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Deployment Pathways and Adaptation Mechanisms of Eldercare Robots: A Structure – Prediction Fusion Modeling Approach

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Abstract: *China's eldercare service system faces dual challenges of rapid demographic aging and persistent caregiver shortages. As robotic technologies emerge as a potential solution, their large-scale integration remains constrained by structural, financial, and user-acceptance barriers. This study aims to bridge this gap by examining the penetration mechanisms and industrialization trajectories of eldercare robots, with a particular focus on aligning service deployment with user experience through a dual-stakeholder adaptation perspective. A comparative PEST analysis of China and Japan, combined with task decomposition, identifies key institutional and market-level constraints shaping deployment scenarios. Enterprise-level analysis of UBTECH Robotics, ECOVACS, and FANUC highlights divergent financial structures and revenue capacities that critically influence deployment capabilities and scalability across domestic and international markets. Building on this, the study develops an integrated analytical framework encompassing service task–functional module adaptation, technology acceptance among older adults, and dual-stakeholder collaborative adaptation. Time-series forecasting and multiple regression analyses of provincial-level data on elderly populations, caregiving expenditures, and workforce shortages reveal national market growth trends and regional demand asymmetries. The findings further inform three key policy recommendations: co-construction of regional service hubs, adoption of performance-based procurement models, and workforce transformation initiatives to support human-robot collaboration. This study provides an integrated framework for analyzing deployment capacity, user acceptance, and structural demand factors, offering empirical insights to inform both policy optimization and product design in advancing the sustainable integration of robotics within eldercare ecosystems.*

Keywords: *Aging; Eldercare Robots; ARIMA and Multiple Regression Analysis; Enterprise Financial Capability Analysis; Dual-Subject Adaptation Model*

1. Introduction

China's rapidly aging population presents growing challenges to its eldercare service system. By 2025, the population aged 60 and above will exceed 300 million[1], with more than 40 million individuals classified as disabled or semi-disabled[2], while the certified eldercare workforce remains severely limited. Under the "9073" eldercare model, where 90% of seniors opt for home-based care, fragmented services and acute labor shortages exacerbate service gaps. At the same time, China's smart eldercare market is projected to reach RMB 7.21 trillion by 2025[3], with the "silver economy" expected to grow by 15.32% annually[4]. Against this backdrop, eldercare robotics is emerging as a key technological solution to address structural caregiving challenges.

Recent literature on eldercare robotics can be broadly categorized into two research streams. The first focuses on deployment pathways and governance mechanisms within institutional care settings. Studies have explored role theory frameworks for human-robot interaction, models of value co-creation and destruction, and the development of international standards such as IEC 63310 to guide institutional adoption [5–9]. Ethical considerations and technical optimization for human-robot collaboration have also been extensively examined [10–13]. The second research stream investigates older adults' acceptance, behavioral responses, and emotional engagement with robotic care technologies. Building on the Technology Acceptance Model framework, subsequent studies have analyzed factors such as trust, privacy concerns, perceived usefulness, ease of use, and emotional responses in shaping acceptance pathways [14–20]. These studies underscore the complex interplay between user characteristics, contextual factors, and robot design features.

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While significant progress has been made, existing research tends to address isolated dimensions of eldercare robotics, either institutional deployment or user acceptance, without systematically integrating these perspectives. Moreover, limited attention has been paid to how deployment capabilities align with evolving market demands and regional structural differences.

To address these gaps, this study adopts a service-oriented perspective, aiming to construct an adaptation analysis framework that meets the dual needs of eldercare institutions and older adults. It systematically examines the deployment feasibility and user acceptance of eldercare robots in typical care scenarios. Furthermore, the study integrates ARIMA and multiple regression models to forecast market demand and evaluates enterprise deployment capabilities. The findings aim to provide both theoretical insights and practical guidance for industry optimization and policy development, thereby advancing the transition of eldercare robotics from pilot applications to embedded service systems.

2. Analysis of Artificial Intelligence Technology Applications in Elderly Care Service Scenarios

2.1 PEST Analysis of the Elderly Care Market in China and Japan

The accelerating process of population aging is placing immense pressure on elderly care systems, which now face the dual challenge of a shrinking caregiver workforce and increasingly diversified service demands. In response, artificial intelligence (AI) technologies are being progressively integrated into elderly care environments. However, the actual penetration and performance of care robots remain significantly below policy expectations. To better understand this gap, this study employs a PEST (Political, Economic, Social, Technological) framework to systematically compare the elderly care markets of China and Japan. The analysis provides essential contextual insights for future research on task-technology adaptation and implementation pathways (See Figure 1 for a comparative summary).

Figure 1 Comparative PEST summary of the elderly care robot markets in China and Japan

1) Political Dimension

Japan's elderly care system has benefited from early policy development and mature regulatory frameworks. Since the enactment of the Long-Term Care Insurance Act in 2000[21], Japan has established a predominantly community-based care system. This foundation has supported the subsequent integration of intelligent technologies. Notably, the "New Robot Strategy" released in 2015 prioritized the deployment of care robots, complemented by targeted fiscal subsidies and equipment approval lists[22]. Through sustained government leadership, care robots have gradually been embedded into routine care processes and widely adopted across the country.

