Heliyon 11 (2025) e41490

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Fueling the development of elderly care services in China with digital technology: A provincial panel data analysis

Jiaxin He [*,1], Dangchen Sui [**,1], Lingpeng Li [***], Xinyan Lv

Department of International Business, School of Economics and Management, Shaanxi Normal University, Xi'an, Shaanxi, China

A B S T R A C T

Background: The global demographic shift towards an aging population presents significant challenges to elderly care cervices, which encompass the range of services designed to meet the health and social needs of older adults. Particularly in China, the aging society's diverse needs are often met with service inadequacies and inefficient resource allocation within the elderly care cervices framework.

Objective: This study aims to investigate the transformative potential of digital technology, which includes innovations such as e-commerce, cloud computing, and artificial intelligence, on elderly care cervices in China. The objective is to assess the impact of digital technology on service quality, resource allocation, and operational efficiency within the elderly care cervices domain.

Methods: Employing Stata software, the study conducts an analysis of panel data from 30 Chinese provinces over the period from 2014 to 2021, examining the integration and application of digital technology within elderly care cervices to identify trends and correlations.

Results: The findings reveal that the integration of digital technology significantly enhances elderly care cervices, improving resource allocation and personalizing care, which in turn boosts the quality of life for the elderly. Specifically, a one-percentage point increase in the development and adoption of digital technology within elderly care cervices is associated with a 21.5 percentage point increase in care quality.

Conclusion: This research underscores the pivotal role of digital technology in revolutionizing elderly care cervices. The findings offer a strategic guide for policymakers and stakeholders to effectively harness digital technology, addressing the challenges posed by an aging society and enhancing the efficiency and accessibility of elderly care cervices in China. The application of digital technology in elderly care cervices is set to become a cornerstone in the future of elderly care, ensuring that the needs of the aging population are met with innovative and compassionate solutions.

1. Introduction

The global challenge posed by aging societies is becoming increasingly urgent. Forecasts by the United Nations suggest that by 2050, the proportion of people aged 65 and over will rise from 10 % in 2022 to 16 %. This demographic transformation, spurred by progress in healthcare and improved living standards, has been especially notable in developed nations. In these countries, elderly care services (ECS) are experiencing a surge in demand, both in terms of quantity and quality. Inefficient resource allocation is making it harder for many countries to satisfy these growing needs, underscoring the importance of a worldwide focus on enhancing ECS development.

In China, rapid economic growth and an aging population have heightened the need for elderly care. The rising number of seniors and their varied needs have revealed the shortcomings of existing services, worsened by inefficient resource allocation. Traditionally,

* Corresponding author.
** Corresponding author.
*** Corresponding author.
E-mail addresses: jiaxinhe@snnu.edu.cn (J. He), he5257384@gmail.com (D. Sui), lilingpeng@snnu.edu.cn (L. Li).
[1] These authors contributed equally to this work.

https://doi.org/10.1016/j.heliyon.2024.e41490
Received 30 June 2024; Received in revised form 23 December 2024; Accepted 24 December 2024
Available online 25 December 2024

eldercare has relied on informal family care and community support, a model that now struggles to cater to the complex and diverse needs of the elderly. The development of ECS is crucial for China to address aging and to balance supply and demand. The rise of digital technology (DT)[2] offers a solution to improve ECS quality, with studies emphasizing the role of digitization in advancing public services.

DT's rapid progress presents innovative solutions to address the challenges facing ECS. Smart home systems, for instance, can improve elderly living conditions through advanced sensors and monitoring devices. Telemedicine enables timely healthcare delivery via video consultations. Meanwhile, data analytics and Artificial Intelligence facilitate optimized resource allocation and personalized ECS solutions. Digital management platforms further boost service efficiency and quality. The integration of these technologies not only alleviates resource shortages but also improves the quality of life for the elderly. Consequently, examining the mechanisms through which DT can drive ECS development is essential for addressing the complex challenges of aging in China.

Current research indicates that the application of DT in the field of ECS mainly focuses on enhancing service efficiency and quality. For example, Sestino et al. (2020) found that "IoT and Big Data technologies create an efficient and stable ecosystem for smart ECS, offering a higher quality service experience for the elderly [1]. On this basis, scholars further argue that DT enhances the overall efficiency of ECS by reducing transaction costs for service exchanges and accelerating the flow of industrial elements, thereby achieving precise alignment between supply and demand [2,3]. Additionally, novel ECS models based on technology have been widely proposed. These models aim to enhance the quality of life for the elderly population, while concurrently alleviating the burden on healthcare systems and minimizing operational costs to the greatest extent possible [4–6]. Scholars have validated the positive role of DT in optimizing resource allocation and enhancing service matching within community-based ECS from the perspective of resource allocation in community ECS [7,8].

