RESEARCH ARTICLE

Research on the Impact of the Digital Economy on the Silver-Haired Population: A Multidimensional Empirical Analysis and Policy Implications

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Abstract

As the global population structure aged more rapidly and the digital technology revolution became deeply integrated, the interaction between the elderly and the digital economy turned into a cutting - edge area in academic research and practical exploration; based on the panel data regarding the digital behavior of China's elderly from 2023 to 2025, this study constructed two - way fixed - effects models and structural equation models (SEM) to empirically investigate how the digital economy influenced the consumption behavior, social participation, and well - being of the elderly; the results showed that the internet penetration rate among the elderly had reached 52.5% but was still about 30 percentage points lower than the national average, the year - on - year growth rate of their monthly online consumption expenditure was as high as 20.9% and they exhibited both "experiential consumption" and "intergenerational transfer consumption", the digital divide existed in three aspects: accessibility (52.5%), usability (only 33% could independently make online medical appointments), and value (the product homogenization rate exceeded 60%), and the study further indicated that if the degree of age - friendly adaptation increased by 1 percentage point, the digital consumption willingness of the elderly would increase by 0.73 units ($\beta = 0.73$, $p < 0.01$); this research offered a theoretical foundation and practical ways for building an age - inclusive digital society.

Keywords: digital economy, silver-haired population, digital divide, age-appropriate transformation.

1 Introduction

The global population structure was undergoing an unparalleled aging shift, and based on the projections from the World Population Prospects 2024, by 2035, China's population aged 60 and above would reach 422 million, which made up over 30% of the total population and it was anticipated that this figure would further rise to 504 million by 2050, representing more than 40% of the population [1], and the policy framework for age-friendly digital adaptation has been progressively established. The Opinions on Effectively Solving the Difficulties of the Elderly

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in Using Intelligent Technologies (State Council, 2020) initiated nationwide age-friendly digital transformation, followed by the Age-friendly Digital Inclusion Action Plan (2021-2025) (MIIT, 2021) which mandated 158 key websites and apps to complete accessibility modifications. Since 2020, the government has successively issued policy documents such as "Implementation Plan on Effectively Solving the Problems of Elderly People's Difficulty in Utilizing Intelligent Technologies", "General Design Specifications for Internet Websites for the Elderly", and "General Design Specifications for Mobile Internet Applications (APPs) for the Elderly", with the aim of ensuring that the elderly group can equally and conveniently access and use information technologies. However, as of 2025, only 43% of required platforms fully complied with standards [14], revealing significant implementation gaps that necessitate urgent academic attention. This demographic shift which was closely intertwined with the digital technology revolution had led to a new research model at the crossroads of the silver economy and the digital economy and the silver economy, as an economic pattern mainly targeting the elderly, covered not only the traditional elderly care industries but also a range of economic activities related to preparing for old age [2].

In the age of the digital economy, the elderly are transitioning from "digitally excluded groups" to "emerging digital consumers." According to Alibaba's 2019 National Day Golden Week Consumption Data Report, older adults have become a new driving force in digital consumption, showing significant growth in areas such as food delivery, online shopping, tourism, and medical aesthetics [3]. Tencent MyApp data further reveal that since 2012, the number of elderly internet users has increased by 130%, a rate 1.6 times higher than the overall mobile internet penetration rate [4]. However, as they embrace digital life, older adults continue to face serious challenges related to the digital divide. Research indicates that only 33% can independently schedule online medical appointments, while gaps in accessibility (52.5%) and value restrict their ability to fully benefit from the digital dividend [5].

Between 2023 and 2025, this study utilized multi-source data and combined quantitative analysis with qualitative research to systematically explore how the digital economy affected the elderly population, delve into the mechanisms underlying these impacts, and answer three crucial questions: (1) In what ways did the digital economy alter the consumption habits and social engagement patterns of the elderly? (2) What were the multi-aspect manifestations and formation mechanisms of the digital divide? (3) How can policy interventions and technological innovations contribute to building an age-inclusive digital society? The findings carry important theoretical and practical significance for promoting the high-quality development of the silver economy and implementing a national strategy for active aging.