In contrast, China's policy emphasis on integrating AI into elderly care emerged later. Beginning with the 13th Five-Year Plan, national policies have increasingly underscored the importance of age-friendly technologies[23]. The 14th Five-Year Plan and various follow-up initiatives have further promoted AI applications in elderly services[24]. In 2025, China led the development of the international care robot standard IEC 63310, reflecting its growing influence in global standardization efforts[25]. However, practical implementation remains uneven. The absence of a unified subsidy system, inconsistent local policies, and a lack of operational guidelines hinder broader adoption. Moreover, regional disparities in policy execution contribute to fragmented progress. As a result, while Japan offers a cohesive policy environment that facilitates widespread care robot adoption, China's policy landscape remains fragmented and less conducive to systematic integration.

2) Economic Dimension

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Japan has entered a phase of deep demographic aging, with the elderly care industry demonstrating steady growth. As of 2024, 29.3% of the population was aged 65 or older, and the elderly care market was valued at approximately $800 billion[26]. Despite the relatively high costs of care robots, government subsidies and institutional procurement mechanisms have facilitated large-scale deployment.

China, while not yet in a deeply aged phase, is experiencing a rapid demographic transition. By 2025, the population aged 60 or above will exceed 300 million, with over 40 million classified as disabled or semi-disabled. The growing prevalence of “empty-nest” elderly households and a severe shortage of qualified caregivers create a compelling market foundation for care robots. According to industry forecasts, China’s elderly care robot market is projected to reach $529 million by 2030, with a compound annual growth rate of 15.9%[27]. Nevertheless, structural challenges persist. Regional income disparities, uneven development levels, and limited purchasing power among older adults constrain market expansion. Consequently, Japan benefits from a more mature and economically supportive market for care robots, whereas China’s market, though promising, faces significant systemic barriers.

3) Social Dimension

Significant differences exist in the societal acceptance of intelligent care technologies between the two countries. Japan has long prioritized public education and ethical discourse surrounding technology in care settings. Government, media, and academic actors have fostered a cohesive and supportive narrative. In 2022, approximately 87% of surveyed Japanese elderly believed that care robots enhanced safety and care quality, with over 80% of caregivers reporting reduced workload[28]. Importantly, robots are perceived as assistive tools rather than replacements for human caregivers.

Conversely, Chinese elderly populations exhibit lower levels of trust toward care robots. Limited understanding of AI, privacy concerns, and cultural preferences for family-based care contribute to psychological barriers. Traditional caregiving norms remain deeply embedded, with many older adults preferring human companionship over robotic assistance. These cultural and perceptual factors represent critical social variables influencing the adoption of care robots. Therefore, Japan’s high level of social acceptance provides a favorable environment for technology integration, while China must address both cultural attitudes and perceptual barriers to achieve similar outcomes.

4) Technological Dimension

Japan’s care robot industry demonstrates a high degree of technological maturity, supported by stable collaborations between industry, academia, and care institutions. Leading companies such as Panasonic, Toyota, and Cyberdyne have launched diverse products targeting mobility assistance, emotional companionship, and rehabilitation. Academic institutions actively contribute to technology development and clinical validation. However, current care robots still face limitations in adapting to complex care environments and maintaining cost efficiency.

China has achieved rapid progress in core AI technologies, including speech recognition, path planning, and facial recognition. Companies such as UBTECH, Changhong, and Canbot have introduced a range of care robot products for both home and institutional use. Nevertheless, most products remain at the early integration stage, with challenges in system stability, environmental adaptability, and human-robot interaction capabilities. Moreover, deployment remains concentrated in major urban centers and premium care facilities, limiting broader market reach. In sum, Japan’s care robot ecosystem is marked by technological maturity and institutional integration, while China’s AI-driven advancements hold significant potential that requires further refinement for scalable and practical deployment.

In conclusion, this PEST analysis reveals systemic differences between the elderly care markets of China and Japan. Japan has cultivated a highly coordinated ecosystem driven by cohesive policy frameworks, mature market structures, strong societal acceptance, and advanced technological integration. In contrast, China’s ecosystem remains in an emergent phase, characterized by fragmented policies, dynamic yet constrained market conditions, cultural barriers, and evolving technological capabilities. To advance in this domain, China should prioritize enhancing policy cohesion, fostering social acceptance, and refining technological solutions that meet the complex demands of elderly care environments.

2.2 Functional Tasks and Robotic Integration in Elderly Care

This section focuses on the integration of robotic technologies into key service processes in institutional elderly care. Figure 2 presents a modular framework of institutional elderly care services, which highlights key process stages where robotic assistance can be integrated. Based on this framework,

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Table 1 summarizes six core functional tasks and the corresponding roles played by care robots across these stages.

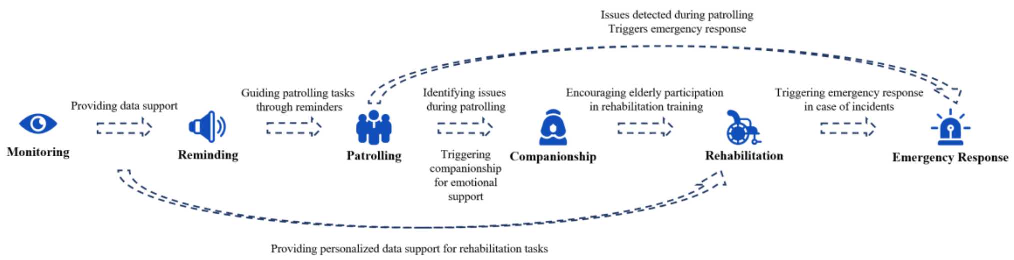

Figure 2 Modular framework of institutional elderly care services

Table 1 Core functional domains of elderly care services and typical robotic applications

