entrepreneurship in Iranian rural areas. By employing a mixed-method approach combined with ISM and MICMAC structural analysis, it moves beyond simple descriptive studies to identify causal and hierarchical relationships among the drivers. The study provides a contextualized framework for policymakers, highlighting the foundational role of government support and digital infrastructure in fostering a dynamic and inclusive entrepreneurial ecosystem in rural regions.

Keywords- Artificial Intelligence, Technological Entrepreneurship, Key Drivers, Rural Development, Structural Analysis, Shemiranat County.

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1.Introduction

Entrepreneurship plays a pivotal role in the economic and social development of rural areas and can function as an effective instrument for increasing employment, reducing poverty, and preventing rural-to-urban migration. However, the development of entrepreneurship in these regions faces numerous challenges, particularly those related to innovation and technology. The lack of access to technology and innovation in rural areas, especially in the field of entrepreneurship, is one of the main barriers to the economic and social development of these regions (Darban Astaneh et al., 2022). This situation not only intensifies poverty and regional inequalities but also increases incentives for migration from rural areas to cities, thereby threatening the social and economic sustainability of rural communities. One of the key strategies for addressing inequality in rural areas and achieving spatial justice in entrepreneurship is the utilization of innovation in rural regions, particularly in the field of entrepreneurship (Mousavi et al., 2016). In fact, innovation, as a main driver of economic and social development, plays a crucial role in transforming rural areas. In these regions, the use of modern methods and technologies can enhance productivity in agriculture, livestock production, handicrafts, and tourism. Innovation not only creates new employment opportunities but also improves the quality of life of rural residents, reduces migration to urban areas, and strengthens environmental sustainability (Khosravani et al., 2024). One of the innovative approaches in entrepreneurship is the use of advanced technologies in this field. Technological entrepreneurship is a concept that has attracted significant attention from economists and policymakers in recent years. It refers to the process of identifying and exploiting business opportunities through the use of advanced technologies to create innovative products, services, or business models (Mhlanga, 2021). This type of entrepreneurship is a combination of creativity, technical knowledge, and business management aimed at solving complex problems, increasing productivity, and responding to the needs of dynamic markets. Technological entrepreneurs not only develop new technologies but also implement them operationally across various industries, thereby generating added value (Moradzadeh, 2022). This concept, especially in the digital era with technologies such as artificial intelligence, the Internet of Things, and blockchain, has become a key driver of economic and social growth (Rahimi Kolur & Akbari Arbatlan, 2023). In this context, technological entrepreneurship can serve as a strategy for diversifying rural economies and reducing dependence on natural resources (Sadeghi Ordoubadi et al., 2022). In fact, technological entrepreneurship and artificial intelligence (AI) have a mutually reinforcing relationship that can lead to significant transformations in businesses and industries. Artificial intelligence, as one of the most advanced technologies, provides entrepreneurs with powerful tools for data analysis, trend forecasting, process optimization, and the creation of innovative products and services (Vlachová, 2024). On the other hand, technological entrepreneurship, by leveraging the capabilities of artificial intelligence, creates new opportunities for designing innovative business models that can meet customer needs in a more intelligent and efficient manner (Chatterjee et al., 2021). This interaction, particularly in areas such as smart agriculture, digital health, e-commerce, and education, can lead to the emergence of businesses that are not only highly productive and profitable but also effective in addressing social and economic challenges (Rastegari et al., 2018). Despite these developments, rural areas continue to face multiple challenges, including limited access to advanced technologies, inadequate technological infrastructure, and insufficient knowledge for exploiting new opportunities. This situation has not only constrained the economic growth of these regions but has also intensified the disparity between urban and rural areas (Mousizadeh et al., 2022). The necessity of examining the impact of artificial intelligence on the development of technological entrepreneurship in rural areas arises from the considerable potential of this technology to address part of these challenges, as artificial intelligence can create new opportunities for rural communities through process optimization, cost reduction, improved market access, and the creation of innovative business models, while the precise identification of its influencing drivers can assist policymakers and planners in designing targeted strategies to effectively utilize these capacities (Mokhtari Kerchgani, 2024). However, an examination of the country's entrepreneurial ecosystem reveals that the realization of technological entrepreneurship objectives in rural areas faces significant gaps in both hard and soft infrastructure dimensions; in terms of hard infrastructure, although official statistics from the Ministry of Information and Communications Technology indicate an increase in internet penetration in rural areas, the quality, stability, and bandwidth required for data-intensive applications and artificial intelligence- and big data-based processing remain limited and uneven, particularly in mountainous regions, thereby constraining the establishment of sustainable platform-based businesses, while in terms of soft infrastructure the challenges appear even more restrictive, as existing supportive regulations such as the Law on Supporting Knowledge-Based Companies are largely designed with a centralized and urban-oriented approach and lack the flexibility required to support the nature of small-scale rural enterprises; moreover, the low level of digital literacy and the shortage of specialized skills among the local workforce necessary to interact with artificial intelligence algorithms—as a critical soft infrastructure component—has created a profound gap between physical access to technology and the capacity for its commercial exploitation; this dual condition, consisting of structural deficiencies in both hard and soft dimensions, has not only limited the economic development of these regions but also emphasizes the main focus of this research, which is to identify the factors that determine the positive or negative effects of artificial intelligence on the development of technological entrepreneurship in rural areas, while existing research in this field remains limited and no comprehensive framework has yet been developed for identifying and analyzing these driving forces (Rezaei et al., 2013). Shamiran County, due to its unique geographical location, proximity to the metropolitan city of Tehran, and significant natural, cultural, and human capacities, has considerable potential to strengthen rural entrepreneurship and contribute to population stabilization in the region; however, challenges such as rural-to-urban migration, environmental degradation, and lack of sustainable employment have led rural areas of this county to be mainly considered seasonal tourist destinations, resulting in demographic imbalance and increasing trends in second-home development and villa construction; therefore, addressing these issues requires special attention to sustainable and innovative entrepreneurship that can contribute to productive and stable job creation, as technological entrepreneurship in the rural areas of Shamiran, particularly in Lavasanat and Rudbar-e Qasran, can foster sustainable development and employment opportunities, and one of the key areas in this regard is rural tourism, which can be strengthened through the application of modern technologies; overall, the integration of technology and entrepreneurship, particularly through emerging technologies such as artificial intelligence, can play a significant role in population stabilization and sustainability, and accordingly, the present study aims to clarify these drivers and provide a deeper understanding of the interaction between artificial intelligence technologies and the development of technological entrepreneurship in rural areas, with the main research question focusing on which drivers can influence the development of AI-based technological entrepreneurship in rural areas and what challenges play a determining role in this process.

2. Research Theoretical Literature

Artificial intelligence refers to the simulation of human intelligence processes by systems and machines that are capable of learning, reasoning, problem-solving, natural language understanding, and decision-making. Through algorithms and data, this technology acquires capabilities such as learning from experience, pattern recognition, and event prediction. As one of the core pillars of modern technologies, artificial intelligence has had profound impacts on economic and social development worldwide. By transforming decision-making processes, data management, and operational automation, it has become a key tool for improving efficiency and fostering innovation across various domains (Ahmadi et al., 2013). The application of artificial intelligence in business dates back to the 1950s, when researchers explored the possibility of developing intelligent systems to solve complex problems. In the 1980s, with the emergence of expert systems and their commercial applications, AI entered the business domain more seriously. In recent years, significant advancements in machine learning, natural language processing, and big data analytics have enabled the wider application of this technology (Rahimi Kolur & Akbari Arbatlan, 2023). Prominent applications of AI in business include supply chain optimization, customer behavior analysis, targeted marketing, and production process automation. In technological businesses, AI plays a critical role in developing products, services, and business models by analyzing big data and providing actionable insights, enabling firms to respond more rapidly to market changes and optimize their processes (Khosravi & Seyd Moradi, 2020). In rural contexts, artificial intelligence can particularly enhance agricultural productivity, improve supply chains, and facilitate access to new markets.