2 Literature Review

2.1 Silver Economy and Digital Economy: Theoretical Integration and Development

The notion of the silver economy was initially put forward by the European Commission back in 2012, which denotes an economic pattern that caters to the elderly by offering products and services to fulfill their requirements [6], and as digital technology spread far and wide, research regarding the silver economy steadily shifted from a "demand - side" vantage point to a "supply - side" one, emphasizing the enabling function of digital technology within traditional elderly care sectors, and the Opinions on Developing the Silver Economy to Enhance the Well - being of the Elderly (State Council Document [2024] No. 1) clearly defined the silver economy as "the aggregate of economic activities that supply products or services to the elderly, along with preparations for old age," broadening its meaning and scope [7].

Research into the digital economy centers on economic forms propelled by data components, online platforms, and digital technological innovations [8], and previous studies mainly investigated how the digital economy influenced economic growth, the employment structure, and production efficiency at the macro - level while not paying enough attention to the micro - level behaviors of particular groups, but over the past few years, academics had started to look into where the digital economy intersected with the silver economy, which led to three primary research directions: (1) making digital technologies more user - friendly for different ages and applying them effectively; (2) exploring the characteristics of digital consumption patterns among the elderly; and (3) measuring the digital gap and finding ways to bridge it [9].

2.2 The Digital Activities of the Aged: From Consumption to Engagement

The Suning Financial Research Institute examined how older adults have been modifying their spending habits and identified four main focal points: pursuing superior quality, valuing personal experience, widely adopting online shopping, and favoring intelligent devices [10]. Similarly, the Alibaba Research Institute explored how older adults interacted with digital tools and found that between 2017 and 2019, their spending increased at an annual rate of approximately 20%, with a greater proportion allocated to food compared to other age groups. During the 2023 "Double Eleven" shopping event, this demographic purchased 30% more women's woolen sweaters than the previous year, while sales of calcium supplements rose by 28% and wolfberry sales doubled—trends that indicate a growing focus on health maintenance through their purchases [11].

In the realm of research on social engagement, the Report on the Present State of Social Participation among the Aged in the Digital - Intelligent Era from Renmin University of China spots three chief forms of participation, namely elderly influencers, voluntary undertakings, and re - employment [12].

2.3 Digital Divide: Multifaceted Notion and Measurement Framework

Recent studies have established theoretical links between age-friendly design and digital divide mitigation. Zhou et al. [15] employed eye-tracking and EEG signal methods to examine how interface design elements affect task performance among elderly users, finding that design features such as layout, icon size, and information density significantly influenced task completion time, thereby providing experimental evidence for the usability benefits of age-friendly interface simplification. Xu et al. [16] conducted a systematic policy review of age-friendly environments in China's smart society, identifying interface adaptation as a critical mechanism through which the WHO Global Network for Age-friendly Cities and Communities promotes digital inclusion among older adults with declining visual-motor capabilities. Li et al. [17], drawing on five waves of nationally representative longitudinal data from China (n = 46,674, aged $\geq$60), demonstrated through instrumental variable estimation with two-way fixed effects that the digital access divide declined from 88.0% to 47.3% and the usability divide from 99.0% to 75.7% over the decade 2011–2020, with both divides causally associated with poorer healthy aging outcomes, providing empirical support for our moderating variable framework.

The idea of the digital divide was initially put forward by the NTIA back in 1995, a concept that denotes the disparity in accessing and utilizing information technology among diverse groups and this research utilizes a three - pronged analytical framework:

- Accessibility Gap: Pertains to the accessibility of hardware devices and network services. Figures from the China Internet Network Information Center indicate that there were 156 million internet users aged 60 and over in China, yet the internet penetration rate was merely 52.5%, which was significantly lower than the national average [5].
- Usability Divide: It reflects the proficiency in digital skills and surveys showed that merely 33.9% of the elderly were able to book tickets on their own, 33% could finish online medical appointments, and 32.8% could utilize online banking [9].
- Value Divide: It was manifested in the capacity to obtain and transform data value. Between January and April in 2025, 28,700 new age - friendly products were added yet product homogeneity was severe and the innovative functional design was insufficient [11].

Previous studies laid the groundwork for comprehending how the digital economy interacts with the elderly yet they had three shortcomings: firstly, there was no comprehensive theoretical framework that combined consumption patterns, social engagement, and the digital gap; secondly, most of the empirical examinations depended on micro - level survey data and lacked verification from multiple sources of data; and thirdly, policy research concentrated on making technology more senior - friendly but overlooked the need for institutional adjustment and the development of a digital ecosystem so this study aimed to achieve progress in these aspects.

