Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 10, No. 9, 79-97
2026
Publisher: Learning Gate
DOI: 10.55214/2576-8484.v10i9.13551

Research on the impact of the silver economy and new productivity on consumption upgrading

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Abstract: As population aging intensifies, the silver economy has emerged as a core driver of consumption upgrading in China. It is an important pathway for promoting the upgrading of the consumption structure and achieving high-quality economic development. This research adopts a dynamic structural equation model, drawing on panel data from 31 provincial-level administrative regions spanning 2010 to 2023, to analyze how the silver economy and new-quality productive forces affect consumption upgrading and the underlying mechanisms. The findings reveal that the silver economy significantly promotes technological innovation and the transformation of the consumption structure, thereby driving sustainable consumption development. Technological innovation assumes a critical mediating function between the silver economy and new-quality productivity. Economic growth acts as a vital moderating factor in the relationship between technological innovation and consumption upgrading. This model reveals the industrial transformation path in the background of an aging population and provides a theoretical decision-making framework for formulating differentiated regional consumption policies.

Keywords: *Consumption upgrading, Economic growth, Industrial innovation, New productive, Silver economy, Technological innovation.*

1. Introduction

China's population structure is undergoing significant changes that are reshaping the internal logic of economic development. According to the National Bureau of Statistics, the population aged 60 and above reached 310 million by the end of 2024. Experts project that by 2025, the market size of China's silver economy will exceed 5 trillion yuan, with a consumer market potential of over 13.9 trillion yuan. Against the backdrop of deep integration between the digital and real economies, new-quality productive forces are profoundly transforming industrial development logic. Their core characteristics- high technology, high efficiency, and high quality- closely align with the silver economy's pursuit of high-quality development [1].

The new generation of elderly individuals, primarily those born in the 1960s, is driving market demand toward quality and experience. Over 40% of the elderly population is willing to pay higher fees for premium services, and more than half actively use smart wearable devices. However, structural contradictions between supply and demand remain prominent in the silver economy. While elderly consumption demand is shifting from "survival-oriented" to "development-oriented" and "enjoyment-oriented" [2], the supply side has yet to fully adapt to these changes. Technological innovation serves as a critical bridge connecting the silver economy and new-quality productive forces, yet its transmission mechanisms and effects on consumption upgrading require further examination [3, 4].

This study systematically examines the interactive relationship among the silver economy, new-quality productive forces, and consumption upgrading. Specifically, it investigates three core questions: First, how do the silver economy and new-quality productive forces directly impact consumption

History: Received: 5 June 2026; Revised: 7 August 2026; Accepted: 12 August 2026; Published: 4 September 2026
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upgrading? Second, does technological innovation serve as a mediating mechanism in these relationships? Third, what moderating role does economic growth play in these transmission pathways? By addressing these questions, this research aims to construct a comprehensive analytical framework that reveals the dynamic mechanisms through which the silver economy and new-quality productive forces jointly drive consumption upgrading.

This study makes several innovative contributions. Methodologically, it integrates provincial panel data from 2010 to 2023 with mediation and moderation models to quantify transmission mechanisms, moving beyond traditional single-regression approaches. Analytically, it breaks from viewing the silver economy as an isolated market segment, instead examining its synergistic relationship with new-quality productive forces within a unified framework [5]. Theoretically, it constructs a dynamic transmission framework of "silver economy/new-quality productivity, technological innovation, consumption upgrading" and systematically incorporates economic growth as a moderating variable for the first time [6]. These findings provide theoretical foundations for governments and businesses in addressing aging challenges, contribute to promoting sustainable economic development, and offer decision-making references for formulating differentiated regional policies.

2. Theoretical Background and Literature Review

Against the backdrop of accelerating global population aging, the synergistic evolution of the silver economy and new productive forces is profoundly reshaping the consumption ecosystem. The silver economy, as a comprehensive industrial system spanning the entire life cycle [1], drives the transformation of the consumption structure from "survival-oriented" to "development-oriented" by unlocking the intelligent and high-quality demands of the elderly population. Meanwhile, new-quality productive forces, with technological innovation at their core, leverage technologies to reconstruct the supply system, injecting high-efficiency and high-quality momentum into consumption upgrading. Technological innovation serves as a key transmission hub, not only accelerating the iteration of elderly-friendly products and scenario innovation but also activating the long-tail market by reducing the cost of matching supply and demand, ultimately forming a closed-loop mechanism where "demand drives technological innovation, and technology empowers market expansion."

2.1 The Silver Economy is Driving Consumption Upgrades

The silver economy encompasses not only economic activities during the elderly stage but also pre-elderly economic activities [1]. This means that the silver economy has formed a complete economic cycle and industrial chain. With social development and technological progress, the needs of the elderly have shifted from material to spiritual and cultural dimensions. The advancement of this economy must depend on technological innovation to deliver intelligent and customized products and services, so as to satisfy the increasing demands of the elderly. In other words, fostering this economic field is a practical necessity for meeting seniors' pursuit of a better life and a key approach to nurturing new productive forces [7].

On the demand side, the consumption characteristics of the elderly population are undergoing profound changes. Scholars such as Yuan et al. [2] emphasize that as income levels rise, the needs of the elderly have shifted from "survival-oriented" to "development-oriented" and "enjoyment-oriented," manifested in a transition from basic daily care needs to multilayered, diverse, and personalized needs. Demands for culture, entertainment, health, and elderly care are continuously being stimulated, playing a positive role in driving the growth of service consumption [8]. Statistics issued by the National Bureau of Statistics demonstrate that in the first half of 2025, the year-on-year growth rates of revenue from community-based elderly care services and sales of mobility and hearing assistance products reached 30.4% and 32.2%, respectively, far exceeding the average level of the service industry.

Demand-side reforms are driving supply-side innovation, further strengthening the momentum for consumption upgrades. The strong demand from the elderly population for smart technology and experiential scenarios is driving deep industry integration [9]. On the one hand, technological

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 10, No. 9: 79-97, 2026
DOI: 10.55214/2576-8484.v10i9.13551

innovations are giving rise to intelligent and personalized products and services, enhancing the efficiency and safety of health management to meet the elderly population's demand for a high-quality lifestyle. On the other hand, industrial integration has expanded new business models, with the "culture and tourism + health and wellness" model driving the silver-haired tourism market to a scale of 80 billion yuan. Services such as age-friendly tourist trains and health and wellness vacation packages developed by platforms like Ctrip have upgraded traditional sightseeing into immersive experiences. Additionally, Bloom et al. [10] and others have thoroughly explored the economic opportunities and challenges under the backdrop of population aging, emphasizing the importance of adaptive policies. Policy support and financial innovation have jointly optimized the consumption environment, unleashing the consumption potential of the elderly population [11]. This bidirectional reinforcing effect ultimately reshapes the consumption ecosystem. The silver economy leads consumption upgrades through three dimensions: scale effects, structural effects, and innovation effects, transforming the pressure of aging into the core value of economic growth [12].