The integration of artificial intelligence with entrepreneurship has led to the emergence of the concept of technological entrepreneurship, which refers to the creation and development of businesses based on advanced technologies that leverage technological innovation to introduce new products or services to the market (Anabestani & Tolabi, 2023). This form of entrepreneurship combines technical knowledge and creativity to solve existing problems and generate added value in society. As one of the leading technologies, artificial intelligence plays a significant role in transforming technological businesses, particularly in rural areas, by offering innovative solutions that improve processes, increase productivity, and create new opportunities for rural communities. In rural regions, the use of artificial intelligence can contribute to the development of technological entrepreneurship and the improvement of economic conditions. AI can be effectively applied in agricultural process optimization, natural resource management, healthcare and education services, and even rural tourism development. For instance, the use of AI in analyzing soil and water data can assist farmers in optimizing agricultural production. In other words, the applications of artificial intelligence in rural businesses can be evaluated across multiple sectors (Mohammadian, 2021).

In agriculture, artificial intelligence can support farmers in increasing production and reducing costs by analyzing environmental data, forecasting weather conditions, and managing resources efficiently. For example, the use of intelligent irrigation systems can optimize water consumption and increase crop productivity. Similarly, in livestock farming, AI can contribute to improving the quality and quantity of animal production by monitoring animal health and predicting diseases (Anabestani et al., 2024). Moreover, artificial intelligence can facilitate the creation and management of digital businesses in rural areas, thereby contributing to employment generation and wealth creation. Studies have shown that the use of digital (smart) businesses in rural regions of less developed areas has had a positive impact on job creation and wealth generation. This can increase rural incomes and contribute to sustainable rural development by eliminating intermediaries and enabling direct connections between rural producers and consumer markets (Mohammadi, 2024). In the field of education and empowerment, information and communication technologies (ICT) and artificial intelligence can support rural residents by providing virtual education and access to learning resources. These educational opportunities can cover areas such as entrepreneurship, digital marketing, and technological business management, ultimately improving quality of life and increasing local economic participation.

Research on the role of intelligent technologies and artificial intelligence in the development of entrepreneurship has attracted growing attention since the early 2010s. Fitriaana, Ariyanto, and Djatna (2011), in a comprehensive review study, examined the development of business intelligence systems in organizations and demonstrated that the use of data-driven technologies and intelligent systems plays a significant role in improving decision-making, knowledge management, and enhancing the competitive advantage of firms. This study is considered one of the earliest foundational works linking artificial intelligence and business. Cavallo, Ghezzi, Dell'Era, and Pellizzoni (2019) emphasized the role of innovation ecosystems and technological investment in the development of digital entrepreneurship, showing that advanced technologies can accelerate the growth trajectory of start-ups. Chatterjee et al. (2021) in an empirical study, demonstrated that the adoption of artificial intelligence in small and medium-sized enterprises, through improving strategic planning and customer relationship management, leads to the strengthening of entrepreneurial processes and enhanced organizational performance. Stahl (2022) investigated the role of artificial intelligence in the development of entrepreneurial ecosystems and concluded that AI accelerates economic growth and innovation by facilitating networking, attracting investment, and reducing barriers to market entry. Lee and Wang (2022), in a study with a sustainable development approach, showed that artificial intelligence can serve as an effective tool for improving economic and social sustainability, particularly in less-developed regions. In recent years, research has increasingly focused on structural and forward-looking analyses. Gjucili and Pellegrini (2023), through a systematic literature review, identified artificial intelligence as a key enabler of entrepreneurs and emphasized its role in business model innovation. Vlachová and Binder (2024) also demonstrated that artificial intelligence, by creating innovative opportunities, plays an important role in transforming entrepreneurial activities at local and regional levels and can act as a driver of balanced development. Fossan et al. (2024) argue that AI influences entrepreneurial opportunity creation, decision-making under uncertainty, technology adoption, and labor market/productivity outcomes, while also highlighting the ambiguity surrounding the definition of AI in empirical research. Botten et al. (2024) further showed that highly cited papers often lack strong theoretical frameworks, with literature reviews and conceptual analyses dominating empirical research; when theoretical foundations are present, multiple theories are often combined, leading to fragmented conceptual structures. Consequently, their review highlights multiple future research directions in this field. From a practical perspective, their integrative effort provides a coherent understanding of the central role of artificial intelligence in entrepreneurship by synthesizing fragmented insights. Abshonga et al. (2025) emphasize the need for theoretical and methodological development in studying "entrepreneurship in the AI era," highlighting issues such as shifts in entrepreneurial practices, methodological ambiguity, and emerging research boundaries. In Iran, studies related to emerging technologies and entrepreneurship have been conducted since the early 2010s. Ahmadi, Darei, Salamezadeh, and Jafari (2013), in a pioneering study, examined the role of artificial intelligence in creating competitive advantage for technology-based businesses and showed that intelligent customer behavior analysis and data-driven planning have a significant impact on firm performance. Rastegari, Mohammadi Tamari, and Sharifzadeh (2018) emphasized the importance of technological skills and innovation in the development of rural entrepreneurship and identified modern technologies as an effective factor in reducing spatial inequalities. Khosravipoor and Seyd Moradi (2020) highlighted the role of information technology in improving and developing rural businesses and identified weak digital infrastructure as one of the main barriers to entrepreneurial development. Hajjarian et al. (2021), using grounded theory in the context of home-based business development, identified causal conditions (including managerial factors and comprehensive policy systems), intervening conditions (educational-promotional factors, motivational factors, and attitudinal factors), and contextual conditions (infrastructure, marketing, skill-related factors, and financial and credit resource development). Momeni Helali et al. (2022) found that among the components of the rural entrepreneurial ecosystem, "support" ranked the highest while the "financial" component ranked the lowest, highlighting the importance of institutional support and the challenges of financing rural businesses. Anabestani et al. (2022) identified key drivers for the formation of smart growth in rural areas, including the use of existing infrastructure to increase employment and income, improvement in land and housing prices, and rural residents' satisfaction with increased external connectivity. Rahimi Kolur and Akbari Arbatlan (2023) examined the opportunities and challenges of artificial intelligence in entrepreneurship development and found that the shortage of skilled human resources, weak technological training, and institutional constraints are among the main barriers to effective AI utilization in Iran. Anabestani and Tolabi-Nejad (2023) introduced technological entrepreneurship as an effective strategy for diversifying rural economies and reducing dependence on traditional resources. Mohibi et al. (2025) analyzed the impact of artificial intelligence on technology-based businesses in Iran and found that AI-based tools play an important role in enhancing innovation, competitiveness, and organizational strategic alignment. Finally, Mokhtari Kerchgani et al. (2024), adopting an endogenous development approach, emphasized the necessity of linking modern technologies with local, institutional, and social contexts in rural areas (Figure 1).