Functional Domain	Service Objective	Typical Robotic Applications
Monitoring	Continuous monitoring of health and safety	Physiological data collection; behavior tracking; fall detection
Reminding	Supporting adherence to daily routines and health management	Timely prompts for medication, nutrition, and personal care
Patrolling	Ensuring environmental safety and hazard detection	Autonomous navigation; obstacle identification; fall prevention
Companionship	Providing emotional support and enhancing social interaction	Voice-based interaction; entertainment activities; emotional state recognition
Rehabilitation	Assisting physical recovery and functional training	Personalized exercise guidance; progress monitoring; mobility support
Emergency Response	Enabling rapid intervention in emergency situations	Automated alerts; initial first aid guidance; caregiver notification

2.3 Technological Bottlenecks and Age-Friendly Design Challenges

Although intelligent technologies have made notable progress in elderly care, several challenges persist, particularly concerning the effective adoption of age-friendly solutions. This section examines key technological bottlenecks and age-related design issues in the Chinese context.

A primary challenge is the limited usability of human-robot interaction. Due to common age-related declines in vision, hearing, and cognition, current intelligent devices often fail to meet the needs of elderly users. For instance, voice recognition systems struggle with dialects, accents, and unclear speech, creating significant barriers to effective interaction. High adaptation costs also hinder widespread adoption. China's elderly care system faces substantial disparities in resource allocation. Many community-based and non-profit care centers, particularly in rural areas, cannot afford the investment, installation, and maintenance costs required for intelligent technologies. Data fragmentation remains another critical issue. While various smart devices collect extensive health and behavioral data, inconsistent data standards and a lack of interoperability between platforms prevent effective integration. This limits the development of comprehensive health profiles and reduces the precision and continuity of care.

In terms of age-friendly design, several key challenges remain. Psychological acceptance barriers are significant, as many elderly users exhibit unfamiliarity and distrust toward intelligent devices. Simplified interfaces and culturally adaptive design are essential to improving user acceptance. Ease of use is also critical; devices must feature intuitive interaction mechanisms tailored to elderly users' capabilities. Response accuracy is paramount in health monitoring and emergency scenarios, where precise and timely feedback is required. Environmental adaptability is another concern, as technologies must perform reliably across diverse living environments. Finally, ensuring the long-term operational sustainability of intelligent devices remains a challenge, particularly for institutions with limited technical support and financial resources. Based on these dimensions, the maturity of elderly care robotics in China can be evaluated using a f-point scale (see Figure 3).

In conclusion, while intelligent technologies hold great potential for enhancing elderly care services in China, significant barriers, including high costs, usability limitations, data fragmentation, and

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inadequate age-friendly design, continue to restrict broader adoption. Addressing these challenges will require coordinated efforts to support the sustainable integration of robotics in elderly care.

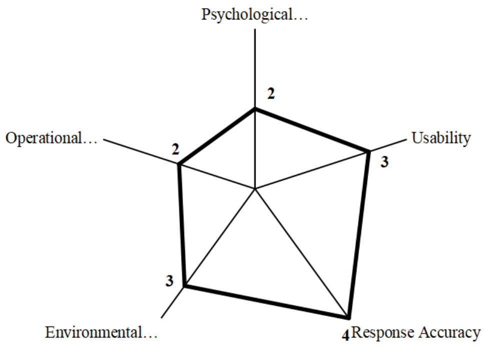

Figure 3 Evaluation of the maturity of age-friendly robotic technologies in Chinese elderly care services

3. Elderly Care Robot Technology Framework and Market Demand Modeling

This chapter builds upon the analysis presented in Chapter 2, examining key technologies and functional modules within domestic and international elderly care robot systems. It further integrates insights from the Chinese market to develop a corresponding demand model. Through an in-depth analysis of both technological and market dimensions, this chapter aims to explore the current application prospects and future potential of elderly care robotics.

3.1 Overview and Potential Analysis of Elderly Care Robot Enterprises

The elderly care robotics industry in China is experiencing accelerated growth. Currently, eight companies listed on the A-share market have entered this sector, reflecting the increasing engagement of domestic capital and enterprises. Alongside these domestic developments, leading international firms are also contributing to the advancement of the elderly care robotics market. This section provides an overview of representative enterprises, UBTECH, Ecovacs, and FANUC. Table 2 highlights their technological trajectories, market positioning, and potential to enter the elderly care sector.

Table 2 Development overview and potential analysis of representative elderly care robot enterprises

Company	UBTECH	Ecovacs	FANUC
Core Technologies and Applications	Natural language processing, deep learning, affective computing, human-robot interaction	LiDAR, SLAM-based navigation, intelligent environmental perception	Advanced automation control, precision robotic arms, sensor technologies
Target Market and Potential in Elderly Care	High-income households and smart elderly care institutions	Home care market, with potential to expand into residential elderly care and small to medium-sized institutions	Industrial robotics with potential applications in elderly care
Main Challenges	High costs and operational complexity	Product adaptation, cost control, and usability	High costs, operational complexity, and lack of market entry
Suggested Approaches	Enhance technological innovation and cost efficiency	Improve age-friendly design and diversify functionalities	Leverage automation expertise to develop elderly care solutions

Both Chinese and international companies demonstrate substantial potential in the field of elderly care robotics. UBTECH has already introduced specialized robots targeting elderly users through technologies such as affective computing and health management. Ecovacs, while primarily focused on smart home applications, possesses a strong technological foundation for future expansion into the elderly care market. FANUC, though currently centered on industrial robotics, also holds the capability to diversify into this sector. As population aging intensifies, the elderly care robotics market will present increasing opportunities for innovation. To fully realize this potential, enterprises must continue to optimize technologies, reduce costs, and address the personalized needs of elderly users.