In terms of driving mechanisms, current research underscores the significance of smart ECS in enhancing the sense of security, happiness, and experience for the elderly. The application of DT not only elevates the level of service professionalization but also bolsters the overall quality of life for the elderly [9–11]. However, the current service model exhibits imbalances in the supply structure and a mismatch between supply and demand [12]. To optimize this, there is a need for institutional development, diversified supply, and standardized service operation mechanisms. Concurrently, the issue of the digital divide faced by the elderly when engaging with smart ECS has garnered significant attention [13].

The current scholarly discourse has examined the role of DT in propelling the enhancement of ECS from multiple dimensions, thereby enriching the theoretical landscape. Nevertheless, there is an identified need for further investigation in this domain: Initially, the delineation of the mechanisms through which DT enhances the quality of ECS remains in its nascent phase, with a need for more rigorous examination of the underlying processes. Secondly, the existing literature predominantly relies on qualitative methodologies to expound on the mechanisms by which DT can elevate the quality of ECS, and there is a paucity of empirical data to substantiate these claims.

In response to the identified research gaps, this paper sets out to investigate the underlying mechanisms through which DT can enhance the quality of ECS. The research is empirical in nature, involving the analysis of primary data obtained from official websites, supplemented by well-organized secondary data. Empirical research, in this context, entails a systematic examination of phenomena by collecting and analyzing data to test hypotheses and derive conclusions supported by statistical evidence. The dataset employed in this study comprises provincial panel data from China, ranging from 2014 to 2021, and includes 240 data points. This dataset is crafted to offer new empirical perspectives on the theories surrounding DT and ECS.

The anticipated contributions of this research are threefold:

1. Theoretical Advancement: By examining the impact of DT on resource allocation and service quality, this paper aims to enhance the theoretical comprehension of how DT can foster the development of ECS, offering a fresh viewpoint on the fundamental mechanisms propelling the advancement of ECS.
2. Empirical Evidence Expansion: By analyzing Chinese provincial panel data, this study seeks to provide empirical support for the theories regarding DT's contribution to the development of ECS, thus filling the gap in empirical evidence in this domain.
3. Policy Formulation and Guidance: The findings of this research are intended to supply policymakers with critical insights on leveraging DT to optimize ECS resource allocation and enhance service quality, thereby guiding the formulation of more impactful policies to address the challenges associated with an aging population.

2. Theoretical analysis and research hypotheses

The integration and advancement of DT are pivotal in driving economic growth [14–16], defined as an enhanced iteration of information and communication technologies (ICT) [17]. DT encompasses hardware, software, and network technologies, and is divided into two primary domains: the digital internet and digital informatization [18]. This paper posits that DT represents a deepened development of ICT, constituting an integrated technological system that merges various information technologies. It includes the growth of the digital internet and the progress in digital informatization, both of which are integral to its advancement.

Enhancing the quality of ECS to achieve higher-quality development is pivotal in the new era for addressing the challenges of aging. This advancement is driven by innovation, leading to a significant improvement in service quality. Additionally, it facilitates the

[2] The application of Digital Technology (DT) encompasses specific examples such as e-commerce platforms, cloud computing, and artificial intelligence.

coordination of resource structures for sustainable supply and promotes the optimization of the resource market through openness, thereby fostering a new model for the elderly to share in the fruits of development [19,20]. Therefore, this paper posits that the optimization of ECS quality represents a new development model, powered by innovation, which aims to elevate service quality, harmonize resource structures between regions and urban-rural areas, ensure the sustainability of production and supply, enhance the openness of ECS resources and markets, and promote the sharing of development outcomes among the elderly [21].

This paper delves into how DT drives the enhancement and rapid development of ECS through five key dimensions: innovation, coordination, sustainability, openness, and sharing [22,23].

Firstly, DT reduces barriers in information transmission [24], fostering the creation, dissemination, and spillover of knowledge, thereby providing a conducive environment for ECS innovation [25–27]. It also promotes the development of intelligent service equipment, significantly improving the efficiency of service provision [28].