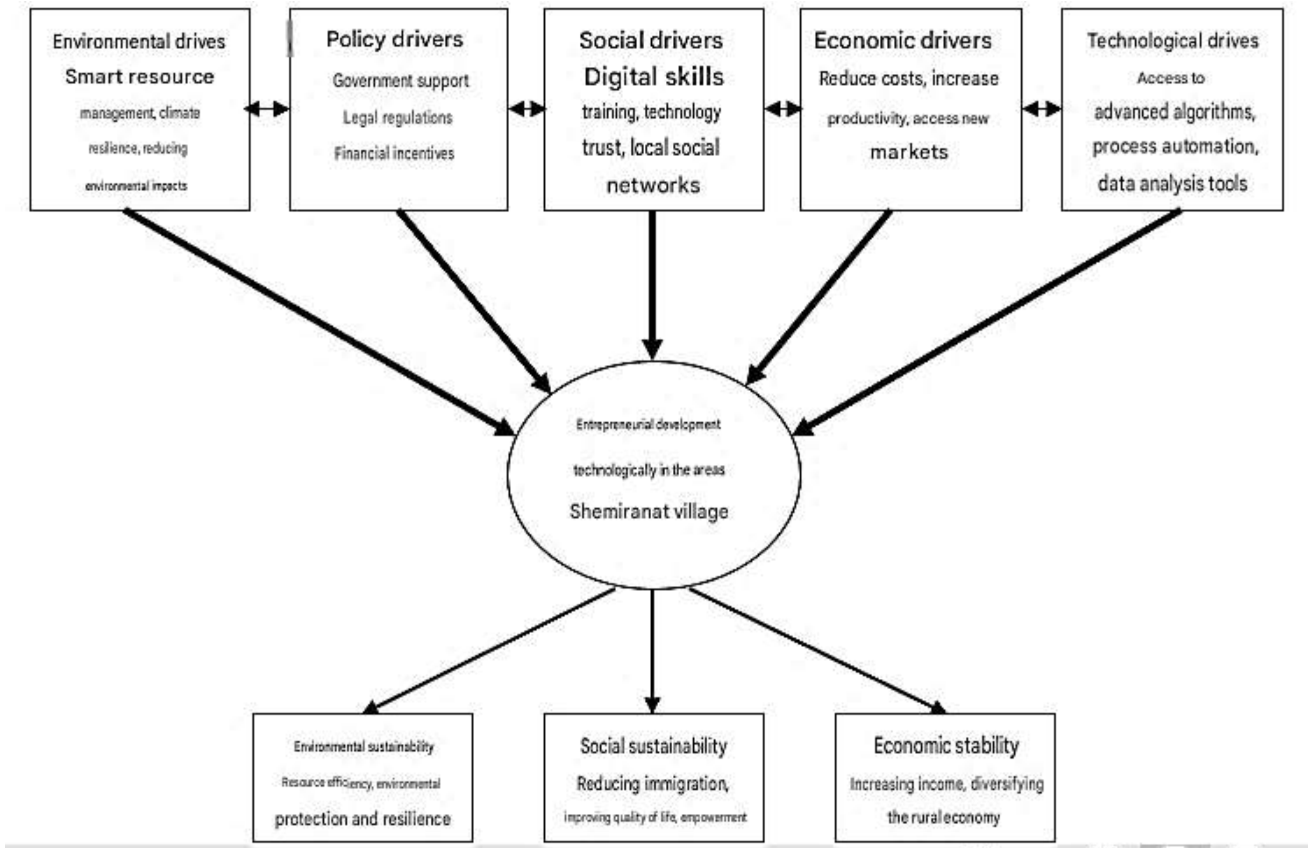

Figure 1. Initial Conceptual Model of the Study

A systematic review of the literature indicates that although numerous international studies have examined the role of artificial intelligence in entrepreneurship, within domestic research, structural analysis of the drivers influencing the impact of artificial intelligence on the development of technological entrepreneurship in rural areas—particularly using integrated approaches and tools such as ISM and MICMAC—has received limited attention. Therefore, the present study seeks to address this research gap by focusing on the rural areas of Shemiranat County and aims to contribute to filling this scientific void.

3. Research Methodology

3.1 Geographical Scope of the Research

Shemiranat County is located in the northern part of Tehran Province. It is bordered by Mazandaran Province to the north, Tehran County to the south, Damavand and Pardis counties to the east, and Alborz Province to the west. With an area of approximately 1,111 square kilometers, it ranks eighth among the thirteen counties of Tehran Province. This area constitutes about 5.9% of the total area of Tehran Province and nearly 0.06% of the total area of Iran. According to the 2016 Population and Housing Census (Table 1), Shemiranat County has a population of 47,279 people, with the majority residing in the Lavasanat district, which accounts for 29,860 inhabitants. Among the cities of this county, Lavasan, with a population of approximately 18,146 people, is the most populous urban center. In addition, among the rural districts, Rudbar-e Qasran, with a population of 7,051 people, is the most populated rural district. The largest village in the county is Niknamdeh, with a population of 3,441, located in Lavasan-e Bozorg rural district, while the smallest village is Ahangarak, with only 4 inhabitants (Figure 2). Due to its proximity to the capital and its rich natural and cultural attractions, the rural areas of Shamiran have consistently attracted both domestic and international tourists, representing a significant potential for regional development. However, the conversion of agricultural and orchard lands into villas, along with declining employment opportunities, has led to the outmigration of young and economically active populations from rural areas, contributing to continued negative population growth and an increase in very small settlements with fewer than twenty inhabitants. For a more precise assessment of the feasibility of the research objectives, the regional context can be described through three key dimensions:

Economic and Market Conditions: The rural economy of Shemiranat is primarily based on two main poles, Lavasanat and Rudbar-e Qasran. According to the 2016 census, Rudbar-e Qasran with a population of 17,419 and Lavasanat with 29,860 inhabitants together form a consumer and producer base of approximately 16,000 households. This population size generates substantial demand for local products such as honey, horticultural products, and medicinal plants. However, the seasonality of tourism-based economic activities and high overhead costs in the region make the adoption of technology essential for reducing operational costs and enabling direct access to Tehran's markets.

Technological and Digital Infrastructure: Unlike the general pattern observed in many rural areas, villages in Shemiranat —particularly more populated settlements such as Niknamdeh with 3,441 residents—benefit from adequate mobile internet coverage (4G). Field results indicate that a significant proportion of the population has access to basic digital devices such as smartphones. The existence of preliminary infrastructure for implementing smart irrigation systems in orchards, along with the increasing use of digital platforms for product marketing, indicates a relatively high level of technological readiness in the region. However, a notable skill gap remains in the commercial utilization of these infrastructures.

Entrepreneurship Conditions: The entrepreneurial ecosystem in this region represents a hybrid structure composed of "traditional businesses in transition" and "emerging innovations." Entrepreneurial activity is gradually shifting away from subsistence agriculture toward value-creating and technology-oriented models. Case studies identified in the research, such as online marketing of organic products and smart water resource management, indicate that entrepreneurial potential exists among the active population (including a large share of the 24,645 male and 22,634 female population). However, the absence of a coherent support network and weaknesses in technological commercialization have hindered the full maturation of this ecosystem.