3.2 Service Task and Robotic Function Adaptation Model

Building upon the functional task analysis presented in Section 2.2, this section develops a

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quantitative model to assess the alignment between robotic technologies and key elderly care service tasks. The objective is to evaluate how current robotic solutions match specific service needs and to identify areas requiring further optimization.

The model employs two primary evaluation dimensions: technical feasibility and deployment simplicity. Technical feasibility refers to the current maturity of robotic technologies in performing specific service tasks, considering the reliability, stability, and completeness of task execution. Deployment simplicity assesses the ease with which these technologies can be integrated into elderly care environments, accounting for factors such as cost, maintenance, user-friendliness, and adaptability to diverse service contexts. Table 3 presents the evaluation criteria for both dimensions, using a five-point scale to quantify performance levels.

Table 3 Evaluation criteria for robotic function module alignment with elderly care service tasks

Score	Technical Feasibility	Deployment Simplicity
5	Reliably and consistently performs all key tasks with high quality	Easy deployment and minimal need for modifications or training
4	Performs most key tasks with relatively stable performance	Moderate deployment adjustments; manageable training requirements
3	Performs some key tasks with certain limitations	Suitable for deployment in selected scenarios
2	Significant technical barriers remain	Highly complex deployment; frequent maintenance required
1	Currently infeasible with existing technology	Deployment largely infeasible

Based on these criteria, a comprehensive scoring assessment was conducted for the six core service tasks identified in Section 2.2, covering relevant functional modules. Table 4 presents the alignment assessment results across service tasks and corresponding robotic modules.

Table 4 Alignment assessment of robotic function module alignment with elderly care service tasks

Service Task	Corresponding Functional Module(s)	Technical Feasibility (5-point scale)	Deployment Simplicity (5-point scale)	Alignment Score (average)
Emotional companionship	Speech recognition and affective computing	5.0	4.0	4.5
	Facial expression recognition and emotional feedback	4.0	3.0	3.5
Health monitoring	Real-time physiological parameter monitoring module	4.0	4.0	4.0
	Sleep quality monitoring module	4.0	4.0	4.0
Fall detection and alert	Fall detection module and automatic alert system	4.0	3.0	3.5
Daily reminders	Schedule management and notification module	5.0	5.0	5.0
	Intelligent voice reminder system	5.0	5.0	5.0
Companionship and social support	Video call and remote interaction module	5.0	5.0	5.0
	Social content delivery module	4.0	4.0	4.0
Intelligent navigation and mobility support	Indoor autonomous navigation module	3.0	3.0	3.0
	Automatic path planning and dynamic obstacle avoidance	3.0	2.0	2.5
Rehabilitation assistance	Active rehabilitation training module	4.0	3.0	3.5
	Passive rehabilitation assistance module	3.0	3.0	3.0
Emergency response	One-touch alarm and remote linkage module	5.0	5.0	5.0
Life support (cleaning)	Environmental inspection and cleaning robot module	5.0	5.0	5.0
Life support (delivery)	Intelligent delivery robot module	4.0	4.0	4.0
Personalized learning and adaptation	User habit learning and behavior prediction module	3.0	2.0	2.5

Note: The alignment score is the arithmetic mean of the technical feasibility score and the deployment simplicity score

The results indicate that robotic solutions currently demonstrate strong alignment with tasks such as monitoring, emergency response, and daily reminders, while tasks involving rehabilitation, intelligent mobility support, and personalized learning and adaptation show lower alignment scores, highlighting opportunities for further technological advancement and optimization.

3.3 Elderly Users' Technology Acceptance Model

Building upon the functional alignment analysis in Section 3.2, this section explores the cognitive and psychological mechanisms influencing elderly users' acceptance of care robots. The acceptance

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pathway model is grounded in three key factors: perceived ease of use, perceived usefulness, and trust.

Perceived ease of use refers to the extent to which elderly users find robotic systems intuitive and easy to operate, particularly considering age-related declines in sensory and cognitive abilities. Perceived usefulness captures the degree to which users believe that robotic functions enhance their daily living, health management, and overall quality of life. Trust is a critical factor that influences users' willingness to adopt care robots, encompassing data security, system reliability, and transparency of interactions. These factors interact dynamically to shape elderly users' acceptance behaviors. As illustrated in Figure 4, perceived ease of use positively influences perceived usefulness and trust, both of which directly affect acceptance intentions. Trust also mediates the relationship between perceived usefulness and acceptance willingness.

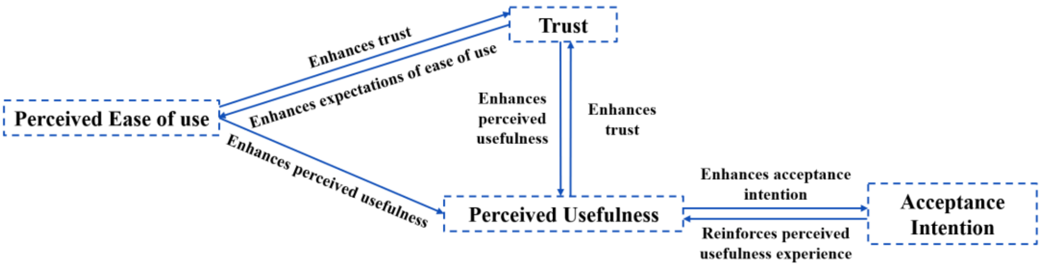

Figure 4 Technology acceptance pathway model for elderly users in care robot applications

This acceptance pathway model provides theoretical insights into elderly users' willingness to adopt care robots. In the following section, a dual-stakeholder evaluation matrix is developed to quantitatively assess the alignment between robotic functionalities, institutional objectives, and elderly user experience.