Secondly, DT lowers transaction costs, accelerating the circulation of innovative elements [29]. It enables the effective integration of capital and labor, optimizing ECS resource allocation and enhancing the comprehensiveness and quality of services [30,31]. The pervasive nature of DT also promotes the coordinated development of ECS, breaking down regional barriers to resource information [32]. This facilitates data sharing and synergizes policies, standards, and functions within the eldercare industry [33,34]. This not only supports cross-regional resource allocation [35] but also fosters the integration of smart eldercare,[3] tourism eldercare,[4] and medical care industries,[5] enhancing urban-rural coordination and facilitating the efficient flow of capital and talent [36,37].

Thirdly, DT plays a pivotal role in promoting the sustainable development of ECS. It accelerates green innovation, optimizing the production models of ECS products, reducing resource consumption and pollution, and fostering green cycles within related industries [38]. Simultaneously, DT enhances resource matching efficiency [39], optimizing the quality and scale of service provision and reducing costs. Finally, DT drives the openness and shared development of ECS. The presence of DT expands the space for global service development, facilitating the transnational flow of resource elements. This meets the growing domestic demand for ECS. Moreover, DT's extensive connectivity provides technical support for integrating into the global value chain, reducing the costs of remote communication [40]. It also aids in learning from and adopting advanced ECS models across countries. Based on the aforementioned analysis, a framework illustrating DT's direct role in promoting high-quality development of ECS is established in Fig. 1.

The following research hypothesis is posited:

H1. Digital technology (DT) positively contributes to the advancement of the supply development of Elderly Care Services (ECS).

The widespread application of DT has accelerated the deep integration of traditional service industries with new technologies, giving rise to the emergence of new models and business formats. Due to data' s influence, a new aspect of production has emerged, leading to a significant change in how resources are distributed. This has improved the overall effectiveness of how production factors are allocated. Specifically, with respect to the allocation of capital elements, DT has optimized capital investment, facilitating an increase in the efficiency of factor allocation within ECS [41,42].

The penetration of DT into traditional finance has led to the development of digital inclusive finance [43], providing extensive financial support to ECS industry [44]. DT has also enhanced the interoperability of data and information [45], breaking down information barriers among ECS supply entities. This has improved the alignment of supply and demand for capital resources [46], expanding the scope of capital allocation in ECS [47]. Moreover, the growth of digital platforms has optimized service transaction processes and reduced the costs associated with information search and management [48], further enhancing the efficiency of capital resource allocation.

Regarding the allocation of labor resources, DT has facilitated the networking and cross-regional mobility of the workforce [49], optimizing labor allocation across different regions and entities and thereby improving the efficiency of factor allocation [50]. The application of DT has also given rise to various new ECS paradigms, creating more employment opportunities for the labor force [51–53]. Additionally, digital platforms have enabled precise matching of personnel to job positions, further optimizing labor resource allocation [54]. The emergence of new elderly care equipment is gradually phasing out low-skilled labor [55], promoting the cultivation and introduction of specialized talent in ECS.

Elevating the efficiency of resource allocation is pivotal to enhancing the quality of care provided by ECS. A well-planned allocation of resources not only boosts the driving force behind ECS development and fosters innovation, but also enhances the efficiency and quality of care delivery. This leads to a triple transformation in momentum, efficiency, and quality, ultimately driving the high-quality growth of ECS. In essence, DT fosters the high-quality development of ECS by improving the allocation efficiency of capital and labor resources. Drawing on the analysis presented, a framework (Fig. 2) has been developed to illustrate DT's indirect role in enhancing the supply quality of ECS.

Based on the aforementioned discussion, the following hypothesis is proposed:

H2. Digital Technology (DT) facilitates the enhancement of Elderly Care Services (ECS) supply quality by optimizing the allocation of

[3] smart eldercare:A Geriatric Care Approach Enhanced by Modern Technology to Improve the Quality of Life for the Elderly. For instance, smart bracelets can monitor the health status of the elderly, while smart home systems automatically adjust indoor temperatures and lighting.

[4] tourism eldercare:Seniors are blending retirement with the joy of travel, opting to reside in desirable locations for varying durations to relish life' s pleasures, engage in social activities, and explore new destinations. For instance, establishments like Haven Senior Living and Silver Travel Advisor facilitate this lifestyle.

[5] medical care industries: This sector encompasses the fusion of medical care with elderly services, aiming to deliver comprehensive care that includes healthcare, rehabilitation, wellness, and retirement support, all tailored to meet the needs of the aging population.