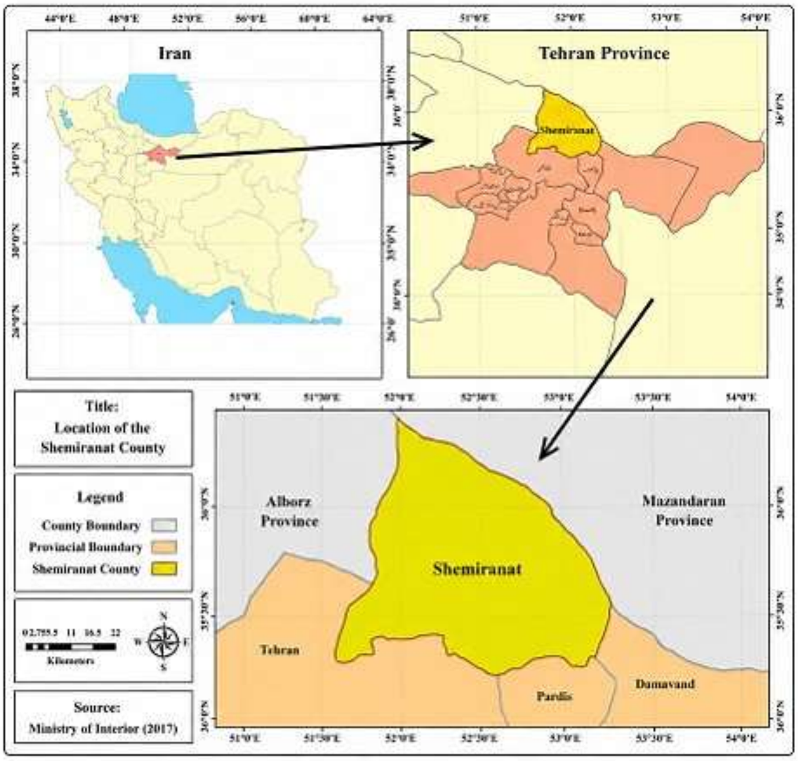

Figure 2. Geographical Location of Shemiranat County within Tehran Province, Iran

Table 1. Population of Shemiranat County by District, City, and Rural District

County	District	City	Rural District	Households	Population	Male	Female
Shamiran	Rudbar-e Qasran	—	—	16,107	47,279	24,645	22,634
	Rudbar-e Qasran	—	—	5,969	17,419	9,071	8,348
	Rudbar-e Qasran	Rudbar-e Qasran	Rudbar-e Qasran	2,478	7,051	3,657	3,394
	Rudbar-e Qasran	Fasham	—	2,294	6,945	3,664	3,281
	Rudbar-e Qasran	Shemshak	—	1,197	3,423	1,750	1,673
	Lavasanat	—	—	10,138	29,860	15,574	14,286
	Lavasanat	Lavasan-e Bozorg	—	2,045	6,034	3,171	2,863
	Lavasanat	Lavasan-e Kuchak	—	1,963	5,680	3,085	2,595
	Lavasanat	Lavasan	—	6,130	18,146	9,318	8,828

3.2. Methodology

The present study is applied in terms of its objective, as it seeks to identify and analyze the driving forces influencing artificial intelligence and to provide a practical framework for the development of technological entrepreneurship as well as to support policymaking and development planning in rural areas. In terms of nature and research design, the study is descriptive–analytical and examines the causal and structural relationships among factors affecting the development of AI-based technological entrepreneurship in rural areas. From a methodological perspective, the study adopts a mixed-methods (qualitative–quantitative) approach. In the first phase, a qualitative approach was used to identify and localize the influencing drivers. Data collection in this phase was based on the Data Triangulation strategy to ensure the validity and reliability of the results. Accordingly, two independent data sources were used: (1) documentary and library research, including a systematic review of previous studies and scientific documents, which led to the extraction of an initial comprehensive list of drivers (as the first independent source), and (2) field study, including semi-structured interviews with 18 experts responsible for localizing, refining, and validating the indicators extracted from the literature. The participants in the qualitative phase consisted of 18 experts in the fields of technological entrepreneurship, rural development, and emerging technologies, who were selected through purposive sampling. The selection criteria included at least five years of academic or executive experience related to the subject, specialized knowledge of artificial intelligence applications in business or development planning, relevant research or practical experience, and familiarity with rural conditions and issues in Shemiranat County or similar regions. Interviews continued until theoretical saturation was achieved, and the collected data were analyzed using qualitative content analysis through coding and categorization (Table 2).

Table 2. Characteristics of Interview Participants

Code	Gender	Education Level	Professional Position
E1	Male	PhD	University Faculty Member
E2	Male	PhD	University Faculty Member
E3	Male	PhD	University Faculty Member
E4	Male	PhD	University Faculty Member
E5	Male	PhD	University Faculty Member
E6	Male	PhD	University Faculty Member
E7	Female	MSc	Smart Systems Specialist
E8	Female	PhD	Smart Systems Specialist
E9	Male	PhD	Smart Systems Specialist

Code	Gender	Education Level	Professional Position
E10	Male	PhD	Tourism Expert
E11	Male	PhD	Cultural Heritage Expert
E12	Male	PhD	University Faculty Member
E13	Male	PhD	Tourism Management and Policy Expert
E14	Male	PhD	University Faculty Member
E15	Male	PhD	University Faculty Member
E16	Male	MSc	Entrepreneurship Specialist
E17	Male	MSc	Entrepreneurship Specialist
E18	Female	MSc	Entrepreneurship Specialist

In the second phase, a quantitative approach was employed to analyze the causal relationships among the identified drivers. In this stage, Interpretive Structural Modeling (ISM) was used, and MICMAC software was applied to assess the level of influence and dependence among the variables. Based on the results of the qualitative phase, a structured questionnaire was designed and distributed among the same group of experts. The results categorized the drivers into four groups: autonomous, dependent, linkage, and key drivers. The spatial scope of the study includes the rural areas of Shemiranat County, while the temporal scope corresponds to the year 2025 (1404 in the Iranian calendar). This methodological framework enables a comprehensive, systematic, and context-based analysis of the drivers influencing the role of artificial intelligence in the development of technological entrepreneurship in rural areas.

To ensure research rigor, the validity and reliability of the instruments were assessed in both qualitative and quantitative phases. The content validity of the semi-structured interviews and the questionnaire was confirmed through expert evaluation in the fields of technological entrepreneurship and rural development, and necessary revisions were applied before final implementation. For reliability assessment of the qualitative content analysis, a portion of the interview transcripts was independently coded by two coders, and inter-coder reliability was measured using Cohen's Kappa coefficient. The obtained Kappa value was 0.78, indicating an acceptable level of agreement and satisfactory reliability of the qualitative analysis.

4. Research Findings

Grounded Theory, as a qualitative approach, provides a powerful framework for examining the driving forces influencing artificial intelligence on the development of rural technological entrepreneurship by extracting concepts from data and building theory. This method consists of three main stages—open coding, axial coding, and selective coding—each of which contributes to the identification of key factors. Based on this approach, the driving forces are analyzed as follows:

4.1. Technological Drivers

In the open coding stage, concepts related to emerging technologies were identified. In the context of artificial intelligence, factors such as access to advanced machine learning algorithms, automation of agricultural and production processes, and the development of rural data analytics tools were identified as key drivers. In axial coding, the effects of these factors on productivity enhancement and cost reduction became more evident.