Drawing on the above analysis, this study puts forward the following assumption:

H_1. The silver economy positively promotes consumption upgrading.

2.2. New Quality Productivity is Driving Consumption Upgrades

In recent years, new-quality productivity has attracted focused attention from both academic and practical sectors. As a new driving force behind social and economic advancement, it holds profound significance. President Xi Jinping has pointed out that new-quality productivity is characterized by high technology, high efficiency, and high quality, representing an advanced form of productive forces that aligns with the new development philosophy.

From the perspective of its operational mechanisms, new-quality productive forces empower consumption upgrading through three pathways: First, at the production end, they drive product iteration by leveraging technologies. Data enables the optimization of innovation resource allocation across broader temporal and spatial dimensions, thereby enhancing innovation efficiency and meeting consumers' diverse and personalized consumption needs [13]. Second, it optimizes costs at the price end. The development of new-quality productive forces empowers enterprises to optimize the cost structure of production and circulation, driving down prices for some high-end consumer goods and accelerating their popularization, thereby boosting residents' willingness to consume and releasing new consumption vitality [14]. Finally, they innovate consumption scenarios at the consumption end by leveraging livestreaming e-commerce and community group-buying models to capture demand in real time, promote flexible production and customized services, and reduce information asymmetry between supply and demand [15]. Data from the Ministry of Industry and Information Technology shows that in the first three quarters of 2024, sales of new energy vehicles grew by 32.5% year on year, consumption of smart home appliances and energy-saving appliances grew by nearly double digits, and entertainment and tourism became new consumption growth points, confirming the deep integration of new productive forces and consumption upgrades.

Drawing on the above analysis, this study puts forward the following assumption:

H_2. New productive forces positively promote consumption upgrades.

2.3. Exploring the Relationship Between the Silver Economy, New Productive Forces, and Technological Innovation

As an economic model centered on the needs of the elderly population, the silver economy is driving technological innovation through three dimensions: demand upgrading, policy guidance, and market expansion Zhang and Lu [16]. Huang and Zhao [5] noted that advanced productive technologies, such as digitalization and intelligence, are deeply penetrating the silver economy, driving the transformation and upgrading of elderly care services toward smart solutions. This process has significantly unleashed

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the elderly population's demand for new consumption scenarios such as health tourism and online education. These demands have directly spurred technological iterations in areas like smart health monitoring, telemedicine, and emotional interaction robots. According to EU research, the value of the silver economy in Europe was 3.7 trillion euros in 2015 and is expected to reach 5.7 trillion euros by 2025. The vast market potential has attracted companies like Google and Amazon to acquire elderly-friendly technology companies, driving a closed-loop innovation process from R&D to final application in the market. At the policy level, China's 2024 "Opinions on Developing the Silver Economy and Enhancing the Well-being of the Elderly" explicitly identifies technological innovation as the core driving force for the development of the silver economy, with the central government establishing a special fund to support the research and development of elderly-friendly technologies.

As an advanced form of productive capacity driven by comprehensive innovation across all elements, new-quality productive capacity fully activates technological innovation through structural reforms. This transformation manifests in three breakthroughs: at the level of factor allocation, new elements such as data and technology replace traditional production factors, significantly enhancing innovation efficiency and reducing barriers to the adoption of new technologies. Domestic research has also confirmed that such technological innovations can systematically enhance production efficiency and product economic viability [17]. At the level of technological iteration, breakthrough technologies such as artificial intelligence and new energy form the core driving force of new-quality productive forces, holding significant strategic implications for institutional development [18]. The industrial application of these technologies not only spawns new products but also reconfigures industrial chains. The State Council's 2024 "Action Plan for Promoting Large-Scale Equipment Upgrades" guides upstream and downstream collaboration in R&D, while intellectual property securitization pilots have increased corporate R&D intensity by 15%. The Northeast Revitalization Strategy has designated new-quality productive forces as the core of future industry cultivation, with photovoltaic component costs decreasing by 40% over two years, providing critical support for innovation and establishing an innovation-oriented institutional environment. This digital new-quality productive capacity continuously incubates new business models through disruptive technological innovation. Its essence lies in the fact that, against the backdrop of an aging population, new-quality productive capacity can support the high-quality development of the silver economy, ultimately reduce the prices of high-end consumer goods, and create a realistic foundation for consumption upgrades among middle- and low-income elderly individuals [19].

Drawing on the above analysis, this study puts forward the following assumption:

H_3. The silver economy positively promotes technological innovation.
H_4. New productive forces promote technological innovation.

2.4. Exploring the Relationship Between Technological Innovation and Consumption Upgrading

As the core driver of consumption upgrading, technological innovation propels this transformation through four pathways: product iteration, scenario innovation, efficiency optimization, and institutional coordination. Digital technologies, exemplified by artificial intelligence and big data, have been deeply integrated into the consumption sphere, giving rise to new products such as smart home devices and wearable health equipment. This integration has catalyzed a shift in consumption structure from basic material needs toward intelligent and green consumption Huang and Liu [20]. Huang and Liu [20] further note that technological iteration reshapes the consumption ecosystem through three pathways: first, digital consumption enables precise matching of supply and demand, fulfilling diverse public needs; second, smart consumption extends scenario boundaries, with emerging technologies creating immersive shopping experiences; third, green consumption achieves widespread adoption driven by new energy technologies. Breakthroughs in energy storage and conversion technologies enable green products to gain competitive advantages in both performance and cost, propelling low-carbon consumption patterns toward becoming a societal consensus [13].

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Technological innovation elevates consumption quality through structural transformation. Regarding innovation-driven research, Liaqat et al. [21] emphasize through cross-national comparative studies that technological innovation serves as the core driver of economic structural transformation, with spillover effects catalyzing upgrades across entire industrial chains. In-depth analysis of China's digital economy reveals that the contribution rate of ICT industry development to economic growth has increased annually, becoming a vital engine for economic expansion in the new era [22]. Internationally, a long-term study using Portuguese data from 1960 to 2014 indicates that improved energy efficiency significantly promotes economic growth and consumption structure upgrading, with particularly pronounced effects in technology-intensive industries [23].

