Original Research Article

Artificial intelligence empowering home-based elderly care: Models, dilemmas, and pathways—An analysis based on the "technology-scenario-governance" framework

Yujin Yan, Hong Liu*
School of Business Administration, University of Science and Technology Liaoning, Anshan, Liaoning, 114051, China

Abstract: The deep integration of artificial intelligence (AI) and home-based elderly care represents a critical pathway for actively addressing population aging. This study constructs a three-dimensional analytical framework of "Technology-Scenario-Governance" (TSG) to systematically investigate the model innovation, practical dilemmas, and implementation pathways of AI-empowered home-based elderly care. The findings reveal that AI-empowered home-based elderly care has evolved into three distinct models: technology empowerment, scenario integration, and governance collaboration. In practice, the field faces technology-dimension dilemmas including insufficient technology adaptation, digital divide, and ethical risks; scenario-dimension dilemmas including demand identification deviation, scenario embedding difficulties, and service suspension; and governance-dimension dilemmas including subject coordination challenges, resource allocation imbalance, and regulatory absence. The root causes of these dilemmas lie in the tension between technical logic and humanistic logic, the conflict between efficiency orientation and fairness orientation, and the imbalance between instrumental rationality and value rationality. This paper proposes collaborative implementation strategies encompassing technology pathways, scenario pathways, and governance pathways.

Keywords: artificial intelligence; home-based elderly care; scenario governance; model innovation; smart elderly care

1. Problem statement

Population aging constitutes a formidable challenge confronting China's economic and social development in the 21st century. According to the Seventh National Population Census, China's population aged 60 and above reached 264 million in 2020, accounting for 18.7% of the total population. By the end of 2024, this figure had surpassed 310 million, representing 22.0% of the population, marking China's official entry into a moderately aging society [1]. Within the elderly care service system characterized by "home-based care as the foundation, community-based care as support, and institutional care as supplementation," home-based elderly care consistently occupies a dominant position. However, with the intensifying trends toward smaller family structures and increasing empty-nest households, traditional family elderly care functions have progressively weakened. The contradiction between supply and demand for elderly care services has become increasingly pronounced. The deep integration of AI and home-based elderly care has emerged as a crucial pathway for resolving the supply-demand contradiction in elderly care services. Nevertheless, in practice, AI-empowered home-based elderly care confronts numerous dilemmas: insufficient age-appropriateness of intelligent products and prominent "digital divide" issues among elderly individuals; disconnection between technology and scenarios, with widespread problems of supply-demand mismatch and service "suspension"; inadequate multi-subject collaboration, with issues such as resource allocation imbalance and regulatory mechanism absence awaiting resolution.

2. Model innovation: Three models of AI-empowered home-based elderly care

2.1. Technology empowerment model

The technology empowerment model takes AI technology as the core driving force, providing intelligent services to home-based elderly individuals through technical means such as intelligent devices, systems, and

platforms. According to technological function and application depth, it can be classified into three types: The intelligent monitoring model represents the foundational model, utilizing technical means such as IoT sensors, wearable devices, and intelligent cameras to collect real-time health data, behavioral data, and location data of elderly individuals, enabling functions such as health monitoring and safety early warning. For instance, Shanghai's "one-touch call" system has covered over 300,000 households, effectively reducing safety risks for elderly individuals living alone. The intelligent care model represents an advanced model, providing elderly individuals with services such as daily care, rehabilitation training, and medical nursing through service robots, intelligent nursing beds, and intelligent rehabilitation equipment. The intelligent companionship model represents a high-level model, providing elderly individuals with services such as spiritual consolation, social support, and cognitive training through emotional robots, intelligent voice assistants, and virtual reality.

2.2. Scenario integration model

The scenario integration model refers to the deep integration of AI technology with home-based elderly care scenarios, forming a technology-scenario integrated service modality. The daily living scenario constitutes the foundational scenario, where AI manifests as smart home systems, smart appliances, and service robots. For instance, Beijing's "property + elderly care" model integrates smart homes with community services; over 200 property service enterprises have launched home-based elderly care services. The health management scenario represents the core scenario, where AI manifests as intelligent health monitoring equipment, telemedicine systems, and intelligent rehabilitation equipment. The safety monitoring scenario represents a key scenario, where AI manifests as intelligent cameras, intelligent wearable devices, and intelligent alarm systems. For instance, Shanghai's elderly living alone safety monitoring system has automatically identified abnormal situations through analysis of water and electricity usage data, with cumulative warnings exceeding 100,000 instances.