Table 3. Outcomes of Technological Drivers

Interview Excerpt	Open Coding	Axial Coding	Interview Output
"In the orchards of Lavasan, we use smart irrigation systems that have significantly reduced water consumption and improved efficiency. These systems analyze weather and soil data to determine the timing and amount of irrigation. However, more advanced tools, such as AI-based plant disease detection systems, are still rarely used. This indicates a need for specialized training so that farmers can properly utilize these technologies."	Access to advanced machine learning algorithms, automation of agricultural and production processes, development of rural data analytics tools	Productivity and cost reduction	Data analysis (65%), process automation (55%), access to technology (40%).

These technologies enhance entrepreneurial capacity by facilitating innovation in products and services. The rural areas of Lavasanat, due to their proximity to the capital and better access to internet and digital infrastructure, have relatively high potential for the application of artificial intelligence technologies. Some local farmers are already using smart systems for precision irrigation and weather forecasting; however, public awareness of more advanced applications of AI—such as agricultural data analytics and production automation—remains limited (Table 3).

4.2. Economic Drivers

In the open coding stage, factors such as reducing operational costs, increasing the efficiency of local resources, and accessing new markets through smart platforms were identified. In the axial coding stage, the relationships between these factors and the development of employment and value-added creation in rural areas were examined. The role of artificial intelligence in optimizing supply chain processes and enabling new business models was also identified as one of the key results at this stage. The Lavasanat region, due to its natural attractions and tourism potential, represents a significant potential market for local products and services. The use of smart platforms, such as online sales applications, has enabled some rural businesses to market their products in urban markets. However, limited investment in advanced artificial intelligence technologies remains a major barrier to cost reduction and the optimization of economic processes (Table 4).

Table 4. Outcomes of Economic Drivers

Interview Excerpt	Open Coding	Axial Coding	Interview Output
"The use of online sales applications in Lavasanat has enabled local products such as honey and medicinal plants to reach Tehran and even other cities. This has increased producers' income; however, challenges such as high digital advertising costs and lack of familiarity with smart marketing tools still exist. Moreover, the use of artificial intelligence for price forecasting or supply chain management could further enhance productivity, which has not yet been sufficiently addressed."	Reduction of operational costs, increased efficiency of local resources, access to new markets	Employment development and value-added creation	Cost reduction (70%), access to new markets (60%), increased efficiency of local resources (50%).

4.3. Social Drivers

In the open coding stage, factors such as increased access to AI-based skill training, strengthening of social networks and local cooperation, and enhanced awareness of technological opportunities among rural communities were identified. In the axial coding stage, these factors were linked to the development of social capital, trust in technology, and improved interactions between local communities and technology experts. In the Lavasanat region, social awareness of new technologies is relatively higher than in many other rural areas due to its close proximity to Tehran. Local educational and awareness-raising programs related to artificial intelligence, particularly in youth skill development, have had a positive impact. However, many individuals still refrain from using AI in their daily lives due to concerns about technological complexity or insufficient trust (Table 5).

Table 5. Outcomes of Social Drivers

Interview Excerpt	Open Coding	Axial Coding	Interview Output
"In Lavasan, some young people have become familiar with artificial intelligence tools, but cultural acceptance of these technologies is still at a low level. Organizing educational workshops, both online and in-person, such as training on smart farm management tools, has had a positive effect on increasing trust and adoption. Furthermore, strengthening rural social networks and creating experience-sharing groups can be effective in expanding awareness and trust in these technologies."	Increased access to AI-based skill training, strengthening of social networks and local cooperation, increased awareness of technological opportunities in rural communities	Social capital, trust in technology, and improved interactions between local communities and technology experts	Skills training (75%), increased social interaction (50%), trust in technology (40%).

4.4. Policy-Making Drivers

In the open coding stage, factors such as government support for technological innovation, the formulation of supportive regulations for the use of artificial intelligence in rural businesses, and the encouragement of investment in digital infrastructure were identified. In the axial coding stage, these factors were recognized as key drivers for the sustainable development of rural areas. Despite the high potential of the Lavasanat region for the development of technology-based businesses, the lack of clear policies and sufficient governmental support remains one of the main challenges. The government can facilitate broader adoption of artificial intelligence by providing financial incentives and free training programs. Although some initial steps have been taken to develop digital infrastructure, more comprehensive and integrated policymaking is still required (Table 6).

Table 6. Outcomes of Policy-Making Drivers

Interview Excerpt	Open Coding	Axial Coding	Interview Output
"Government support such as subsidies and loans for purchasing smart equipment has started in Lavasanat, but the lengthy and complicated application process has discouraged many entrepreneurs. Creating a simple platform for registration and local consultation could remove these barriers. In addition, clear policymaking for expanding technological infrastructure in these areas is necessary to improve access to the internet and equipment."	Government support for technological innovation, formulation of supportive laws for AI use in rural businesses, encouragement of investment in digital infrastructure	Key drivers for sustainable rural development	Government support (60%), technology-oriented regulations (50%), infrastructure investment (40%).

4.5. Environmental Drivers

In the open coding stage, factors such as intelligent management of natural resources, reduction of environmental impacts of production processes, and increasing the resilience of rural communities against climate change through artificial intelligence were identified. In the axial coding stage, these factors were associated with the enhancement of sustainability and environmental efficiency in rural communities. The Lavasanat region, with its rich natural resources including orchards and rangelands, requires smart management of these resources to prevent environmental degradation. The use of artificial intelligence technologies for monitoring water consumption and soil management can contribute significantly to the preservation of natural resources. Although some initial efforts have been made in this regard, the widespread implementation of these technologies has not yet been realized (Table 7).

Table 7. Outcomes of Environmental Drivers

Interview Excerpt	Open Coding	Axial Coding	Interview Output
"Lavasan, with its rich natural resources, has a strong need for smart management. The use of intelligent water and soil monitoring systems has reduced water consumption in orchards and improved soil fertility. However, the large-scale implementation of these technologies requires financial and educational support. If training workshops are organized for farmers, they can effectively benefit from smart monitoring systems."	Intelligent management of natural resources, reduction of environmental impacts of production processes, increasing resilience of rural communities to climate change	Enhancement of environmental sustainability and efficiency in rural communities	Resource management (70%), reduction of environmental impacts (50%), rural resilience (45%).

After identifying 18 influential drivers across five domains—technological, economic, social, policy-making, and environmental—the relationships among these factors were evaluated in a pairwise manner based on expert judgments. The resulting data were entered into MICMAC software for analysis. This software enables the classification of variables by calculating their driving power (the extent to which a factor influences other variables) and dependence (the extent to which a factor is influenced by other variables), thereby allowing the categorization of factors into four main clusters:

1. **Key drivers:** high driving power and low dependence, which determine the overall direction of the system.
2. **Linkage drivers:** high driving power and high dependence, which are highly unstable and require careful management.
3. **Dependent drivers:** low driving power and high dependence, which represent the outcomes of the system.
4. **Autonomous drivers:** low driving power and low dependence, which have limited influence on the overall system.

The results of the direct influence matrix revealed that environmental policies and the role of technology in resource management, access to emerging technologies (such as artificial intelligence), and governmental support policies exert the highest driving power over other factors. In contrast, factors such as legal and regulatory frameworks, economic growth, and social interactions exhibited higher levels of dependence on other drivers, while still maintaining a degree of influence within the system (Table 8).