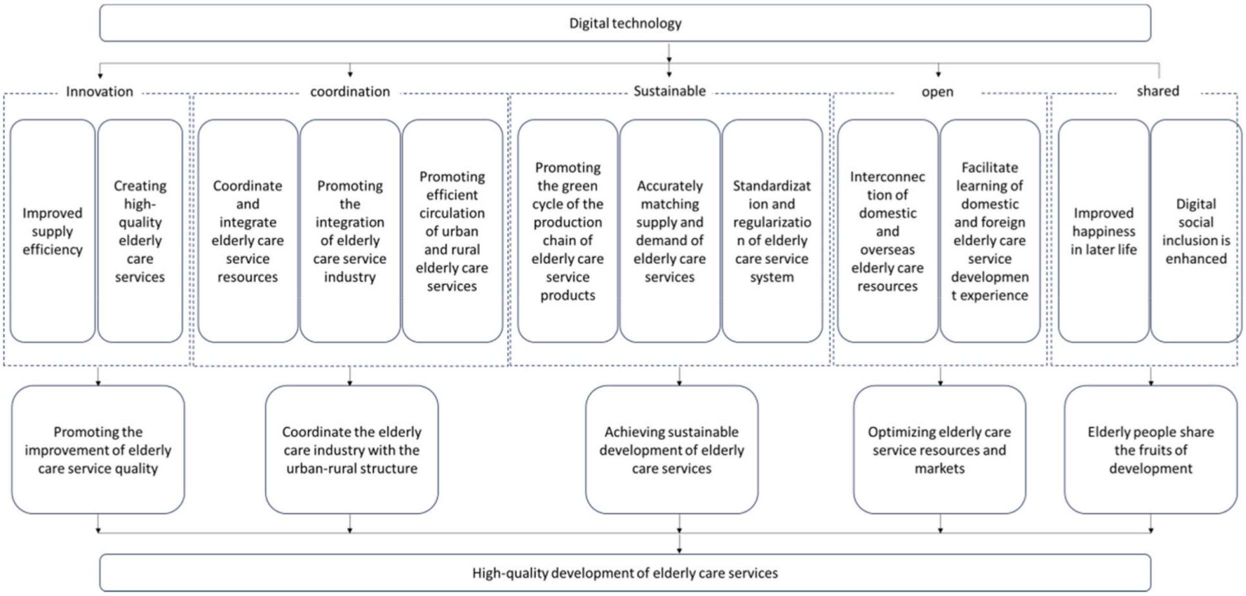

Fig. 1. The direct effect of digital technology in promoting high-quality development of elderly care services.

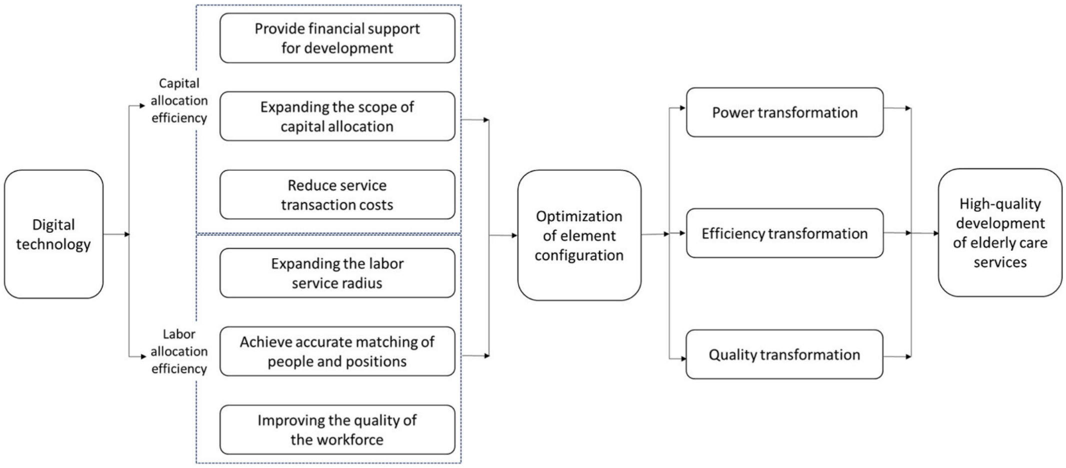

Fig. 2. Indirect effects of digital technology in promoting high-quality development of elderly care services.

resources.