2.3. Governance collaboration model

The governance collaboration model refers to the joint participation of multiple subjects in the governance process of AI-empowered home-based elderly care, forming a collaborative governance pattern. The government-led type takes government as the lead, promoting smart elderly care development through policy guidance, financial support, and standard formulation. The market-driven type takes enterprises as the lead, satisfying elderly individuals' needs through product innovation, service innovation, and business model innovation. The multi-subject collaboration type is characterized by joint participation of multiple subjects, forming a pattern of co-construction, co-governance, and sharing. For instance, the Beihang Community model takes the community party committee as the core, integrating resources from multiple parties, constructing a "demand perception—resource matching—Service delivery" service logic [6].

2.4. Evolutionary logic of models

From the technology empowerment model to the scenario integration model and then to the governance collaboration model, the evolution presents a triple logic: from technology-driven to demand-driven, embodying a perspective shift from "technocentrism" to "humanism"; from tool application to scenario integration, embodying a transformation from "instrumental rationality" to "value rationality"; from single subject to multi-subject collaboration, embodying an expansion from "single governance" to "collaborative governance."

3. Practical dilemmas: Triple dilemmas of AI-empowered home-based elderly care

3.1. Technology-dimension dilemmas

Insufficient technology adaptation constitutes the primary obstacle constraining application. Existing intelligent products are predominantly designed for younger users, with complex interfaces and cumbersome operations that struggle to accommodate the physiological characteristics and cognitive habits of elderly individuals. Research indicates that elderly individuals experience declining visual acuity, elevated auditory thresholds, and reduced motor precision, necessitating special requirements for interaction modalities [19]. Simultaneously, a mismatch exists between intelligent product functions and elderly individuals' needs: Wang et al. [19] found through factor analysis that functional quality, emotional companionship, and interactivity are

the primary factors influencing elderly individuals' use of robots, yet existing products predominantly focus on health monitoring and safety early warning, with insufficient attention to daily living assistance and spiritual consolation. The prominent digital divide constitutes a key factor constraining acceptance. Niehaves and Plattfaut [9], based on information systems technology acceptance theory, found that age-related digital divide hinders elderly individuals from benefiting from information technology. The digital divide problem among elderly individuals in China is particularly pronounced: elderly individuals generally have lower educational attainment and insufficient digital literacy; the insufficient age-appropriateness of intelligent products exacerbates usage barriers. Ethical risk concerns cannot be ignored. Intelligent monitoring equipment requires collecting sensitive information such as health data, behavioral data, and location data, posing risks of data leakage and misuse. AI algorithms may harbor biases leading to discrimination. When intelligent products malfunction or make erroneous decisions causing harm to elderly individuals, responsibility delineation remains unclear [10].

3.2. Scenario-dimension dilemmas

Demand identification deviation leads to supply-demand mismatch. Elderly individuals' elderly care service demands exhibit heterogeneity and dynamic characteristics, with significant differences in needs among elderly individuals of different ages, health conditions, and economic circumstances [21]. However, existing intelligent products predominantly adopt standardized designs that struggle to satisfy personalized needs; demand identification relies largely on traditional questionnaire survey that struggle to capture dynamic changes. Scenario embedding difficulties constrain efficacy realization. Wang et al. [14] pointed out that scenarios constitute the key determinant of whether technology can be transformed into service quality, yet in practice, problems of disconnection between technology and scenarios exist. On one hand, technology designers have insufficient understanding of elderly care service scenarios, leading to product designs that deviate from actual needs; on the other hand, home-based elderly care involves multiple sub-scenarios, and existing products are predominantly designed for single scenarios, struggling to achieve cross-scenario coordination. The service suspension problem is prominent. Wang et al. [22] found in their research that the demand gap for community home-based elderly care services has generally narrowed but remains at a relatively high level, indicating that elderly individuals' actual needs remain unmet. The root cause of service suspension lies in the disconnection between technology and services.