Table 8. Key Drivers Based on Driving Power and Dependence

No.	Key Factor	Driving Power	Dependence	Initial Position
1	Environmental policies and the role of technology in resource management	33	25	Key
2	Access to emerging technologies (artificial intelligence)	28	30	Linkage
3	Government support policies (incentives and subsidies)	28	17	Key
4	Social awareness and cultural promotion policies	28	23	Linkage
5	Governmental legal frameworks and regulations	26	25	Linkage
6	Economic growth and social interactions	25	26	Linkage

These results indicate that governmental policies and technological infrastructures are positioned as the most influential driving forces, and any changes in these domains can lead to significant transformations across other dimensions of the system. Based on the MICMAC analysis, the drivers are classified into four main groups (Table 9):

Table 9. Direct and Indirect Influence of Drivers

Variable	Influence	Dependence	Net Influence	Type
Environmental policies in resource management	33	25	+8	Key
Access to emerging technologies	28	30	-2	Linkage
Government support policies and incentives	28	17	+11	Key
Legal and regulatory frameworks	26	25	+1	Linkage
Development of digital infrastructure	27	20	+7	Key
Economic growth and social interactions	25	26	-1	Linkage
Social awareness and cultural promotion	24	28	-4	Linkage
Digital skills of local communities	20	30	-10	Dependent
Social networks and social capital	18	27	-9	Dependent
Public awareness	17	26	-9	Dependent
Micro and local environmental factors	15	16	-1	Autonomous

Key drivers exhibit the highest level of influence over other factors while showing the lowest level of dependence. According to the quantitative MICMAC results, environmental policies in resource management, government support policies and incentives, and the development of digital infrastructure achieved the highest driving power scores. The qualitative interview results also emphasized that these factors constitute the main driving engine of technological entrepreneurship development in rural areas, and any change in them triggers a cascading effect across other variables Linkage drivers demonstrate both high influence and high dependence, indicating their instability and dynamic nature. This category includes access to emerging technologies, legal and regulatory frameworks, economic growth and social interactions, and social awareness and cultural promotion. Qualitative results revealed that these factors are deeply interdependent, and changes in one can generate reciprocal and cascading effects in others. The MICMAC results confirmed this interdependency, highlighting the need for integrated and coordinated management to avoid unpredictable fluctuations. Dependent drivers have low influence but high dependence on other variables. This group includes digital skills of local communities, social networks and social capital, and public awareness. The MICMAC results indicated that these factors are primarily outcomes of key policy interventions. Qualitative results further confirmed that improvements in infrastructure and strategic policies directly enhance these indicators Autonomous drivers represent factors with both low influence and low dependence. These micro and local environmental factors were positioned in the low-impact quadrant in the MICMAC analysis, and qualitative results suggested that they do not significantly affect the system in the short term. Overall, this analysis demonstrates that for the development of technological entrepreneurship in rural areas, priority should be given to key drivers. Specifically, governmental support policies and the development of technological infrastructure form the fundamental foundation for systemic change across other dimensions. In the second stage, linkage drivers should be managed through an integrated and coordinated approach to minimize instability and prevent negative reciprocal effects. Finally, dependent drivers should be monitored as outcome indicators to evaluate the effectiveness of implemented policies. This framework provides a clear causal chain of drivers and offers valuable insights for policymakers regarding which areas of investment yield the highest systemic impact (Table 10).

Table 10. Final Interpretation and Classification of Variables

Variable Group	Characteristics	Example Variables	Description
Key	High influence, low dependence	Environmental policies, government support policies, digital infrastructure	These variables act as the main driving forces of development, and changes in them lead to cascading systemic effects.
Linkage	High influence, high dependence (unstable)	Emerging technologies, legal frameworks, economic growth, cultural promotion	Changes in this group generate instability and bidirectional effects; therefore, they require integrated management.
Dependent	Low influence, high dependence	Digital skills, social capital, public awareness	These variables are outcomes of key drivers and reflect the final performance of the system.
Autonomous	Low influence, low dependence	Micro-level environmental factors	These variables have limited impact on the system, and their changes are short-term and marginal.

4.6. Stability and Sensitivity Analysis of the Model

To assess the robustness and stability of the identified causal structure among the drivers, in addition to confirming the reliability of qualitative coding through Cohen's Kappa coefficient (0.78), the quantitative stability of the model was examined from two perspectives. First, the analysis of net influence (Table 9) indicated that key drivers such as "government support policies" and "development of digital infrastructure," with the highest net influence values (+11 and +7, respectively), exhibit the lowest dependence on other variables and function as fundamental independent variables that determine the overall direction of the system. In other words, changes in these variables generate cascading effects across lower-level components, whereas changes in dependent variables (such as digital skills or social capital) do not exert reverse effects on these core driving forces. This asymmetry reflects the high stability of the causal structure. Second, based on the hierarchical levels derived from the ISM model (Table 11), it is observed that fourth-level (base) drivers are sufficiently stable such that even under hypothetical removal of some intermediate or dependent variables in analytical scenarios, their position at the top of the causal hierarchy remains unchanged, due to their minimal dependence on other variables. Although a formal stepwise quantitative sensitivity analysis through variable elimination was not prioritized in the present study due to the expert-based nature of the data and the limited sample size (18 experts), the high convergence of expert opinions and the stability of key variable positions in both direct and indirect influence matrices indicate the robustness of the model against minor variations in individual judgments. Nevertheless, as a methodological suggestion, future research with a quantitative approach and larger sample sizes could conduct sensitivity analysis through scenario-based elimination of variables with near-zero net influence (such as micro-level environmental factors), in order to more precisely quantify the extent to which the model structure is affected by marginal variables. Such an approach would not only enhance the robustness of results but also enable the development of more resilient managerial scenarios. Overall, the results confirm that the extracted causal structure possesses acceptable stability and can serve as a reliable foundation for policymaking in the field of rural technological entrepreneurship.

Table 11. ISM-Based Hierarchical Classification of Drivers Influencing AI-Based Technological Entrepreneurship Development

ISM Level	Driver Type	Driver Title	Role in the Causal Structure
Level IV (Base)	Key	Government support policies and incentives	Institutional foundation and main driver of technological entrepreneurship development
		Environmental policies and the role of technology in resource management	Establishing sustainability foundations and long-term system orientation
		Development of digital and communication infrastructure	Enabling access to and utilization of AI-based technologies
Level III (Intermediate)	Linkage	Access to emerging technologies (artificial intelligence)	Transferring effects from policies and infrastructure to the operational level
		Legal and regulatory frameworks related to technology	Regulating interactions between government, market, and entrepreneurs
Level II (Intermediate)	Linkage	Social culture building and technology acceptance	Facilitating effective use of technology at the societal level
		Local economic growth and social interactions	Strengthening innovation cycles and local cooperation
Level I (Outcome)	Dependent	Improvement of digital skills in local communities	Direct result of institutional and technological investments
		Strengthening social networks and social capital	Social outcome of technological entrepreneurship development
		Increasing public awareness of AI opportunities	Final output of the causal structure and indicator of policy success
Autonomous variables	Autonomous	Micro and local environmental factors	Limited and non-systemic influence