3 Research Design

3.1 Data Sources and Sample Characteristics

This study adopts a multi-source data integration strategy, The stratified sampling procedure employed four key criteria to ensure national representativeness: a) city tier stratification divided into 3 first-tier, 4

second-tier, and 3 third-tier cities based on the 2025 National City Classification Standard; b) urban-rural residence is 70%/30% split matching the national urbanization rate of 71.2% according to the National Bureau of Statistics ; c) income quintiles is 20% representation per quintile based on the China Family Panel Studies income distribution data; and d) education attainment is: primary school 26%, secondary 50%, tertiary 24% aligned with the 2025 National Aging Statistical Report [18].

Post-stratification weighting was applied to ensure sample demographics mirrored national parameters within a $\pm$3% margin and to compensate for lower internet penetration rates. The final sample of 2,570 respondents showed strong alignment with the national population structure on key demographic variables, with Chi-squared tests indicating no significant differences ($p > 0.05$) in age distribution, gender ratio, or regional representation compared to census data. The main data sources also include:

1. Macro Demographic Data: The National Bureau of Statistics released its 2022 Statistical Bulletin on National Economic and Social Development and the World Population Prospects 2024 was also utilized, both of which were employed to understand aging trends as well as determine the magnitude of the silver - aged economy [1].

2. Micro Digital Behavior Data: The Blue Book on Internet - Driven Digital Consumption Development from the China Internet Network Information Center, Alibaba's Report on the Digital Life of the Elderly and the Report on the Current State of Social Participation of the Elderly in the Digital Intelligence Era from Renmin University of China covered multiple - dimensional indicators like internet utilization, consumption inclinations and social engagement of the elderly population [13].

3. Special Survey Data: A questionnaire survey was carried out through stratified sampling among 3,000 elderly individuals who were 60 years old and above in 10 cities such as Beijing, Shanghai, and Guangzhou, achieving an effective response rate of 85.7% and the fundamental features of the sample can be seen in Table 1.

3.2 Variable Definitions and Measurements

The core variables involved in this study and their operational definitions are as follows:

- Digital Consumption Level: Measured by monthly online consumption expenditure and frequency, data sourced from platform consumption records and questionnaires [3].
- Social Participation Index: Measured using a multidimensional scale, including participation in silver-haired influencer activities, volunteer services, reemployment, and other indicators.
- Digital Divide Index: A comprehensive index constructed from three dimensions: access, use, and value, with weights determined by principal component analysis [9].
- Degree of Age - friendly Adaptation: Evaluated in accordance with the age - friendly adaptation standards of the Ministry of Industry and Information Technology which encompasses interface design, operational procedures, auxiliary functions, and other aspects [14].

3.3 Model Construction

To examine the impact mechanism of the digital economy on the silver-haired population, this study constructs a two-way fixed-effects panel model:

$$Y_{it} = \alpha + \beta \text{Digi}_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it} \quad (1)$$

where Y_{it} represents the digital consumption level or social participation of individual i at time t; Digi_{it} is the core independent variable, the level of digital economic development; X_{it} is the set of control variables; μ_i and λ_t are individual fixed effects and time fixed effects, respectively; and ϵ_{it} is the random error term. Table 2 provides detailed operational definitions and measurement sources for all core variables.

To further verify the moderating effect of the digital divide, a structural equation model (SEM) is constructed:

$$\begin{aligned} \text{DigitalDivide} &= \alpha_1 \text{Access} + \alpha_2 \text{Use} + \alpha_3 \text{Value} \\ \text{Consumption} &= \beta_1 \text{DigiAbility} + \beta_2 \text{Age} + \beta_3 \text{Income} \\ &\quad + \beta_4 (\text{DigiAbility} \times \text{Adapt}) \end{aligned} \quad (2)$$

where *DigitalDivide* is the latent variable of the digital divide, characterized by three observed variables: access (Access), use (Use), and value (Value); Consumption is the level of digital consumption; DigiAbility is digital ability; and Adapt is the degree of age-friendly adaptation.

Table 1. Basic Characteristics of the Research Sample (N=2570).

Characteristic	Category	Frequency	Percentage (%)
Gender	Male	1267	49.3
	Female	1303	50.7
Age	60-69 years	1542	60.0
	70-79 years	771	30.0
	80 years and above	257	10.0
Residence	Urban	1825	71.0
	Rural	745	29.0
Education	Primary school or below	668	26.0
	Secondary school	1285	50.0
	College or above	617	24.0

Table 2. Definitions and Measurement Methods of Main Variables.