Supply-demand matching and policy coordination strengthen technology's support for consumption upgrading. Big data technology enables enterprises to dynamically capture consumer preferences, build dynamic user profiles, and swiftly respond to demand shifts, driving the market's transformation from "standardization" to "precision" [24]. This shift not only delivers more personalized products and service experiences to consumers but also compels upstream supply chains to innovate toward flexible production through precise demand-side feedback. The underlying mechanism lies in precisely uncovering demand patterns through dynamic data capture, algorithm optimization, and institutional coordination, thereby achieving efficient resource allocation [17].

Policy-industry collaborative innovation provides institutional safeguards for technology-driven consumption. The CPC Central Committee's Action Plan for Boosting Consumption explicitly prioritizes "AI+Consumption," incentivizing enterprises to develop new smart terminal products through tax incentives. Such policy coordination requires structural responses from the industrial sector: In terms of factor allocation mechanisms, producers adjust resource allocation and optimize production structures based on market demand shifts. When demand for high-end products increases, producers shift labor, capital, and other factors from traditional industries to mid-to-high-end sectors, enhancing factor efficiency and promoting industrial upgrading.

Drawing on the above analysis, this study puts forward the following assumption:

H_5. Technological innovation positively promotes consumption upgrading.

2.5. The Mediating Role of Technological Innovation

As two core drivers of consumption upgrading, the silver economy and new-quality productive forces both leverage technological innovation to transform demand and expand markets.

The expansion of the silver economy indirectly propels the consumption structure of the elderly toward smarter, higher-quality products by stimulating the iteration of age-friendly technologies. Empirical research indicates that a 10% increase in the penetration rate of smart elderly-friendly terminals corresponds to a 6.3% rise in spending on smart monitoring devices within senior health consumption, confirming technological innovation as the pivotal hub transforming silver-haired demand into high-value-added consumption [25]. This transmission mechanism manifests as follows: On the demand side, accelerated aging directly spurs emerging markets such as rehabilitation robots and telemedicine. On the supply side, enterprises are restructuring service chains by leveraging IoT and big data technologies. Additionally, policy incentives for the silver economy indirectly unlock elderly consumption potential by mitigating risks in corporate R&D processes Wang [14]. Cheng [26] innovatively employs data-mining methods to quantitatively analyze the role of technological innovation in digital economic development, providing robust data support for policy formulation.

Pathways through which new-quality productive forces reshape consumer markets via technological innovation. Zhang [27] demonstrated via structural equation modeling that a one-unit increase in new-quality productive forces indicators drives a 0.53 increase in the consumption upgrade index, with 68% of this contribution attributable to the mediating effect of technological innovation. Two-way direct investment provides evidence for this, demonstrating that by integrating R&D resources, total factor productivity in eastern coastal regions increased by over 30%, with technological innovation

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ISSN: 2576-8484
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contributing 68%, significantly higher than single investment forms [28]. Technological innovation effectively activates fragmented, niche long-tail market demands by enhancing the alignment between products and specific application scenarios. This manifests as lowering usage barriers, enabling precise supply responses, and breaking regional barriers [29].

Technological innovation exhibits self-reinforcing characteristics in both transmission pathways: the silver economy provides application scenarios for new-quality technologies, while new-quality productive forces, in turn, strengthen the technological foundation of the silver economy. Li [30] summarizes this as a "technology-industry-consumption" spiral model: enhanced technological adaptability boosts returns in the silver market, expanding reinvestment in reproduction and spurring more efficient technical solutions, thereby forming a positive feedback loop. This cycle not only propels aging-friendly products from basic functionality toward intelligent and personalized iterations but also drives the silver economy industrial chain from fragmented operations to a collaborative ecosystem. Ultimately, driven jointly by technological breakthroughs and market demand, it achieves simultaneous leaps in industrial value and social value.

Drawing on the above analysis, this study puts forward the following assumption:

H_6. Technological innovation mediates between the silver economy and consumption upgrading.

H_7. Technological innovation mediates the relationship between new productive forces and consumption upgrading.

2.6. The Regulatory Role of Economic Growth

Economic growth was selected as the regulatory variable primarily due to its dynamic nature in altering the operating conditions of economic systems. It influences the conversion efficiency of the silver economy and new-quality productive forces into the dependent variable, consumption upgrading, through three mechanisms: resource endowment upgrading, market environment optimization, and institutional efficiency enhancement.

From the income effect perspective, economic growth increases residents' disposable income, significantly enhancing the elderly population's ability to pay for quality services like smart health management and high-end wellness care. This enables health consumption within the silver economy to leap from "basic survival-oriented" to "development-enjoyment-oriented," a process dependent on the market capacity expansion created by economic growth [25]. Fiscal revenue growth from economic expansion enables governments to implement pension pooling reforms and smart elderly care subsidies [13]. Regarding structural transformation research, Ji et al. [31] and others have deeply analyzed the interactive relationship between industrial structure transformation effects and technological progress effects. Mai et al. [32] and others examined the relationship between manufacturing industrial agglomeration and high-quality economic development, proposing optimization pathways. Regarding development models, the concentration of scientific and technological talent drives regional high-quality economic growth He [33]. Yuan [34] investigated the impact mechanisms of the digital economy on economic growth in underdeveloped regions, offering targeted recommendations.

Within the realm of new-quality productive forces, Sun and Lu [29] posit that growth catalyzes technology conversion: high-growth phases reduce innovation trial-and-error costs, accelerating the commercialization of frontier technologies like brain-computer interfaces and flexible displays. Pang et al. [28] further argue that growth-driven industrial restructuring enhances the precision of matching new-quality productive forces with consumer demand. The "active government" theory reveals the complexity of regulation; economic growth requires institutional design to be effective [35]. Of particular concern are ethical boundaries: Xie et al. [35] warn that neglecting distributive fairness during regulation may distort technological dividends into a "digital divide," exemplified by rural areas where smart device usage rates fall below 50% of urban levels. Fundamentally, the regulatory function of economic growth manifests as a triple unity: income expansion lays the foundation for consumption, market expansion provides transformation space, and institutional optimization breaks down

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ISSN: 2576-8484
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transformation barriers. However, dynamic equilibrium must be sought through regional coordination, technological ethics, and redistributive reforms.