Source: Research results, 2025

5. Discussion and Conclusion

Rapid technological transformations in recent decades have significantly highlighted the role of artificial intelligence (AI) across economic, social, environmental, and institutional domains. In this context, rural areas face a dual challenge: on the one hand, an urgent need for economic development, social improvement, and environmental sustainability, and on the other, technological backwardness and weak digital infrastructure. The present study, using a mixed-methods approach and focusing on Shemiranat County, systematically examined the drivers influencing AI's role in fostering technological entrepreneurship in rural areas. The results indicate that the impact of AI on rural technological entrepreneurship can be categorized into five main groups of drivers: technological, economic, social, policy-related, and environmental. In the technological dimension, access to advanced machine learning algorithms, development of data analytics tools, smart agricultural systems, and production automation play a significant role in reducing costs, increasing productivity, and creating innovative opportunities for local businesses. These results are consistent with studies such as Vlachová (2024) and Giuggioli (2023), which identify AI as a key tool for improving decision-making, innovation, and forecasting within entrepreneurial ecosystems. In the economic dimension, the study confirmed that AI contributes to employment development, income growth, and productivity improvement in rural areas through supply chain optimization, price forecasting, market identification, and facilitation of digital sales. These results align with the work of Anabestani (2022) and Chatterjee et al. (2021), who emphasize AI's role in economic empowerment and access to new markets in the social dimension, AI indirectly influences the formation of social capital and the enhancement of interactions by improving access to technological skills training, strengthening local communication networks, increasing trust in technology, and raising public awareness. This finding is consistent with Mohammadian (2020) and Rahimi Kloor (2023), who reported that technological education and access to digital platforms enhance local participation in development processes. In the policy and governance dimension, the results show that government support, enabling regulatory frameworks, financial incentives, and the development of digital infrastructure are among the most important institutional drivers for implementing AI in rural areas. This finding is supported by studies such as Ahmadi et al. (2013) and Basaki & Duffy (2021), which emphasize the critical role of government in strengthening innovative ecosystems through policy-making and investment. In the environmental dimension, the application of AI in natural resource management, monitoring water and soil consumption, forecasting climate risks, and enhancing rural resilience plays a crucial role in environmental sustainability. These results are consistent with Lee et al. (2022), who highlighted the contribution of AI to sustainable development in underprivileged regions. From an analytical perspective, the use of the MICMAC method enabled the identification and classification of key, linkage, dependent, and autonomous drivers. Environmental policies, access to technology, and government support emerged as key drivers with the highest influence on other factors, shaping the overall trajectory of technological entrepreneurship development. This analytical framework enables policymakers to focus on leverage points that generate cascading effects across multiple dimensions. In comparison with the existing literature, the present study offers several key contributions. Based on the identified drivers, it is recommended that policymakers and local institutions prioritize the development of rural digital infrastructure. Expanding high-speed internet coverage, establishing public digital access centers, and equipping local administrations with smart systems can facilitate the effective use of AI-based tools by rural entrepreneurs. To strengthen technological drivers, it is suggested that rural innovation hubs and specialized accelerators focused on AI applications be established in areas such as smart agriculture, rural tourism, and local creative industries. These centers can reduce entry barriers for rural entrepreneurs by providing technical consultancy, business mentoring, and initial financial support. Given the role of institutional and policy drivers, it is essential to design targeted incentive frameworks for rural technology-based businesses, including low-interest loans, temporary tax exemptions, and support for the commercialization of AI-driven ideas. Such measures can enhance private sector investment and encourage youth participation in rural entrepreneurship. In terms of human capital, specialized training and empowerment programs in digital literacy, practical AI applications, and technological entrepreneurship skills should be developed in collaboration with universities, vocational training centers, and the private sector. These programs must be aligned with local market needs and regional capacities. From a social and cultural perspective, awareness-raising initiatives regarding the adoption of emerging technologies should be strengthened through local workshops, dissemination of successful rural entrepreneurial cases, and use of local media platforms. Such efforts can reduce resistance to new technologies and facilitate broader acceptance of AI. Finally, the results of this study indicate that artificial intelligence is not merely a complex imported technology, but rather a transformative tool that, through proper management, training, targeted policymaking, and local participation, can become a dynamic foundation for sustainable and inclusive rural development. Achieving this transformation requires an integrated, long-term, and cross-sectoral approach involving government, academia, civil society, and the private sector.

Author Contributions

The authors contributed equally to the development and preparation of this research.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the authorship or publication of this article.

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تبیین پیشران‌های اثرگذاری هوش مصنوعی بر توسعه کارآفرینی فناورانه (مطالعه موردی: نواحی روستایی شهرستان شمیرانات)

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چکیده مبسوط

۱. مقدمه

در دهه‌های اخیر، فناوری‌های نوین، به‌ویژه هوش مصنوعی(AI)، به‌عنوان موتور محرک تحول در الگوهای کسب‌وکار و توسعه کارآفرینی شناخته شده‌اند. هوش مصنوعی با قابلیت‌هایی نظیر تحلیل داده‌های کلان، پیش‌بینی روندها، خودکارسازی فرآیندها و بهینه‌سازی تصمیم‌گیری، بستری مناسب برای شکل‌گیری کسب‌وکارهای نوآورانه و کارآفرینی فناورانه فراهم می‌کند. کارآفرینی فناورانه، که بهره‌گیری خلاقانه از فناوری‌های نوین برای خلق محصولات، خدمات و مدل‌های کسب‌وکار جدید است، می‌تواند نقش مهمی در توسعه پایدار، به‌ویژه در نواحی روستایی ایفا کند. این نوع کارآفرینی با افزایش بهره‌وری، ایجاد اشتغال مولد و کاهش وابستگی به منابع سنتی، می‌تواند به پایداری اقتصادی-اجتماعی جوامع روستایی کمک شایانی نماید. پژوهش حاضر، با تمرکز بر نواحی روستایی شهرستان شمیرانات، به‌دنبال پاسخ به این سوال اصلی است که "پیشران‌های کلیدی اثرگذاری هوش مصنوعی بر توسعه کارآفرینی فناورانه در این مناطق کدام‌اند و این پیشران‌ها چه روابط علی و ساختاری با یکدیگر دارند؟" شناسایی این پیشران‌ها می‌تواند به سیاست‌گذاران و برنامه‌ریزان در طراحی استراتژی‌های هدفمند و کارآمد برای بهره‌گیری از ظرفیت‌های هوش مصنوعی در راستای توسعه روستایی کمک کند.

۲. مبانی نظری تحقیق

هوش مصنوعی، به‌عنوان شاخه‌ای از علوم رایانه، به شبیه‌سازی فرآیندهای هوش انسانی توسط ماشین‌ها می‌پردازد. این فناوری با بهره‌گیری از الگوریتم‌ها و داده‌ها، توانایی یادگیری، استدلال، درک زبان طبیعی و تصمیم‌گیری را به سیستم‌ها می‌دهد. از سوی دیگر، کارآفرینی فناورانه، فرآیند شناسایی و بهره‌برداری از فرصت‌های کسب‌وکار از طریق خلق محصولات، خدمات یا مدل‌های تجاری نوآورانه مبتنی بر فناوری است. ادبیات نظری نشان می‌دهد که رابطه هوش مصنوعی و کارآفرینی فناورانه، رابطه‌ای متقابل و تقویت‌کننده است. هوش مصنوعی با ارائه ابزارهای تحلیلی قدرتمند، امکان شناسایی فرصت‌های جدید، بهینه‌سازی فرآیندها و کاهش هزینه‌ها را برای کارآفرینان فراهم می‌آورد و کارآفرینان نیز با خلق کاربردهای نوآورانه از هوش مصنوعی، به توسعه و تکامل این فناوری کمک می‌کنند. مرور نظام‌مند پیشینه نشان می‌دهد که علی‌رغم غنای پژوهش‌های بین‌المللی و داخلی، یک خلأ علمی در تحلیل ساختاری و سیستمی پیشران‌های اثرگذاری هوش مصنوعی بر کارآفرینی فناورانه در نواحی روستایی ایران، به‌ویژه با رویکرد ترکیبی و استفاده از تکنیک‌هایی مانند مدل‌سازی ساختاری تفسیری (ISM) وجود دارد که پژوهش حاضر درصدد پر کردن آن است.