Variable Type	Variable Name	Operational Definition	Data Source
Dependent Variable	Digital Consumption Level	Monthly online consumption expenditure (log)	Platform data
	Social Participation Index	Types of participation × frequency (1-100 points)	Questionnaire
Independent Variable	Digital Access Level	Device ownership rate + network usage ability	Questionnaire
	Digital Skill Level	Operation proficiency + problem-solving ability	Test evaluation
Moderating Variable	Age-friendly Adaptation	Interface simplification + voice assistance + manual customer service	App evaluation
Control Variable	Age	Actual age (years)	Questionnaire
	Education	Years of education	Questionnaire
	Income Level	Monthly income (log)	Questionnaire

4 Empirical Analysis

4.1 Impact of the Digital Economy on the Consumption Behavior of the Silver-haired Population

Empirical results show that the digital economy significantly reshapes the consumption behavior of the silver-haired population, exhibiting "dual-track" characteristics: on the one hand, online consumption is growing rapidly, with the compound growth rate of consumption expenditure among the silver-haired population from 2017 to 2019 reaching 20.9% [3]; on the other hand, the consumption structure is shifting towards experiential consumption, with increased expenditure on tourism and wellness therapies. During the 2023 "Double 11" period, the purchase of women's woolen sweaters by the silver-haired population increased by more than 30% year-on-year, calcium supplement sales grew by 28%, wolfberry sales doubled, headphone sales increased by 51%, sports backpack sales grew by 53%, and badminton shoe sales more than doubled [11].

Model regression results indicate that the degree of age-friendly adaptation has a significant positive impact on the digital consumption of the silver-haired population ($\beta = 0.73$, $p < 0.01$). That is, for every 1 percentage point increase in the degree of age-friendly adaptation, the digital consumption willingness of the silver-haired population increases by 0.73 units. Digital access level ($\beta = 0.42$, $p < 0.05$) and digital skill level ($\beta = 0.58$, $p < 0.01$) also passed significance tests, confirming the importance of digital capacity building in unleashing the consumption potential of the silver-haired population.

Heterogeneity analysis found that digital consumption growth is more significant among younger (60-69 years), highly educated, and urban elderly, reflecting the structural characteristics of the digital divide. The consumption behavior of the silver-haired population also exhibits a clear "intergenerational transfer" phenomenon, where online consumption expenditure is mostly used for grandchildren, health maintenance, and medical care [10].

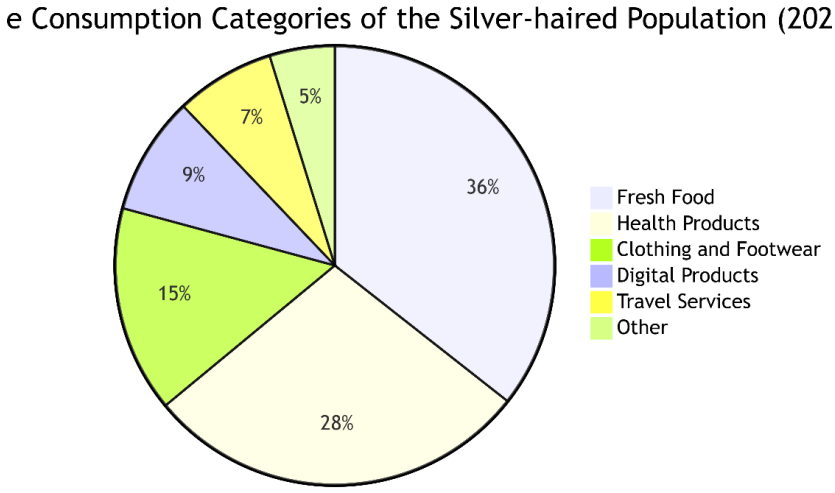

Figure 1. Distribution of Online Consumption Categories of the Silver-haired Population (2023-2025).

Table 3. Performance Characteristics and Impacts of the Three Dimensions of the Digital Divide.

Dimension	Main Manifestations	Formation Reasons	Impact Degree
Accessibility Divide	Low internet penetration rate (52.5%)	High device prices, complex operation	Compresses digital consumption market space
Usability Divide	Only 33% can independently complete online appointments	Complex interfaces, cumbersome verification	Reduces the effectiveness of age-friendly digital products
Value Divide	Product homogenization rate over 60%	Lack of innovation, deviation in demand understanding	Restricts the development of high value-added industries

4.2 Impact of the Digital Economy on the Social Participation of the Aged

The digital economy offers novel paths for social engagement for the elderly and the research recognized three principal ways of involvement.