3.3. Governance-dimension dilemmas

Subject coordination dilemmas are prominent. Smart elderly care involves multiple departments including civil affairs, health, industry and information technology, and science and technology, with overlapping functions and unclear rights and responsibilities, resulting in high coordination costs [11]. Coordination mechanisms among government, enterprises, and social organizations are imperfect. Resource allocation imbalance affects fairness. Urban-rural resource allocation is imbalanced, with rural areas lacking elderly care service resources and having weak economic foundations, resulting in lagging smart elderly care development [23]. Regional resource allocation is imbalanced; Li et al. [25] found in their research that community home-based elderly care service capabilities across 31 provinces exhibit obvious spatiotemporal heterogeneity. Regulatory absence constrains sustainable development. The standard and norm system for smart elderly care is imperfect, with technical standards, service standards, and data standards for intelligent products yet to be unified [26]. Mechanisms for intelligent product quality supervision, service process quality control, and data security protection remain imperfect, with regulatory gaps existing [27].

3.4. Root causes of dilemmas

Behind the aforementioned dilemmas exist three tensions: The tension between technical logic and humanistic logic. AI technology follows a technical logic of efficiency priority, standardization, and calculability, while elderly care services follow a humanistic logic of people-centeredness, personalization, and emotional orientation. The tension between these two logics results in technology struggling to effectively respond to elderly individuals' genuine needs. The conflict between efficiency orientation and fairness orientation. AI-empowered home-based elderly care pursues service efficiency improvement but may exacerbate service inequity. The imbalance between instrumental rationality and value rationality. AI-empowered home-based elderly care easily falls into the trap of instrumental rationality, excessively focusing on the effectiveness of

technological means while neglecting the value of service purposes [14].

4. Implementation pathways: From technology-driven to scenario governance

4.1. Technology pathway: From technology-driven to human-machine collaboration

Advance technology age-appropriateness transformation. Formulate age-appropriateness standards and norms for intelligent products, clarifying age-appropriateness requirements for interface design, interaction modalities, and function settings. Establish an age-appropriateness product certification mechanism to enhance elderly individuals' trust in products. Construct human-machine collaborative design models. Transform the "technology replacing humans" mindset toward a "technology assisting humans" human-machine collaboration model. Intelligent products should be positioned as assistive tools rather than replacement tools, helping elderly individuals enhance capabilities and compensate for deficiencies [28]. Improve ethical regulatory systems. Formulate ethical guidelines for AI-empowered home-based elderly care, clarifying ethical requirements for data collection, algorithm design, and service delivery.

4.2. Scenario pathway: From scenario embedding to scenario governance

Establish precise demand identification mechanisms. Through intelligent devices, collect real-time health data, behavioral data, and service usage data of elderly individuals, utilizing big data analysis technology to identify demand characteristics and change trends. Promote deep scenario integration. Advance collaborative design of technology and scenarios, with technology designers, elderly care service providers, and elderly individuals jointly participating in product design to ensure technology-scenario adaptability. Achieve "scenario governance" paradigm transformation. Break through traditional "scenario control" and "scenario management" paradigms, transitioning toward a "scenario governance" paradigm: open scenario construction with multi-subject participation; scenario interconnection and dynamic adjustment to maintain adaptability.

4.3. Governance pathway: From single subject to multi-subject co-governance

Clarify the rights and responsibilities boundaries of multiple subjects. As policy formulators, resource providers, and regulators, governments should formulate development plans, provide financial support, and establish regulatory mechanisms. As product providers and service innovators, enterprises should research and develop age-appropriate products and innovate service models. As service providers and resource connectors, social organizations should provide specialized services. As emotional supporters and service supervisors, families should assist elderly individuals in using intelligent products. As demand expressers and service participants, elderly individuals should exert their subjectivity. Optimize resource allocation mechanisms. Promote balanced urban-rural resource allocation, increase investment in rural smart elderly care, improve infrastructure, and cultivate service personnel [29]. Construct a whole-process regulatory system. Formulate technical standards and service standards for intelligent products, establishing product entry and exit mechanisms. Formulate smart elderly care service quality standards, establishing service quality evaluation mechanisms..