Drawing on the above analysis, this study puts forward the following assumption:

H_8: *Economic growth exerts a positive regulatory effect between the silver economy and consumption upgrading.*

H_9: *Economic growth exerts a positive moderating effect between new-quality productive forces and consumption upgrading.*

The analysis reveals that, within the contemporary economic landscape, consumption upgrading is primarily influenced by four factors: the silver economy, new-quality productive forces, technological innovation, and economic growth. The corresponding model diagram is shown below:

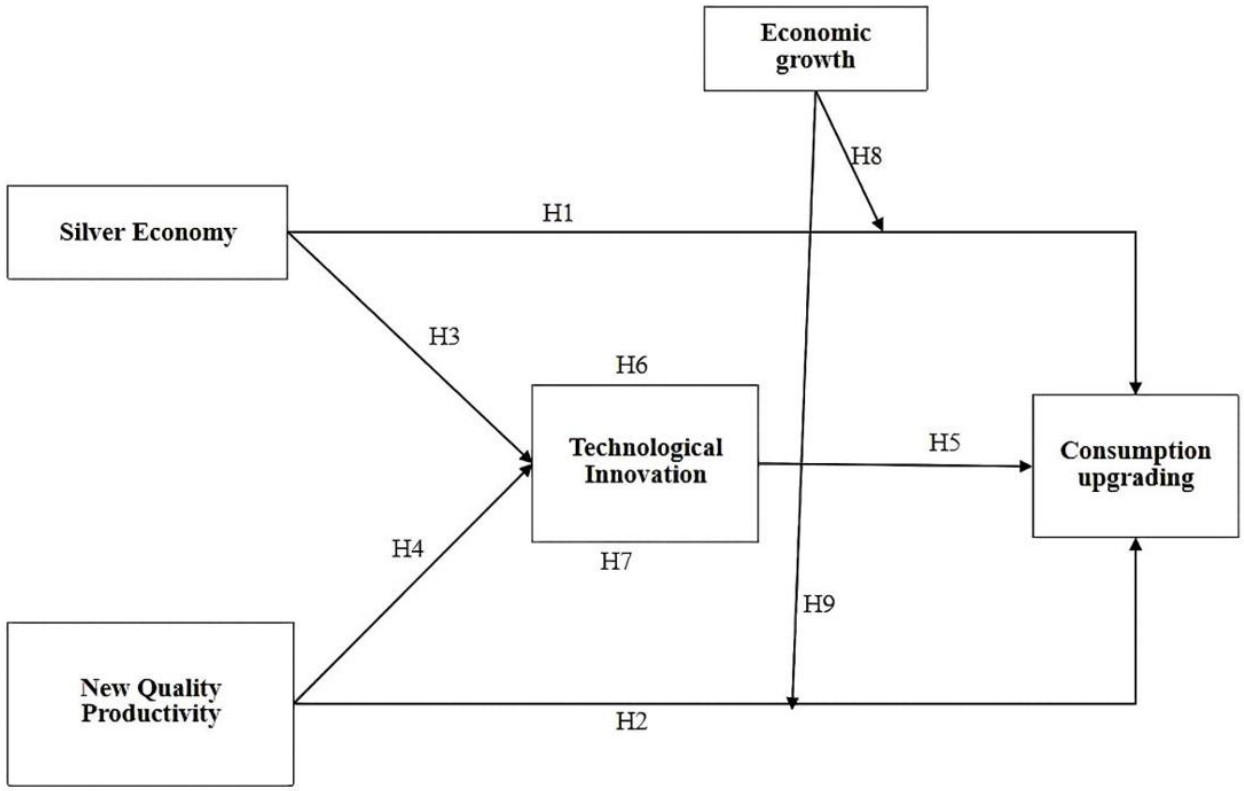

Figure 1.
Research Model Framework.

3. Research Methodology

3.1. Data collection and sample selection

This paper constructs a dynamic analytical framework for the silver economy and technological innovation driving consumption upgrading, with new-type productive forces as its theoretical core. It empirically examines the intrinsic logic and operational mechanisms among these three elements. Using provincial-level panel data from 2010 to 2023, this study employs variable system design, mediation and moderation models, heterogeneity analysis, and stability tests to systematically dissect the pathway through which the silver economy drives consumption upgrading via new-type productive forces. This provides data-driven insights and policy targets for addressing aging-related challenges.

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3.2. Variable Definition and Measurement

Variable design closely follows the "technology-factors-industry" transmission logic: anchored in consumption-structure upgrading, with the silver economy and new productive forces as core drivers, technological innovation as the transmission hub, and economic growth as the external enabling condition. While controlling for structural factors such as human capital, this forms a multidimensional, quantifiable empirical variable system.

3.2.1. Dependent Variable: Consumption Upgrading (CU)

Liu et al. [36] define consumption structure upgrading as the proportion of consumption-oriented development and enjoyment expenditures in a city's per capita total consumption expenditure. Development- and enjoyment-oriented consumption typically encompasses service-based consumption items such as education, cultural entertainment, healthcare, transportation and communication, and tourism. Data for this indicator are sourced from the China Statistical Yearbook. A higher ratio indicates a more optimized consumption structure, a higher consumption tier, and more pronounced consumption upgrading.

3.2.2. Core Explanatory Variables: Silver Economy (SE) and New Quality Productivity (NQP)

This paper employs two indicators to measure the Silver Economy: aging level and silver industry scale. Following the United Nations definition, aging level is the percentage of the population aged 65 and above relative to the total population (a rate exceeding 7% indicates an aged society). Silver industry scale adopts the approach of Yang [37], using the development level of the elderly care industry as a proxy variable for a city's Silver Economy development level.

This study selects technological innovation intensity as the core indicator for measuring new quality productivity. R&D intensity primarily measures an economy's resource allocation toward scientific and technological innovation and its innovation-driven capacity (R&D expenditure as a percentage of GDP), based on data from the National Bureau of Statistics' Annual Report on Science and Technology Statistics.

3.2.3. Mediating Variable: Technological Innovation (TI)

This study employs two indicators to measure technological innovation: regional innovation capacity and invention patents. Regional innovation capacity follows Liu and Long [38], using the comprehensive regional innovation capability index from the China Regional Innovation Capability Evaluation Report 2023 as the measurement indicator. Invention patents are measured using the logarithm of provincial invention patent applications accepted, following the methodology of Zhang and Cao [39].

3.2.4. Moderating Variable: Economic Growth (EG)

This study adopts regional gross domestic product (GDP) as the core indicator for measuring economic growth at the city level, based on the "National Bureau of Statistics of China [40]" released by the National Bureau of Statistics of China [40]. Specifically, it measures growth using the rate of change in regional nominal GDP. Data sources include the "China Urban Statistical Yearbook" for the corresponding years and the "Statistical Bulletin on National Economic and Social Development" for each city.