3. Research design

This study employs a comprehensive research methodology, beginning with the construction of a measurement index system for enhancing the quality of ECS based on five dimensions: innovation, coordination, sustainability, openness, and sharing, with a particular focus on the needs of the elderly population. For assessing the level of DTdevelopment, a multidimensional measurement approach is adopted. Utilizing Stata software for data analysis, the study conducts regression analyses using Ordinary Least Squares (OLS) and fixed-effect models to examine the impact of DT on the improvement of ECS quality. Additionally, the paper performs regional heterogeneity analysis by dividing China's 30 provinces into eastern, central, and western regions to investigate regional variations in DT's influence. To ensure the robustness of the results, the study includes variable robustness tests, which involve alternative indicator systems, adjustments to the sample period, and the use of instrumental variables to address potential endogeneity issues. Moreover, the research integrates literature review and theoretical analysis, selecting appropriate control variables. All these analyses are conducted within Stata, effectively quantifying and validating the significant role of DT in enhancing the quality of ECS services.

4. Data sources

The data for this study are sourced from the "China Civil Affairs Statistical Yearbook," as well as the public statistical data released by the National Bureau of Statistics of China, provincial statistical bureaus, and relevant departments. To ensure data integrity and comparability, we excluded data from the Hong Kong, Macau, Taiwan regions, and Tibet during the data screening process. The administrative systems and statistical frameworks in the Hong Kong, Macau, and Taiwan regions differ from those in mainland China, making direct comparison with provincial data challenging. Additionally, the unique geographical environment, smaller population size, and occasional gaps in statistical data for Tibet might compromise the accuracy of the overall dataset and the reliability of the analytical outcomes. Consequently, to maintain research consistency and analytical precision, we selected data encompassing only the 30 provinces in mainland China as our study sample. Within the selected eight-year time frame (specific years determined by research requirements), each province provided continuous annual data, forming a sample set of 240 observations (30 provinces × 8 years). Although this decision restricts the geographic scope of the study, it contributes to the quality of the data used and the depth of the research conducted.

5. Variable definition and analysis

Drawing inspiration from Shi Dan and Wang Tao's (2022) [56]work on enhancing the quality of economic supply and Wang Xianju and Si Jianping's (2020) [57] research on improving the supply quality of institutional Elderly Care Services (ECS), this paper constructs a measurement indicator system for the development of ECS supply quality from the five dimensions of innovation, coordination, sustainability, openness, and sharing. This system particularly considers the unique needs of the elderly population, as well as social responsibility and equity, aiming to enable all elderly individuals to share in the fruits of social development, narrow the gaps between regions and urban-rural areas, and enhance the sense of well-being in life.

In essence, innovation serves as the pivotal driving force behind enhancing the quality of ECS supply [58,59]. Increasing financial investment and cultivating professional technical personnel can significantly optimize service content and models, thereby boosting both the quantity and quality of services [60]. Consequently, the indicators for the innovation dimension include the ratio of ECS financial investment to total fiscal expenditure and the number of professional technical personnel in eldercare institutions [61,62]. Coordination is a crucial characteristic of improving ECS supply quality, necessitating the integration and synergy within the eldercare industry and between urban and rural areas. The corresponding evaluation indicators are the ratio of ECS facility numbers between urban and rural areas and the ratio of minimum living security standards between urban and rural regions.

Sustainability, as emphasized by Sun et al. (2020), focuses on long-term development, with indicators such as the elderly dependency ratio and the accumulated surplus of basic endowment insurance [63–65]. Openness represents an inevitable trend for the long-term stable development of ECS, relying on the effective utilization of domestic and international resources, market optimization, and the continuous improvement of management knowledge. Thus, the indicator for the openness dimension is the proportion of social-run eldercare institutions in the total number of eldercare institutions.

The dimension of sharing is the ultimate goal of high-quality development, aiming to allow the elderly to share in the fruits of societal progress, enhance their well-being, and reduce disparities. The design of sharing indicators includes elder welfare expenditure, the coverage rate of community service institutions, and the number of eldercare beds per thousand elderly individuals, as indicated by Feng et al. (2020) [66] [67]. A detailed breakdown of these indicators is provided in Table 1.

6. Core explanatory variables

Currently, the academic community has not yet established a standardized definition of DT. Common measurement methods include keyword frequency, single indicators, and multidimensional indicators. Given the richness of the DT concept, this paper advocates for a multidimensional measurement approach to more comprehensively and accurately assess the level of DT development.

Table 1
Index system for measuring the development level of elderly care services.