۳. روش تحقیق

پژوهش حاضر از نظر هدف، کاربردی و از نظر ماهیت، توصیفی-تحلیلی است که با رویکردی ترکیبی (کیفی-کمی) انجام شده است. در مرحله کیفی، به‌منظور شناسایی و بومی‌سازی پیشران‌ها، از روش تحلیل محتوای کیفی مبتنی بر استراتژی تثلیث داده‌ها استفاده شد. داده‌های این بخش از دو منبع گردآوری گردید: ۱) مطالعات اسنادی و کتابخانه‌ای برای استخراج فهرست اولیه پیشران‌ها، و ۲) مصاحبه‌های نیمه‌ساختاریافته با ۱۸ نفر از خبرگان حوزه‌های کارآفرینی فناورانه، توسعه روستایی و فناوری‌های نوین که به‌صورت هدفمند انتخاب شدند. معیارهای انتخاب خبرگان شامل داشتن حداقل پنج سال سابقه علمی یا اجرایی مرتبط و آگاهی از شرایط مناطق روستایی بود. مصاحبه‌ها تا دستیابی به اشباع نظری ادامه یافت و داده‌ها با استفاده از کدگذاری باز، محوری و گزینشی تحلیل شدند. برای تأمین روایی، از نظر خبرگان و برای پایایی، از ضریب

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کاپای کوهن (با مقدار ۰.۷۸) استفاده شد که نشان‌دهنده توافق مناسب است. در مرحله کمی، برای تحلیل روابط علّی میان پیشران‌های شناسایی‌شده، از تکنیک مدل‌سازی ساختاری تفسیری (ISM) و نرم‌افزار MICMAC استفاده گردید. قلمرو مکانی پژوهش، نواحی روستایی شهرستان شمیرانات (با دو بخش اصلی لواسانات و رودبار قصران) در استان تهران و قلمرو زمانی آن سال ۱۴۰۴ است.

۴. یافته‌های تحقیق

یافته‌های بخش کیفی منجر به شناسایی ۱۸ پیشران اثرگذار در پنج حوزه اصلی گردید: پیشران‌های فناورانه، اقتصادی، اجتماعی، سیاست‌گذاری و محیطی. نتایج مصاحبه‌ها نشان داد که با وجود پتانسیل‌های بالا در منطقه لواسانات، چالش‌هایی نظیر محدودیت سرمایه‌گذاری، نبود سیاست‌های حمایتی مشخص و شکاف مهارتی، موانع اصلی بهره‌گیری از هوش مصنوعی محسوب می‌شوند. نتایج بخش کمی از تحلیل ISM و MICMAC نشان داد که پیشران‌های کلیدی با بالاترین قدرت نفوذ و کمترین وابستگی، عبارتند از: سیاست‌های زیست‌محیطی و نقش فناوری در مدیریت منابع، سیاست‌های حمایتی دولتی و توسعه زیرساخت‌های دیجیتال . این عوامل به‌عنوان موتور محرک اصلی سیستم معرفی شدند و در سطح چهارم (پایه‌ای) مدل قرار گرفتند. پیشران‌های پیوندی با نفوذ و وابستگی بالا، شامل دسترسی به فناوری‌های نوین، قوانین حقوقی، فرهنگ‌سازی اجتماعی و رشد اقتصادی محلی بودند که در سطوح دوم و سوم (میانی) جای گرفتند و نشان‌دهنده ناپایداری و نیاز به مدیریت هماهنگ هستند. پیشران‌های وابسته که پیامد اقدامات کلیدی محسوب می‌شوند، شامل مهارت‌های دیجیتال، سرمایه اجتماعی و آگاهی عمومی بودند و در سطح اول (پیامدی) قرار گرفتند. همچنین، برخی عوامل محیطی خرد در گروه مستقل با تأثیرگذاری محدود قرار گرفتند. سطح‌بندی مدل نشان‌دهنده یک ساختار سلسله‌مراتبی است که در آن پیشران‌های نهادی و زیربنایی، جهت‌گیری کل سیستم را تعیین می‌کنند.

۵. بحث و نتیجه‌گیری

این پژوهش با ارائه یک چارچوب جامع، نشان داد که توسعه کارآفرینی فناورانه مبتنی بر هوش مصنوعی در نواحی روستایی، نتیجه تعامل پیچیده و سلسله‌مراتبی از پیشران‌های پنج‌گانه است. مهم‌ترین نتیجه، نقش محوری و بنیادین **سیاست‌گذاری و حکمرانی** به‌عنوان زیربنای اصلی تحول است. حمایت‌های دولتی، قوانین تسهیل‌گر و سرمایه‌گذاری در زیرساخت‌های دیجیتال، نه‌تنها به‌عنوان پیشران‌های کلیدی با بیشترین قدرت نفوذ شناسایی شدند، بلکه به‌عنوان پایه‌های ساختار علّی، تمامی سطوح دیگر را تحت تأثیر قرار می‌دهند. در مقابل، عواملی مانند مهارت‌های دیجیتال و سرمایه اجتماعی که غالباً در کانون توجه برنامه‌های توسعه قرار دارند، در این مدل به‌عنوان متغیرهای وابسته یا پیامدی ظاهر شدند. این به آن معناست که آموزش و توانمندسازی به‌تنهایی نمی‌توانند موتور محرک توسعه باشند، بلکه پس از فراهم شدن بسترهای نهادی و زیرساختی، به‌عنوان حلقه‌های تکمیل‌کننده و نتیجه‌بخش عمل می‌کنند. این یافته، دیدگاه‌های رایج در توسعه روستایی را به چالش کشیده و تأکید می‌کند که اقدامات آموزشی باید به‌موازات و پس از اصلاحات ساختاری انجام شوند.

از منظر نوآوری مفهومی، این پژوهش با تفکیک پیشران‌ها به سطوح مختلف و شناسایی روابط علّی آن‌ها، درک عمیق‌تری از پویایی‌های سیستم ارائه می‌دهد. برخلاف مطالعات پیشین که بیشتر به توصیف کاربردها پرداخته‌اند، این پژوهش با رویکرد سیستمی، نقطه‌ی اهرمی تأثیرگذاری را معرفی می‌کند. در نهایت، این پژوهش نشان داد که هوش مصنوعی، فارغ از پیچیدگی‌های فنی، می‌تواند با یک رویکرد یکپارچه و نهادی، به ابزاری کارآمد برای توانمندسازی جوامع روستایی، کاهش نابرابری‌ها و دستیابی به توسعه پایدار تبدیل شود.

کلیدواژه‌ها: هوش مصنوعی، کارآفرینی فناورانه، توسعه روستایی، پیشران‌های کلیدی، تحلیل ساختاری، شهرستان شمیرانات.

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