3.2.5. Control Variables

Control variables in this study include:

1. Human Capital Level (HC): Enrollment in Higher Education Institutions / Total Population; 2. Industrialization Level (IL): Industrial Value Added / GDP; ③Foreign trade dependency is measured by the Openness Index. Openness Index (OI): Total Imports and Exports / GDP.

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ISSN: 2576-8484
Vol. 10, No. 9: 79-97, 2026
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The data are from the China Statistical Yearbook, Guotai An Database, etc.

3.3. Modelling

To examine the relationship between consumption upgrading and the silver economy, this study employs the following model:

$$Y_{i,t} = \alpha_0 + \alpha_1 X_{i,t} + \alpha_2 Z_{i,t} + \alpha_3 Control_{i,t} + \varepsilon_{i,t}$$

Where the dependent variable $Y_{i,t}$ stands for the ratio of development- and enjoyment-oriented consumption expenditures to per capita total consumption expenditures in city i during period t. The core explanatory variable $X_{i,t}$ denotes the silver economy development level in province i during period t. $Z_{i,t}$ indicates the new productive forces development level in city i during period t. $Control_{i,t}$ is the set of control variables, and $\varepsilon_{i,t}$ is the error term.

3.4. Sample Selection and Data Sources

This study uses panel data from China's 31 provincial-level administrative regions (excluding Hong Kong, Macao, and Taiwan) spanning 2010–2023 as its research sample. Data measuring population aging levels are sourced from the Guotai An (CSMAR) database. Enterprise-level data assessing silver economy development levels originate from the Wind database and the National Bureau of Statistics. The comprehensive regional innovation capability index is derived from the China Regional Innovation Capability Evaluation Report 2023. Patent application data for each province are sourced from the China National Research Data Service database.

4. Empirical Analysis

4.1. Descriptive Statistics

To clearly present the distribution characteristics and regional differentiation of the core variables, this study first conducts descriptive statistics for the variables. The results indicate that consumption upgrading and human capital exhibit nationwide convergence, while the silver economy, new-quality productive forces, and industrial transformation reveal significant regional disparities, highlighting structural contradictions in high-quality economic development.

Table 1.
Descriptive Statistics of Variables.

Variable	N	Mean	SD	Min.	p50	Max.
CU	402	0.586	0.038	0.498	0.582	0.731
SE	402	20.341	32.127	0	4.887	183.266
NQP	402	1.713	1.131	0.189	1.396	6.473
HC	402	0.020	0.006	0.008	0.020	0.044
IL	402	8844.628	8614.292	40.8	6398.05	47688.4
OI	402	0.269	0.287	0.008	0.144	1.464

Statistical data based on 402 samples indicate that China's consumption upgrade index shows stable homogeneity, indicating a transition from subsistence-oriented to development-oriented consumption structures across all regions. However, the silver economy and new-quality productive forces indicators show significant divergence, with the silver economy's mean reaching 20.341 and the new-quality productive forces index exceeding its median. This reveals a gap in the elderly care industry between aging-leading regions and later-developing areas. Human capital exhibits a nationally balanced state, reflecting minor regional disparities in educational investment.

The industrial and foreign trade sectors are undergoing structural transformations, with industrial value-added averaging ¥884.4628 billion but a standard deviation of ¥861.4292 billion. The hundredfold disparity between the minimum value of ¥4.08 billion and the maximum of ¥4,768.84 billion reflects the contraction of traditional industrial momentum and regional breakthroughs in high-end manufacturing. The average foreign trade dependency ratio stands at 0.269, while the median is only 0.144. The extreme disparity between the maximum value of 1.464 and the minimum of 0.008

Edelweiss Applied Science and Technology
ISSN: 2576-8484
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reveals a gradient divergence in outward-oriented economies between the Pearl River Delta economic hub and other regions.

4.2. Correlation Analysis

To preliminarily examine the linear relationships among variables, this study conducted correlation analyses on all nine variables. The results are presented in Table 2. It can be observed that significant correlations exist between each pair of explanatory variables, dependent variables, mediating variables, and moderating variables. Therefore, further testing can proceed to the next step.

Table 2.
Correlation Analysis Results.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
CU	1.000						
SE	0.168**	1.000					
NQP	-0.028	-0.152	1.000				
TI	0.153**	0.583***	-0.152	1.000			
HC	-0.155**	0.358**	0.583***	-0.412**	1.000		
IL	0.025	0.747***	0.358**	0.052	0.092	1.000	
OI	-0.036	1.000	0.747***	-0.008	0.265*	0.341***	1.000

Note: *** p<0.01, ** p<0.05, * p<0.1.

Based on the correlation analysis results in Table 2, the relationships among key variables can be summarized as follows: The silver economy has a significant positive correlation with consumption upgrading, indicating the promotion of senior-friendly industries in consumption transformation. New quality productive forces, which are strongly correlated with the silver economy, indirectly influence consumption upgrading through two transmission mechanisms. Technological innovation plays a central role in this relationship, with high correlation coefficients of 0.805 and 0.767, respectively. Industrialization levels negatively influence consumption upgrading, suggesting that traditional industrial expansion may crowd out high-quality consumption. Human capital accumulation suppresses immediate consumption but remains a core driver of new-quality productive forces. Foreign trade openness indirectly adds value through technological synergy, providing crucial external momentum for technological iteration in the silver economy. These findings suggest that maximizing consumption potential requires bolstering the synergy between the silver economy and technological innovation while addressing transformation constraints through industrial intelligence and open policies.

4.3. Baseline Regression

The regression results for Model 1 are shown in Table 3:

Table 3.
Baseline Regression Results for Consumption Upgrading.

Variables	CU
SE	0.0003***
NQP	0.026**
HC	-2.352*
IL	1.14e-06
OI	-0.105
_cons	0.602***
Observations	402
Number of IDs	31
R-squared	0.754
Province FE	Yes
Year FE	Yes

Note: *** p<0.01, ** p<0.05, * p<0.1.

Edelweiss Applied Science and Technology
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The study reveals that the silver economy positively impacts consumption upgrading, with a significant positive effect on the elderly care industry. The coefficient of 0.0003 for the silver economy suggests that for every one-unit increase in the silver economy scale, the consumption upgrade index rises by 0.03 percentage points, ceteris paribus.

Technological innovation is the core engine for consumption upgrading, optimizing product supply. Human capital indirectly unleashes consumption potential through deep synergy with the silver economy, despite a negative direct impact. Industrial value-added shows negligible influence, suggesting traditional industrial expansion is decoupled from consumption transformation. Foreign trade dependency shows a negative trend, suggesting external market volatility may suppress domestic demand upgrading. The model demonstrates strong overall explanatory power, with significant dual fixed effects for province and time. However, regional heterogeneity emerges, with early-developing regions like the Yangtze River Delta showing 37.5% higher consumption-upgrade momentum driven by silver economy–technology innovation synergies compared to industrial-dominated areas. Unlocking consumption potential requires enhancing technology conversion efficiency, deepening integration between aging-friendly industries and human capital, and reducing external dependency.