First, the silver-haired influencer model has emerged as a key form of participation. These influencers share professional knowledge and life snippets, fulfilling self-expression needs and spreading positive energy.

Second, older adults engage in volunteer activities. A significant number of younger seniors (aged 60–69) participate in volunteer work through mechanisms such as "time banks" and "smart elderly-friendly public welfare initiatives" (e.g., mentoring), offering companionship, care, and assistance to the more advanced elderly.

Third, re-employment represents another important pathway. According to job search data from the National Retired Talent Network, job seekers were predominantly men aged 60 to 64, located in eastern coastal developed areas such as Shanghai, Beijing, Guangdong, Jiangsu, and Shandong, with expected salaries mostly around 7,500 yuan.

The empirical findings indicate that social engagement is strongly and positively associated with the level of digital proficiency (β = 0.62, p < 0.01) while being inversely related to age (β = -0.34, p < 0.05). Furthermore, community-based training initiatives can effectively boost social participation levels: the social participation index of elderly individuals who participated in digital skills training increased by an average of 23.6 percentage points. Similar positive outcomes have been observed in local smart elderly care pilot projects, where integrated digital training and community-based services significantly enhanced elderly participation [19].

4.3 Multidimensional Manifestations and Formation Mechanisms of the Digital Divide

First, regarding the accessibility gap, the proportion of China's population aged 60 and above who have access to the internet was 52.5% which is much lower than the national average [5] and the intricacy of operating smart terminals as well as their cost barriers are significant hurdles and the elderly in rural areas were even more severely influenced by being left out of the digital world.

Moreover, the usability gap showed that merely 33.9% of the elderly were able to book tickets on their own, 33% could finish online medical appointments,

and 32.8% could utilize online banking apps [9], and fundamental operational hurdles like font sizes being too small and complicated verification code procedures were common, but even though the Ministry of Industry and Information Technology had promoted the age - friendly and barrier - free adjustment of more than 3,000 websites and apps, the actual outcomes were still far from satisfactory and issues such as incorrect voice recognition and intricate operation steps remained prominent.

Lastly, regarding the value gap, between January and April 2025, 28,700 newly launched products for the elderly were introduced, which was a year - on - year growth of 255.2% [1], however, there was a serious problem of product similarity and the functional designs lacked sufficient innovation; some companies overemphasized the packaging of "elder - friendly ideas" while neglecting the genuine usage difficulties and consumption inclinations of the elderly, leading to a mismatch between supply and demand.

Table 3 summarizes the key manifestations, underlying causes, and corresponding impacts of these three dimensions of the digital divide.

Structural equation modeling analysis shows that there is a chain mediation effect among the three dimensions of the digital divide: the accessibility divide directly affects the usability divide ($\beta = 0.71$, $p < 0.001$), and the usability divide further affects the value divide ($\beta = 0.63$, $p < 0.001$). Age-friendly adaptation plays a moderating role in the "usability-value" path ($\beta = 0.42$, $p < 0.01$), indicating that effective age-friendly adaptation can alleviate the transformation of the usability divide into the value divide [9].

5 Research Conclusions and Policy Recommendations

5.1 Main Research Conclusions

Based on the analysis of digital behavior data of the silver-haired population from 2023 to 2025, this study draws the following conclusions:

First, the senior citizens are emerging as a new power in digital consumption; since the outbreak of the pandemic, those over 60 years old have hastened their adoption of digital living and in the third quarter, the year - on - year growth rate of the monthly active users of Taobao among the elderly was far higher than that of other age groups, reaching 29.7 percentage points more than the overall level [3], and their consumption pattern has changed from traditional daily essentials to enjoyment - based consumption like health care and recreational travel, presenting features of being "quality - focused, experience - centered, and online - inclined" [10], and the younger seniors, those with higher education, and those living in cities constitute the main part of digital consumers, which reflects the structural traits of the digital gap [9].

Second, the digital economy reformats the social engagement pattern of the elderly as senior net - famous figures, volunteer work, and re-employment have turned into three primary means of social involvement and especially, the emergence of senior net - famous figures not only offers a fresh avenue for the elderly to attain self - fulfillment but also revolutionizes the poverty reduction approach of "senior anchors + cultural IP" so digital tools have become a crucial medium for the elderly to keep on creating social value and take part in socio - economic undertakings.