4.4. Pathway collaboration mechanisms

The three pathways are interrelated and mutually reinforcing. Technology and scenario collaboration: technology development is oriented toward scenario demands, and scenario design is supported by technological capabilities. Technology and governance collaboration: technology development requires governance guarantees, and governance innovation requires technological support. Scenario and governance collaboration: scenarios serve as governance carriers, and governance provides scenario operation guarantees. Technology, scenarios, and governance form an integrated collaboration, together supporting the deep integration of AI and home-based elderly care.

5. Conclusions

This paper constructs a three-dimensional analytical framework of "Technology-Scenario-Governance" to systematically investigate the model innovation, practical dilemmas, and implementation pathways of AI-empowered home-based elderly care. The main conclusions are as follows: First, AI-empowered home-based elderly care has formed three types of innovative models. The technology empowerment model takes technology

as the core driving force, the scenario integration model takes scenarios as the core carrier, and the governance collaboration model takes multi-subject collaboration as the core mechanism. The model evolution presents logical characteristics of transitioning from technology-driven to demand-driven, from tool application to scenario integration, and from single subject to multi-subject collaboration. Second, AI-empowered home-based elderly care faces triple dilemmas. The technology dimension exhibits insufficient technology adaptation, digital divide, and ethical risks; the scenario dimension exhibits demand identification deviation, scenario embedding difficulties, and service suspension; the governance dimension exhibits subject coordination dilemmas, resource allocation imbalance, and regulatory absence. The root causes of these dilemmas lie in the tension between technical logic and humanistic logic, the conflict between efficiency orientation and fairness orientation, and the imbalance between instrumental rationality and value rationality. Third, AI-empowered home-based elderly care requires triple pathway collaboration. The technology pathway transitions from technology-driven toward human-machine collaboration; the scenario pathway transitions from scenario embedding toward scenario governance; the governance pathway transitions from single subject toward multi-subject co-governance.

About the author

*Corresponding author:Hong Liu.

References

[1] Lu J H, Liu Q. Characteristics, impacts and coping strategies of China's new form of aging society: An interpretation based on the "Seventh Census" data [J]. Population & Economics, 2021(5): 15-29.

[2] Qian W, et al. AIoT for Elderly Care: A Systematic Review [J]. IEEE Access, 2022, 10: 32145-32170.

[3] Zhang Y, et al. Smart Home Elderly Care in China: Development Stages and Challenges [J]. Journal of Ambient Intelligence and Smart Environments, 2023, 15(2): 89-106.

[4] Maswadi K, et al. Systematic Review of IoT-Based Smart Home Monitoring for Elderly [J]. Sensors, 2022, 22(7): 2589.

[5] Ning X S, et al. Research on classification of smart elderly care models based on TOE-P framework [J]. Chinese Public Administration, 2022(8): 112-120.

[6] Wang Z X, et al. Models and mechanisms of digital empowerment for community home-based elderly care service innovation [J]. Management World, 2023(4): 98-115.

[7] Zhou X X, et al. The evolution and strategic implications of China's active aging system [J]. Population Research, 2024, 48(1): 104-117.

[8] Liu T C, et al. Research on data resource integration of smart elderly care comprehensive service platform [J]. Chinese Health Service Management, 2022(9): 689-694.

[9] Niehaves B, Plattfaut R. Internet Adoption by the Elderly: Employing IS Technology Acceptance Theories [J]. European Journal of Information Systems, 2014, 23(6): 708-726.

[10] Xing Y H. Ethical risks and governance of generative AI embedded in health elderly care [J]. Studies in Science of Science, 2024(2): 234-243.

[11] Wang L Z, et al. Evolutionary logic and optimization pathways of China's smart elderly care policy [J]. Chinese Public Administration, 2021(10): 89-96.

[12] Trist E L, Bamforth K W. Some Social and Psychological Consequences of the Longwall Method of Coal-Getting [J]. Human Relations, 1951, 4(1): 3-38.

[13] Lefebvre H. The Production of Space [M]. Oxford: Blackwell, 1991.

[14] Wang K, et al. Research on scenario adaptability of elderly care service robots [J]. Management World, 2022(10): 145-162.

[15] Commission on Global Governance. Our Global Neighbourhood [M]. London: Oxford University Press, 1995.

[16] Do H M, et al. Social Robots for Older Adults with Mild Cognitive Impairment [J]. International Journal of Social Robotics, 2023, 15(3): 395-415.