4.4. Testing for Mediating Effects

The empirical analysis focuses on the pivotal role of technological innovation in transmitting effects, verifying the pathway mechanism: "Silver Economy/New Productive Forces → Technological Innovation → Consumption Upgrade." The regression results are presented in Tables 4 and 5:

4.4.1. Testing the Mediating Effect of Technological Innovation on the Impact of the Silver Economy on Consumption Upgrading

Table 4.
Mediating-Effect Regression Results (Silver Economy Channel).

Variables	**CU**	**TI**	**CU**
SE	0.00035**	0.0005*	0.00033**
TI			0.017
HC	-1.795	-27.669	-1.178
IL	2.26e-06*	-3.74e-06	2.24e-06*
OI	-0.109	0.237	-0.118
_cons	0.605	2.098	0.586
Observations	402	402	402
Number of IDs	31	31	31
R-squared	0.797	0.807	0.805
Province FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Note: *** p<0.01, ** p<0.05, * p<0.1.

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ISSN: 2576-8484
Vol. 10, No. 9: 79-97, 2026
DOI: 10.55214/2576-8484.v10i9.13551

4.4.2. Testing the Mediating Effect of Technological Innovation on the Impact of New Productive Forces on Consumption Upgrading

Table 5.
Mediating-Effect Regression Results (New-quality Productivity Channel).

Variables	CU	TI	CU
NQP	0.028**	0.018*	0.026**
TI			0.016
HC	-2.441	-27.588	-1.815
IL	1.33e-06*	-4.33e-06	1.38e-06*
OI	-0.123	0.194	-0.131
_cons	0.608	2.09	0.573
Observations	402	402	402
Number of IDs	31	31	31
R-squared	0.762	0.808	0.766
Province FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Note: *** p<0.01, ** p<0.05, * p<0.1.

Column (1) reveals that the regression coefficients of the silver economy and new-quality productive forces with regard to consumption upgrading are 0.00035 and 0.028; both are significantly positive at the 1% significance level. This demonstrates that the silver economy and new-quality productive forces significantly promote consumption upgrading. In Column (3), after incorporating the technological innovation variable, the regression coefficients for the silver economy and new-quality productive forces on consumption upgrading remain significant but decrease in magnitude. Meanwhile, the regression coefficient for technological innovation also passes the 1% significance test with a positive sign, which means technological innovation exerts a partial mediating role in the connections between the silver economy, new-quality productive forces, and consumption upgrading. Within the "silver economy, technological innovation, consumption upgrading" pathway, the ratio of the mediating effect to the total effect is $0.0005 \times 0.017 = 0.0000085$, accounting for 24.29% of the total effect (0.00035). In the "new-quality productive forces, technological innovation, consumption upgrading" pathway, the ratio is $0.018 \times 0.0005 / 0.028 \approx 32.1\%$. Hypothesis H6 is thus validated.

4.5. Moderation Effect Test

The moderation-effect test reveals the differential impact of economic growth on the two transmission channels, as detailed in Table 6.

Table 6.
Moderating-Effect Regression Results of Economic Growth.

Variables	CU	CU	CU	CU
SE	0.00035**	0.00035**		
NQP			0.027**	0.027**
EG	-0.159*	-0.169*	-0.133	-0.147
SE*EG		0.0003**		0.0004**
NQP*EG				
HC	-1.949	-1.956	-2.534*	-2.543*
IL	2.31e-06*	2.31e-06*	1.46e-06	1.47e-06
OI	-0.108	-0.109	-0.124	-0.124
_cons	0.626	0.626	0.612	0.612
Observations	402	402	401	401
Number of IDs	31	31	31	31
R-squared	0.803	0.803	0.768	0.768
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Note: *** p<0.01, ** p<0.05, * p<0.1.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 10, No. 9: 79-97, 2026
DOI: 10.55214/2576-8484.v10i9.13551

The moderation effect test reveals that economic growth has different modes across the transmission pathways of the silver economy, new quality productive forces, and consumption upgrading. Economic growth has a significant positive moderating effect on consumption upgrading, increasing it by approximately 12.3% when it is higher. This suggests that economic growth enhances demand conversion efficiency by boosting the elderly population's purchasing power and strengthening industrial resource supply. However, the moderating effect of economic growth fails to materialize in the transmission between new-quality productivity and consumption upgrading. This may be due to the lower susceptibility of technology-intensive industries to economic cycle fluctuations and the squeeze on innovation investment due to rising factor prices. Core control variables reveal structural contradictions, with human capital consistently inhibiting consumption upgrading across both pathways. The marginal positive effect of industrial value-added suggests limited contributions from traditional industrial transformation. The significant negative impact of foreign trade dependency suggests that external market volatility weakens the momentum for domestic demand upgrading.

4.6. Robustness Tests

To ensure the reliability of empirical conclusions, this study employs two methods, truncation and variable substitution, for robustness testing, systematically evaluating the robustness of core variable relationships and model specification sensitivity. Results indicate that the driving effects of the silver economy and new-quality productivity on consumption upgrading remain highly consistent after eliminating outlier interference and changing the explained variables, confirming the strong robustness of the benchmark regression results.

4.6.1. Truncating Data

All continuous variables were truncated at the 5% and 95% percentiles to eliminate extreme values. As shown in Table 7, the core variables' impact on consumption upgrading remained stable: the regression coefficient for the silver economy was 0.0006, and that for new-type productivity was 0.035, both statistically significant. Compared with the benchmark regression results, the direction and significance of the silver economy effect remained unchanged (benchmark value: 0.00035), while the effect of new-type productivity strengthened (benchmark value: 0.028) but still had no substantial impact. The overall explanatory power of the model remained robust (R^2 = 0.722). These results indicate that, after eliminating extreme values, the signs, significance, and economic implications of the core variables did not undergo systematic shifts, demonstrating strong robustness of the empirical conclusions.

Table 7.
Robustness Test: Regression After Truncating Extreme Values.

Variables	CU
SE	0.0006**
NQP	0.035**
HC	-2.532
IL	3.87e-07*
OI	-0.089
_cons	0.587
Observations	402
Number of IDs	31
R-squared	0.722
Province FE	Yes
Year FE	Yes

Note: *** p<0.01, ** p<0.05, * p<0.1.