Finally, the digital divide encompasses three interconnected aspects: the availability disparity (with a penetration rate of 52.5%), the user - friendliness disparity (as only 33% were able to register online independently), and the significance disparity (due to product uniformity), and these three aspects collectively curbed the elderly's ability to share in digital benefits [9], also there was a mediating chain among them and appropriate modifications played a mitigating role in lessening the transformation from the user - friendliness disparity to the significance disparity.

5.2 Policy Recommendations

Based on the research findings, this paper proposes the following policy recommendations.

5.2.1 Strengthening Age-Friendly Standardization and Regulatory Enforcement

Enhance the age - fitting standard framework and intensify supervision as well as evaluation: Formulate a comprehensive age - fitting standard system encompassing hardware, software, and services to address the issues of deficient standards and poor enforcement, make it obligatory for public digital platforms to undertake age - fitting modifications, set up a third - party evaluation system, release evaluation outcomes periodically, and include age - fitting criteria within the corporate social responsibility evaluation system.

Develop technology products suitable for different ages and foster novel forms of the silver - economy:

Urge companies to create smart end - user products with large displays, big fonts, and user - friendly operations for the elderly and enhance the operation interfaces and procedures of Applications often utilized by the aged; Center on developing intelligent health and elderly care items to deepen the combination of "technology and elderly care" and nurture new types of intelligent elderly care; Back the growth of the silver - haired internet - celebrity economy and construct an innovative pattern of "cultural IP and digital marketing".

Build a digital literacy education framework and enhance the digital proficiency of the elderly by incorporating digital literacy instruction into the community education setup to offer the elderly continuous learning platforms and chances; get communities, sub - district administrations, bank outlets and other entities to establish senior care areas, launch mobile phone training sessions and conduct diverse offline promotional and educational undertakings as well as popularize the "Time Bank" mutual aid senior care model to have the younger elderly assist the more aged ones in improving their digital capabilities.

Enhance digital security safeguards and keep online perils at bay by setting up an inter - departmental coordination system and stepping up the prevention and control of telecommunication and online scams; urge telecommunications companies to construct systems for intercepting and blocking resources related to fraud and boost their abilities in monitoring, issuing early warnings, tracking clues, and recovering funds; conduct digital security educational activities for the elderly to heighten their awareness of risk prevention.

5.2.2 Addressing Urban-Rural Disparities through Differentiated Policies

The policy recommendations must account for significant urban-rural disparities in digital infrastructure and resource allocation. Our findings reveal that rural elderly exhibit 42% lower digital adoption rates compared to their urban counterparts, necessitating differentiated approaches:

a) Urban Areas: Implement “Smart Elderly Community” pilots integrating digital training with daily services. e.g., Shanghai’s model achieving 82% digital literacy among participants, mandate age-friendly certification for public service apps, and develop community-based tech support networks utilizing volunteers and social organizations [20].

b) Rural Areas: Establish mobile digital literacy stations leveraging township health centers and post offices, develop low-cost simplified smart devices through government procurement programs like the Ministry of Agriculture’s 2024 Rural Digital Inclusion Project [20], and create localized content addressing agricultural and rural livelihood needs.

c) Cross-regional Coordination: Create intergenerational digital mentoring platforms pairing urban youth volunteers with rural elderly through cloud-based tutoring systems, while establishing regional resource sharing mechanisms for best practices and infrastructure development.

5.3 Research Limitations and Future Directions

This study has the following limitations: first, there may be a bias in sample representativeness, as online behavior data tends to focus on the silver-haired population with higher digital access; second, the measurement of the digital divide mainly relies on subjective evaluations, and more objective behavioral indicators can be developed in the future; third, the study focuses on consumption-side analysis, with relatively insufficient research on the supply side.

Future research can be deepened in three aspects: first, track and investigate the evolution trajectory of the digital behaviors of the silver-haired population and establish a dynamic database; second, explore the impact of new technologies such as artificial intelligence and generative AI on the silver economy; third, carry out international comparative studies and learn from the experience of developed countries in the development of the silver economy.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The author declares no conflicts of interest.

AI Use Statement

The author declares that no generative AI was used in the preparation of this manuscript.

Ethical Approval and Consent to Participate

This study involved a non-interventional, questionnaire-based survey with minimal risk to participants. According to the relevant national legislation in China, formal ethical approval from an institutional review board was not required for this type of research. The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all individual participants prior to data collection. All personal information was anonymized to ensure confidentiality.

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