3.4 Dual-Stakeholder Demand Alignment Model

The preceding section established a technology acceptance model from the perspective of elderly users, highlighting the roles of perceived ease of use, perceived usefulness, and trust in shaping adoption intentions. However, in real-world applications, care robots serve both individual users and institutional stakeholders. Institutions, as key actors in technology deployment and service delivery, often have distinct functional priorities compared to elderly users. Effective robot deployment thus requires alignment between institutional objectives and user experience.

To systematically assess this alignment, a dual-stakeholder evaluation matrix was developed, mapping robotic functionalities against institutional goals and elderly user experience. The matrix evaluates core functions by using a 5-point scoring system. Institutional evaluation focuses on operational efficiency, safety management, and service quality, while elderly user experience emphasizes ease of use, emotional interaction, and perceived value. Table 5 presents the alignment assessment results across key service functions and functional modules.

The evaluation results indicate that basic safety-related functions, such as health monitoring, fall detection, and daily reminders, exhibit high alignment across both institutional and user perspectives. Emotional companionship functions demonstrate strong user acceptance but receive more cautious institutional evaluation due to limited direct impact on operational performance. Conversely, data-intensive modules, such as real-time physiological monitoring and personalized behavior prediction, are highly valued by institutions but raise privacy concerns among elderly users.

Based on these findings, several optimization recommendations are proposed. First, privacy protection mechanisms should be strengthened for sensitive data collection, enabling elderly users to control data access and sharing. Second, emotional interaction modules could be better integrated with institutional service frameworks to enhance organizational incentives for deployment. Third, for complex functions such as intelligent navigation and mobility support, user interfaces should be simplified to improve usability. Finally, a dynamic two-way feedback mechanism should be established, continuously collecting input from both institutional staff and elderly users to guide iterative optimization of robot design and deployment strategies.

In conclusion, the effective promotion of care robot technologies depends not only on the acceptance of individual users but also on the alignment between institutional objectives and user experience. The dual-stakeholder evaluation matrix provides a systematic framework for identifying alignment gaps and guiding future innovation in care robot applications.

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Table 5 Dual-stakeholder evaluation matrix of robotic function modules in elderly care applications

Service Task	Corresponding Functional Module	Institutional Goal Satisfaction (5-point scale)	Elderly User Experience Satisfaction (5-point scale)	Dual-Stakeholder Alignment Analysis
Emotional companionship	Speech recognition and affective computing	3	5	High user experience; moderate institutional evaluation
	Facial expression recognition and emotional feedback	3	4	Good user experience; cautious institutional deployment
Health monitoring	Real-time physiological parameter monitoring module	5	4	Highly aligned across both stakeholders
	Sleep quality monitoring module	4	4	Well aligned across both stakeholders
Fall detection and alert	Fall detection module and automatic alert system	5	4	Highly aligned across both stakeholders
Daily reminders	Schedule management and notification module	4	5	Highly aligned across both stakeholders
	Intelligent voice reminder system	5	5	Highly aligned across both stakeholders
Companionship and social support	Video call and remote interaction module	3	5	High user acceptance; limited institutional incentives
	Social content delivery module	3	4	High functional recognition
Intelligent navigation and mobility support	Indoor autonomous navigation module	4	3	Complex deployment; moderate user experience
	Automatic path planning and dynamic obstacle avoidance	3	2	Technical challenges affect alignment
Rehabilitation assistance	Active rehabilitation training module	4	3	Requires individualized customization
	Passive rehabilitation assistance module	3	2	Complex equipment; low alignment
Emergency response	One-touch alarm and remote linkage module	5	5	Simple deployment; high alignment
Life support (cleaning)	Environmental inspection and cleaning robot module	5	4	High institutional satisfaction; limited user perception
Life support (delivery)	Intelligent delivery robot module	4	4	Overall good satisfaction
Personalized learning and adaptation	User habit learning and behavior prediction module	3	2	Privacy concerns affect user experience

3.5 Scenario-Based Demand Forecasting and Technology Trend Projections

To forecast the development trajectory of China's elderly care robot market and analyze structural demand across different service scenarios, this study adopts a three-step forecasting framework: time-series modeling, structural variable interpretation, and scenario trend projection. For the overall market forecast, data were primarily sourced from Grand View Research's *China Elder Care Assistive Robots Market Size & Outlook* report, covering annual market size from 2018 to 2023. As the original dataset was not fully available, part of the data was estimated through graphical interpretation. The 2024 data point was inferred using the reported 2030 market projection, the 2023 market size, and the estimated compound annual growth rate (CAGR), forming a seven-period annual time series for modeling.

An ARIMA model was employed to project market size for 2025 to 2030. ARIMA is well-suited for scenarios with limited time series data and clear growth trends, allowing for differencing to achieve stationarity and incorporating lag terms to capture growth inertia and error correction mechanisms. Due to the initial non-stationary nature of the data, first-order differencing was applied, and ARIMA (1,1,1) was identified as the optimal model structure. ARIMA (1,1,1) model was specified as:

Table 6 ARIMA (1,1,1) model variables

Symbol	Definition
Y_t	Market size of elderly care robots in year t
ΔY_t	Annual growth of market size
$\emptyset_1$	First-order autoregressive term
θ_1	First-order moving average term
ε_t	Error term

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$$\Delta Y_t = \varnothing_1 \Delta Y_{t-1} + \theta_1 \varepsilon_{t-1} + \varepsilon_t$$

The model parameters and variables are detailed in Table 6.