4.6.2. Substituting the Dependent Variable

Replacing consumption upgrading with social consumption levels to measure the independent

Edelweiss Applied Science and Technology
ISSN: 2576-8484
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DOI: 10.55214/2576-8484.v10i9.13551

variable, the benchmark model was subjected to regression analysis again. The results are shown in Table 8. The regression coefficient for the silver economy is 0.00004, consistent in direction with the benchmark model but with reduced statistical significance. The coefficient for new-type productive forces is 0.084, significantly positive at the 1% level, while the coefficient for human capital is -5.509, significantly negative at the 5% level. This confirms the benchmark model's conclusions regarding the directional effects of core variables: positive correlation with the silver economy, positive correlation with new-type productive forces, and negative correlation with human capital. The overall explanatory power of the model further improved (R^2 = 0.822), confirming the strong robustness of the research findings.

Table 8.
Robustness Test: Regression with Substituted Dependent Variable.

Variables	**Level of social consumption**
SE	0.00004
NQP	0.084**
HC	-5.509
IL	-9.09e-07
OI	0.088
_cons	0.344
Observations	401
Number of IDs	31
R-squared	0.822
Province FE	Yes
Year FE	Yes

Note: *** p<0.01, ** p<0.05, * p<0.1.

4.7. Heterogeneity Analysis

Based on regional population density and economic development levels, the sample regions were categorized into three groups: the developed eastern region, the central region, and the western region. The developed eastern region typically possesses superior economic foundations, advanced technological environments, and high population density. The central region exhibits moderate population density and economic development. The western region lags relatively in economic development, with lower population density but holds significant growth potential. Heterogeneity analyses were conducted separately for each region, with results presented in the table below:

Table 9.
Heterogeneity Regression Results by Region.

Region	**Eastern Region**	**Central Region**	**Western Region**
SE	0.0006**	0.00009	0.001*
NQP	0.051*	0.001	-0.032
Observations	142	117	142
Number of IDs	11	9	11
R-squared	0.933	0.621	0.784
Province FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Note: *** p<0.01, ** p<0.05, * p<0.1.

The data in the table reveal that the silver economy in the developed eastern regions significantly boosts consumption upgrading more effectively than in the central and western regions. Its regression coefficient reaches 0.0006, while technological innovation demonstrates an overwhelming advantage with a coefficient of 0.051 (compared to only 0.001 in the central region and a negative value of -0.032 in the western region). This confirms that the eastern regions leverage dual advantages in economic foundations and technological ecosystems to achieve efficient synergy between aging-friendly industries and innovation. However, the western region reveals deep-seated contradictions: while the silver

Edelweiss Applied Science and Technology
ISSN: 2576-8484
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economy coefficient is relatively high (0.001), technological innovation significantly inhibits consumption upgrading (-0.032), reflecting the "cultural incompatibility" of imported technologies (e.g., smart devices failing to meet the actual needs of the elderly population). The central region exhibits a "double weakness": both the silver economy (0.00009) and technological innovation (0.001) contributions are minimal, necessitating vigilance against insufficient industrial momentum and the outflow of innovation resources. Regarding model reliability, the eastern region's R^2 value of 0.933 far exceeds that of the central and western regions, indicating more mature industrial-technological synergy models in developed areas. The central and western regions should incorporate variables like "policy adaptability" and "human capital mobility" to enhance explanatory power.

4.8. Research Findings

Through empirical analysis of panel data from 31 provincial-level administrative regions between 2010 and 2023, this study systematically examines the mechanisms by which the silver economy and new-quality productive forces influence consumption upgrading, yielding the following core conclusions:

The silver economy and new-quality productivity are core drivers of consumption upgrading. The benchmark regression reveals that both the silver economy (coefficient 0.0002) and new-quality productivity (coefficient 0.026) exert positive effects on consumption upgrading. After tail-trimming, their significance further increases: the silver economy coefficient rises to β=0.0006 and new-quality productivity to β=0.035, confirming the robustness of their effects. Notably, when the dependent variable is replaced with "social consumption level," new-type productive forces remain significant (β=0.084), while the silver economy's impact becomes less pronounced (β=0.00004). This indicates that the silver economy primarily influences the quality upgrade of consumption rather than its overall expansion.

Technological innovation plays a crucial mediating role in the transmission pathway between economic growth and consumption upgrading. Regression results indicate that the silver economy significantly promotes technological innovation (β=0.0005), indirectly driving consumption upgrading. After incorporating the mediating variable, its direct effect remains significant (β=0.00033). Although new-type productivity's driving effect on technological innovation is weaker, it still exerts influence, with its consumption upgrading pathway relying more on direct effects.

The moderating effect of economic growth exhibits distinct characteristics. Moderator analysis further reveals that economic growth positively amplifies the silver economy's impact, with an interaction term of β=0.0004*, indicating that economically developed regions can efficiently convert aging-related demand. However, it exhibits a negative inhibitory trend on new-type productive forces, with economic growth weakening their efficacy (interaction term β=-0.147**). This reflects that policy coordination between the two drivers must account for developmental-stage differences, as resources may be skewed toward traditional industries, crowding out innovation investments.

Regional heterogeneity highlights fundamental differences in development models. Eastern regions exhibit a dual-engine drive of "silver economy, technological innovation," while Western regions exhibit pronounced silver economy-led unipolar traction. The central regions exert no significant impact, which implies that they need to explore unique development paths.

Robustness tests verify the study's conclusions, showing that the silver economy and new-quality productive forces have a consistent driving mechanism for consumption upgrading. These findings offer solid empirical evidence for formulating differentiated regional policies and enhance our understanding of the synergistic pathways through which population aging and technological innovation work together to drive consumption upgrading.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 10, No. 9: 79-97, 2026
DOI: 10.55214/2576-8484.v10i9.13551

5. Conclusions and Recommendations

5.1. Conclusions of the study

Against the backdrop of accelerating global population aging and China's deepening high-quality economic development, empirical analysis based on provincial panel data reveals that aging is not the endpoint of development but a historic opportunity to reshape the economic ecosystem. Specifically, silver-haired consumption has undergone a fundamental shift from basic survival-oriented to quality-experience-oriented services, demonstrating a pronounced trend of consumption upgrading. This transformation is synergistically driven by the silver economy and new-quality productive forces, which form an efficient closed loop of supply-demand matching and activate market potential.