The model estimation results indicate that $\emptyset_1 = 0.654$ and θ_1=-0.473. No significant autocorrelation or heteroskedasticity was observed in the residuals, confirming a good model fit suitable for mid-term forecasting.

Based on this model, a six-period rolling forecast was conducted for 2025 to 2030, projecting market growth from approximately $247 million USD in 2025 to $347 million USD in 2030, reflecting a stable linear growth trend. Figure 5 illustrates the forecasted trajectory, suggesting steady market potential under current technology diffusion and demand inertia.

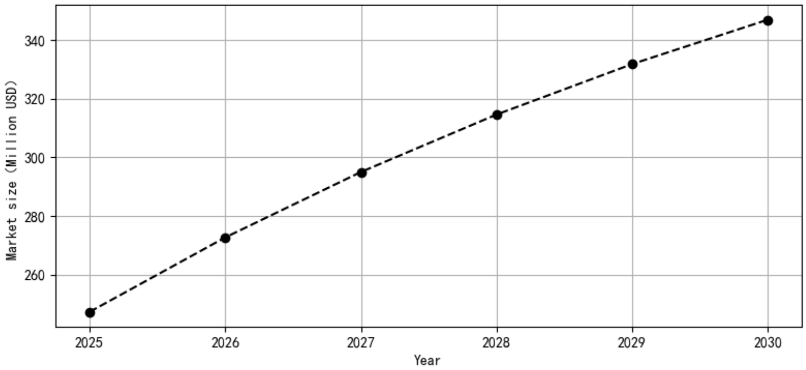

Figure 5 Forecasted market size of elderly care robots in China, 2025-2030

To enhance interpretability, the ARIMA results were compared with the CAGR-based projections from the Grand View Research report, which assumes a 15.9% CAGR and forecasts a 2030 market size of $529.3 million USD. Figure 6 compares the two forecast paths: while they align closely for 2025–2026, divergence emerges from 2027 onwards, with the ARIMA projection falling short by approximately $180 million USD by 2030. This discrepancy reflects the distinction between ARIMA's inertia-based forecast and the elasticity-driven projection that incorporates anticipated policy support, capital investment, and technological breakthroughs. The comparison offers valuable insights into possible growth boundaries under "steady-state development" and "accelerated evolution" scenarios, informing future policy decisions.

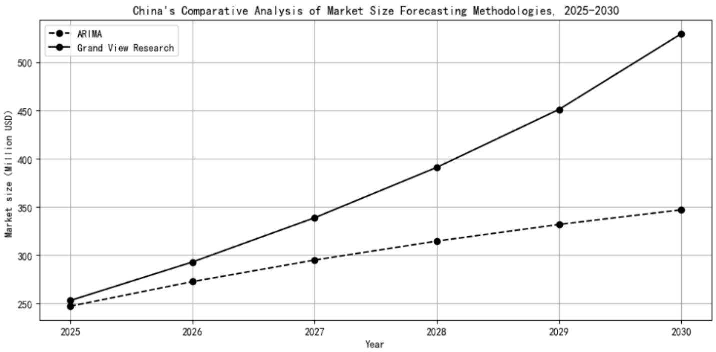

Figure 6 Comparison of ARIMA and Grand View Research Forecast Trajectories for China's Elderly Care Robot Market Size (2025-2030)

In addition to total market projections, a multivariate linear regression model was developed to explore the drivers and mechanisms influencing potential demand intensity across different regions. Using a constructed proxy indicator for potential demand as the dependent variable, explanatory variables included the number of elderly residents, per capita healthcare expenditure, and a care workforce shortage index for each provincial-level region in 2022. The linear model structure is summarized below:

$$Y_i = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \varepsilon_i$$

Table 7 defines the model variables.

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Table 7 Variable Definitions for the Multiple Regression Model

Symbol	Definition
Y_i	Penetration rate of elderly care robots in each application scenario
X_1	Elderly population (aged 65 and above)
X_2	Per capita healthcare expenditure
X_3	Degree of caregiver shortage
α_0	Baseline penetration level when all explanatory variables are at their baseline values
$\alpha_1, \alpha_2, \alpha_3$	Coefficients representing the marginal effects of the corresponding explanatory variables on robot penetration rate in each scenario
ε_i	Error term

The model was estimated using ordinary least squares (OLS). Results (see Table 8) indicate strong model performance ($R^2 = 0.859$), with all explanatory variables significant at the 1% level. The model passed the F-test ($F = 56.99$, $P < 0.001$) and residual diagnostics indicated no major autocorrelation issues (D-W = 1.628).

Table 8 Summary of Multiple Regression Results

Variable	Regression Coefficient	Standard error	t-value	p-value
Constant	-0.0954	0.0610	-1.563	0.129
Elderly population aged 65 and above	1.435e-06	3.63e-07	3.952	0.000
Per capita healthcare expenditure	9.709e-05	2.25e-05	4.320	0.000
Caregiver shortage index	0.9175	0.0880	10.421	0.000

Note: All significant levels are tested at the 1% level ($p < 0.01$)

Findings show that all three explanatory variables exert significant positive effects on potential demand. Notably, the care workforce shortage index has the largest coefficient, underscoring the strong demand for robotic solutions in regions with limited caregiving resources. Higher healthcare spending likely reflects enhanced technological integration and payment capacity, further driving demand. While the population variable shows a smaller marginal effect, its high significance highlights its structural role as a foundational demand driver. Figure 7 presents the model fit versus actual proxy values, while Figure 8 displays the residual distribution, confirming model robustness.

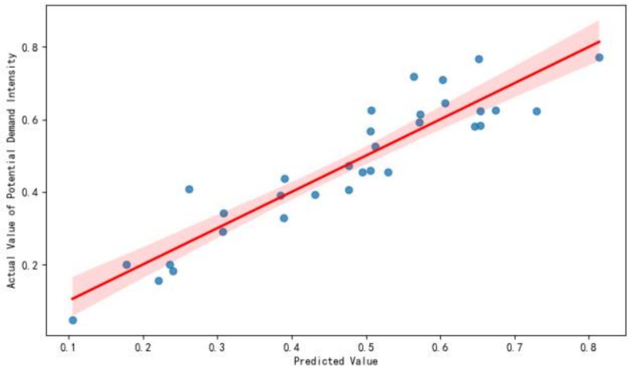

Figure 7 Comparison between Predicted and Actual Values

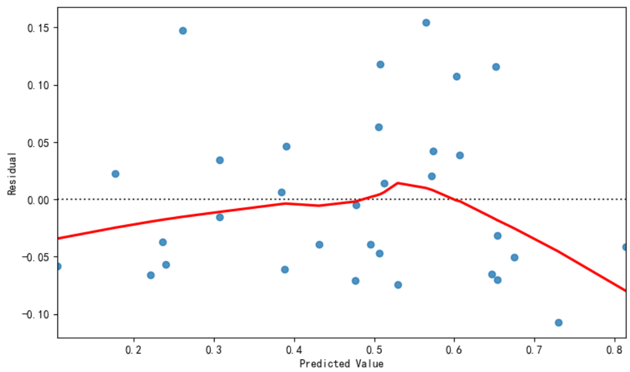

Figure 8 Model Residual Plot

Building on current policy priorities, technological maturity, and market accessibility, the

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development trajectory of care robots across different service scenarios follows a phased evolution pattern: care services first → healthcare integration → emotional companionship breakthrough. From a policy perspective, key documents such as the Smart Health and Elderly Care Development Action Plan (2017-2020) and the 14th Five-Year Plan for Aging Services emphasize enhancing basic services like community care and life support, fostering early deployment of care-focused robots. In terms of technological maturity, care-focused robots rely on path planning, environmental sensing, and basic interaction modules that are cost-effective and suitable for rapid industrialization. In contrast, health-monitoring robots require integration with medical information systems and wearable devices, and their deployment is constrained by regional healthcare system disparities and data policy fragmentation, making them suitable for phased deployment in mature regions. Emotional companionship robots, which depend heavily on natural language processing, semantic understanding, and emotion recognition, remain in the validation and scenario development stage. They are expected to achieve broader adoption around 2030 as multimodal AI technologies advance. These three scenario pathways constitute the functional evolution roadmap for elderly care robot applications, providing a strategic reference for future product development, policy orientation, and resource allocation.

4. Policy Recommendations and Industrialization Strategy for Elderly Care Robots

The deployment of elderly care robots in real-world settings presents challenges that extend beyond technical maturity. Institutional readiness, workforce structure, service adaptation, and financial viability critically shape adoption outcomes. In China, although technological advancements in elderly care robotics are progressing, large-scale industrialization remains constrained by high deployment costs, slow market responsiveness, and the misalignment between evolving service models and existing occupational structures. To address these systemic barriers, this chapter proposes actionable policy recommendations and analyzes the financial capability of key industry players to support sustainable industrialization.

4.1 Policy Recommendations

Public service infrastructure must be strengthened to accelerate adoption. It is recommended to establish Elderly Care Robot Public Service Stations in urban communities and regions with dense elderly service demand. These stations, funded through government procurement and operated by technology enterprises, would provide robots as on-demand functional services rather than as capital-intensive assets. A shared-services model leveraging unified scheduling platforms would enable dynamic allocation and standardized task management. This approach would lower financial barriers for small-scale care institutions and low-income elderly users, while also generating valuable usage data to support continuous algorithm optimization and performance improvement.

Procurement mechanisms should prioritize long-term performance and market incentives. A performance-driven and credit-based procurement system is proposed to replace current models that emphasize contract fulfillment over service quality. Under this system, robot enterprises would undergo annual evaluations based on product failure rates, user satisfaction, algorithm update frequency, and service responsiveness. Evaluation outcomes would directly influence procurement quotas and participation in future pilot programs. This feedback loop would incentivize sustained performance improvements and foster a quality-driven market environment.

Workforce transition support is essential for fostering effective human-robot collaboration. Many frontline caregivers face skill mismatches, role ambiguity, and occupational anxiety regarding robot-assisted care, which impedes service integration. Government-funded transitional subsidies and retraining programs should be provided to care institutions adopting robots. This support would enable caregivers to shift from repetitive physical tasks to more interactive, emotional, and judgment-based roles. Establishing a human-machine collaborative service structure with clearly defined roles and responsibilities will enhance service quality and support workforce development.

Ultimately, the successful deployment of elderly care robots depends not only on technological advancements but also on systemic integration into care service frameworks. Policymakers should embed robots within institutional structures and feedback mechanisms, rather than relying solely on fiscal subsidies to scale pilot programs. Public service platforms, performance-based procurement, and workforce transition initiatives collectively form a synergistic pathway to transition from technology availability to practical integration. As demographic aging accelerates, establishing a stable institutional foundation is critical to achieving this transformation.