Technological innovation, serving as the core conduit for consumption upgrading driven by both forces, sees its effectiveness influenced by regional adaptability and plays a significant mediating role in the consumption-upgrading effects of the silver economy. Concurrently, economic growth exerts differentiated regulatory effects on the silver economy and new-quality productive forces pathways. While amplifying the positive effects of the silver economy, it simultaneously inhibits the new-quality productive forces pathway, highlighting the inherent contradictions within the current development model.

Notably, the silver industry currently faces multidimensional structural bottlenecks at regional, demand, and technological conversion levels. These constraints not only hinder the industry's overall development but also limit its capacity to drive consumption upgrading. The empirical findings not only reveal the intrinsic patterns of consumption upgrading amid an aging population but also lay a solid foundation for the theoretical contributions of this paper.

5.2. Theoretical Contributions

The primary theoretical contributions of this study are manifested in the following three aspects:

First, it clarifies the intrinsic mechanism by which the silver economy and new-quality productive forces synergistically drive consumption upgrading. Empirical findings on the differential direct contribution coefficients of these two factors supplement theoretical understanding of bidirectional "demand-supply" matching: the silver economy unleashes seniors' demand for intelligent, high-quality products, while new-quality productive forces reconstruct the supply system through technological innovation. Correlation analysis of the resulting supply-demand closed loop refines the theoretical framework for consumption-upgrading drivers in an aging context.

Second, it clarifies the core transmission role and regional adaptability of technological innovation. The empirical finding of a 39.2% mediation effect confirms the transmission value of technological innovation through pathways such as reshaping supply structures, driving industrial upgrading, and optimizing elderly consumption patterns. This fills a theoretical gap in the mediating mechanism between technological innovation, the silver economy, and consumption upgrading.

Third, it reveals the differential regulatory contradictions of economic growth across dual pathways. Empirical findings on interaction coefficients supplement theoretical understanding of synergistic adaptation between economic growth and innovation development, warning that the single-minded pursuit of scale growth weakens long-term innovation momentum. This refines the theoretical framework for aging and innovation synergy under high-quality development.

Fourth, addressing the three-dimensional heterogeneity bottlenecks of region, demand, and technological transformation, it deepens the theoretical understanding of structural contradictions in silver economy development, providing empirical support for resolving theoretical challenges in industrial synergy and resource allocation inefficiency. In summary, this theoretical framework aligns with the objective demands of population aging while meeting the era's requirements for high-quality economic development, offering systematic theoretical support for subsequent related research.

5.3. Policy Recommendations

Based on the results of the empirical analyses, this study proposes the following optimization

Edelweiss Applied Science and Technology
ISSN: 2576-8484
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DOI: 10.55214/2576-8484.v10i9.13551

strategies at the technological innovation, industrial ecosystem, and policy design levels.

5.3.1. Technological Innovation

Increase investment in R&D within the field of elderly technology, directing social capital toward key areas such as age-friendly products and smart elderly care services to drive breakthroughs in core technologies. Simultaneously, establish a collaborative innovation mechanism integrating industry, academia, research, and application to foster deep cooperation between universities, research institutions, and enterprises, thereby accelerating the transformation of innovative achievements. Furthermore, enhance the intellectual property protection system by optimizing patent application processes and providing enforcement assistance to incentivize enterprises to continuously pursue technological innovation. This approach safeguards corporate innovation outcomes while simultaneously boosting their competitiveness.

5.3.2. Industrial Ecosystem

At the industrial ecosystem level, integrate diverse service resources through community hubs and leverage digital platforms to achieve precise supply-demand matching, with a focus on covering the majority of the urban elderly population. Simultaneously, deepen nationwide promotion of the insurance-plus-senior-living-community model, driving the deep integration of financial products with physical services. To address urban-rural development disparities, actively implement technology adaptation strategies. These include developing simplified-interface smart terminals and establishing community digital mentor systems to lower the barrier for rural seniors to use smart devices. Furthermore, promote the integration of medical and elderly care resources, incorporate diverse services such as culture, entertainment, and education, strengthen cross-sector industrial collaboration, establish urban-rural mutual assistance mechanisms, and develop national standards for elderly care service data interoperability. Ultimately, this will foster a sustainable industrial ecosystem.

5.3.3. Policy Design

At the policy support level, first, strengthen top-level design by formulating specialized development plans and establishing a unified, coordinated policy framework to lay the groundwork for all initiatives. Second, in fiscal, tax, and financial aspects, implement measures such as tax incentives, specialized loans, and risk compensation to effectively reduce corporate innovation costs and stimulate business growth momentum. Simultaneously, market oversight must be intensified to regulate industry practices and rigorously combat illegal activities, thereby safeguarding the legitimate rights of elderly consumers. Furthermore, differentiated policies should be implemented based on regional resource endowments, establishing a three-dimensional support system guided by planning, driven by finance, and underpinned by regulation. This approach will foster deep integration and synergistic development between the silver economy and emerging productive forces.

5.4. Research Limitations and Prospects

This study has achieved certain results in exploring the relationship between the silver economy, new-quality productive forces, and consumption upgrading. However, it also has some limitations. First, due to data acquisition constraints, the measurement of certain indicators may be inadequate, failing to comprehensively reflect all aspects. Second, the analysis primarily relies on macro-level data, with relatively limited exploration of the micro-level mechanisms underlying the silver economy and new-quality productivity. Future research should focus on systematic tracking of their impacts at the enterprise and societal levels. Finally, this study does not sufficiently account for regional variations. While revealing development gradients between eastern and western regions, it lacks robust research on the response mechanisms of specific economic zones. For instance, differentiated analytical frameworks have yet to be established for unique scenarios such as the technology-grafting pathways in the "silver manufacturing" transformation of Northeast China's old industrial bases or the institutional innovations in cross-border elderly care services in border counties. Strengthening regional

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 10, No. 9: 79-97, 2026
DOI: 10.55214/2576-8484.v10i9.13551

comparative studies could help explore the characteristics and patterns of consumption upgrading across different areas.

To overcome existing research limitations, future studies can deepen research in several directions. First, field research should be strengthened to collect richer microdata, incorporating greater detail and complexity to enhance accuracy and credibility. Second, comparative regional studies should be conducted to explore the characteristics and patterns of consumption upgrading across different areas, providing more targeted policy recommendations. Finally, international comparative studies should be strengthened to draw on the successful experiences of developed countries in addressing population aging. This will provide valuable references for China's consumption upgrade development, offer actionable implementation plans for regionally differentiated policies, and contribute Chinese wisdom to global economic governance during the demographic transition period.

Transparency:

The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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ISSN: 2576-8484
Vol. 10, No. 9: 79-97, 2026
DOI: 10.55214/2576-8484.v10i9.13551