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4.2 Financial Capability and Industrialization Readiness

Financial capability is a critical determinant of whether robot enterprises can transition from technological innovation to scalable industrialization. DuPont analysis reveals distinct capital return structures among UBTECH Robotics, ECOVACS, and FANUC (Table 9). UBTECH, while still operating at a deep loss, demonstrated improving margins and asset turnover, reflecting early-stage recovery driven by expanding revenues and cost control. ECOVACS maintained a stable ROE, leveraging higher-margin products and moderate leverage expansion to offset declining asset turnover amid increased R&D investment. FANUC exhibited exceptional stability, with ROE rising to 8.70% solely through profit margin growth, underpinned by consistent asset efficiency and low financial risk.

Table 9 Comparative DuPont Analysis of Three Enterprises (2023-2024)

Company	Year	Return on Equity (ROE)	Net Profit Margin	Total Asset Turnover (times)	Equity Multiplier
UBTECH	2023	-60.54%	-119.79%	0.22	2.28
	2024	-51.61%	-88.86%	0.25	2.28
ECOVACS	2023	10.31%	4.36%	1.16	2.04
	2024	10.87%	4.73%	1.10	2.09
FANUC	2023	7.88%	17.04%	0.41	1.12
	2024	8.70%	18.99%	0.41	1.11

R&D investment trends (Figure 9) further underscore strategic differences. UBTECH prioritizes aggressive R&D despite financial constraints, aiming to drive future growth. ECOVACS pursues targeted R&D to sustain product differentiation. FANUC maintains disciplined and steady R&D spending aligned with its strong profitability and operational resilience.

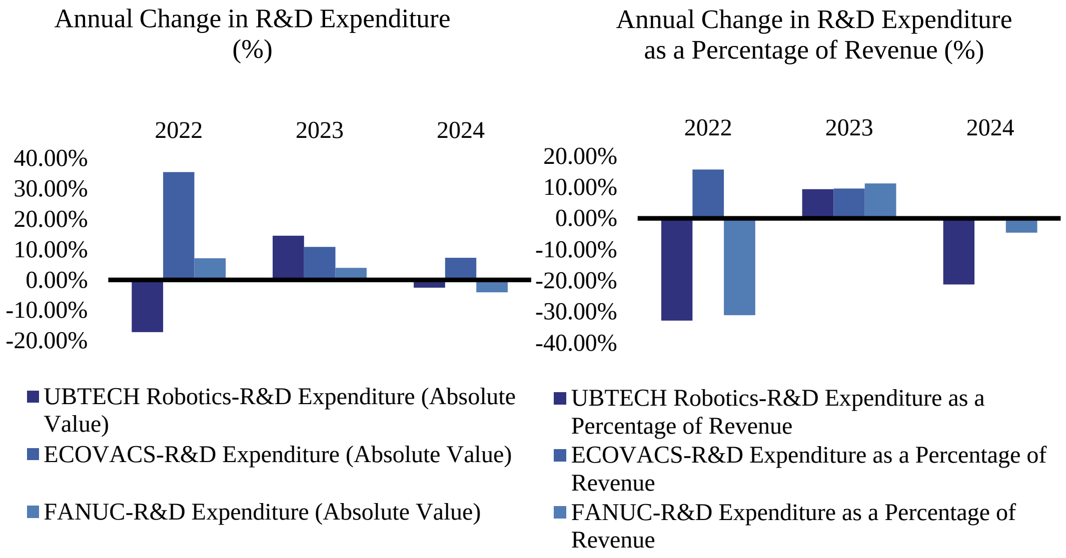

Figure 9 Annual Change in R&D Expenditure and R&D Intensity of Major Enterprises (2022–2024)

Overall, these differentiated financial profiles signal varying capacities for industrialization. UBTECH remains in a resource-intensive development phase, with scaling potential contingent on continued financial stabilization. ECOVACS balances financial returns with innovation investment to support gradual market expansion. FANUC, with robust financial strength and disciplined R&D, is well-positioned to pursue steady, low-risk industrialization. Aligning financial capability with strategic innovation will be pivotal for sustained success in the evolving elderly care robotics sector.

5. Conclusion

This study systematically analyzed the penetration mechanisms and evolutionary pathways of elderly care robots within complex service scenarios. The findings underscore that China's elderly care robot market is entering a phase of sustained expansion, driven by aging demographics, rising healthcare expenditures, and persistent caregiver shortages. Time-series modeling and multivariate regression highlighted the critical role of workforce gaps in shaping demand growth and regional adoption patterns.

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Comparative enterprise analysis revealed three distinct strategic trajectories: UBTECH exemplifies high-intensity R&D and platform integration; ECOVACS balances product innovation with cost control for broader market penetration; FANUC demonstrates a traditional manufacturing model enhanced through advanced automation. These differentiated financial profiles will fundamentally shape each firm's capacity to scale and sustain innovation in the elderly care sector. The dual-stakeholder evaluation framework further emphasized that effective deployment hinges on aligning institutional objectives with elderly user experiences. High alignment was observed for basic safety and monitoring functions, whereas rehabilitation and adaptive learning modules require further optimization. Emotional companionship remains highly valued by users but is cautiously adopted by institutions. To bridge persistent gaps, this study recommends redesigning service delivery models through the establishment of regional service hubs, performance-based procurement, and integrated human-robot collaborative roles. Future research should leverage higher-quality micro-level data to incorporate variables such as user acceptance dynamics, institutional deployment capacity, and regional resilience. Developing dynamic adaptation models and cross-level resource allocation strategies will be critical to advancing the systemic integration of elderly care robotics.

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