First level indicator	Secondary indicators	Specific indicators	unit
Development of elderly care services	Innovation	Ratio of fiscal investment in elderly care services to fiscal expenditure	%
		Number of professional and technical personnel in nursing homes	people
	coordination	Ratio of the number of urban and rural elderly care service facilities	%
		Ratio of urban and rural minimum living standards	%
	Sustainable	Old-age dependency ratio	%
		Accumulated balance of basic pension insurance	10,000 Yuan
	openness	The proportion of social-run elderly care institutions to the total number of elderly care institutions	%
	sharing	Old-age welfare expenditure	10,000 Yuan
		Community service agency coverage	%
		Number of nursing beds per thousand elderly people	indivual

Drawing on an in-depth elucidation of the connotation of DT and referencing the evaluation index system constructed by Li Shuina (2021) [68], this study categorizes the level of DT development into two aspects: digital informatization and digital internetization. A total of 10 indicators are selected to establish a measurement index system for DT development. Considering the differences in population and area across regions, relative indicators are chosen to mitigate the impact of these factors on the overall assessment of development levels.

In the context of ECS, where the focus is on the unique needs of the elderly population, the application of DT is tailored to ensure simplicity, ease of use, and the fulfillment of health and daily living requirements. The integration of DT in ECS, as exemplified by health monitoring and management through wearable devices [69], is measured by a set of indicators that collectively highlight the importance of usability, customization, and health management. These include fiber optic density for stable online medical services and health monitoring, the proportion of employed personnel for personalized technical support, total business volume for the range and quantity of services, per capita income for service affordability, the number of domain names for online service platform diversity, density of internet access ports for connectivity convenience, resident population for the overall demand and market potential of ECS, and per capita mobile internet access traffic for usage frequency. These indicators are particularly relevant and targeted, ensuring that the DT deployed in ECS is both applicable and specifically designed to meet the needs of the elderly, as detailed in Table 2.

7. Mediating variables

The efficiency of factor allocation is a key mechanism in promoting the sustainable development of ECS. Optimizing the efficiency of factor allocation has a significant impact on improving the quality of ECS supply; the higher the efficiency, the better the development trend of supply quality. This study categorizes production factors into two main types: capital elements and labor elements. Following the research method of Xu Dongmei et al. (2022) [70], this paper employs the following indicators to quantify the efficiency of factor allocation: the ratio of elderly care institution revenue to fixed asset investment to measure capital allocation efficiency (CAP), and the ratio of elderly care institution revenue to the number of social workers to assess labor allocation efficiency (LAB). To ensure the uniformity of data at different orders of magnitude and prevent potential interference with regression analysis results, this paper performs logarithmic transformation on the aforementioned ratios.

8. Control variables

Drawing upon the research of Li Shiheng and Qu Xiao'e (2022) [71], this paper selects the following control variables: Infrastructure Level (INF), measured by per capita urban road area; Government Intervention (GOV), represented by the ratio of fiscal expenditure to regional GDP; Economic Openness Level (FDI), indicated by the ratio of total imports and exports to regional GDP; and the Proportion of the Tertiary Industry (TIT), calculated as the value added of the tertiary industry divided by regional GDP. The definitions of the main variables are presented in Table 3.

Descriptive statistics of the main variables are shown in Table 4.

9. Econometric model construction

Drawing on the research of Jiang Ting (2022) [72], the following model is established (the detailed process is provided in the Appendix).

$$CAP_{i,t} = \beta_0 + \beta_1 DIG_{i,t} + \rho X_{i,t} + C_{i,t} + D_{i,t} + \mu_{i,t} \tag{1}$$

$$LAB_{i,t} = \gamma_0 + \gamma_1 DIG_{i,t} + \sigma X_{i,t} + E_{i,t} + F_{i,t} + \varphi_{i,t} \tag{2}$$

Table 2
Digital technology development level measurement indicator system.

First level indicator	Secondary indicators	Specific indicators	unit
The level of development of digital technology	Digital information development level	Optical cable density (cable length per unit area)	km/hectare
		Ratio of employees in information transmission, software and information technology services to employees in urban areas	%
		Total telecommunications business volume per capita	10,000 yuan/person
		Software business revenue per capita	10,000 yuan/person
		Number of Internet domain names per capita	personal
	Digital Internet Development Level	Internet access port density (number of Internet access ports/number of permanent residents)	personal
		Mobile phone penetration rate	%
		Ratio of broadband Internet users to permanent population	%
		Ratio of mobile Internet users to permanent population	%
		Mobile Internet access traffic per capita	GB per person

Table 3
Main variable definitions.

Variable Types	Variable Symbols	Variable Name	Measurement method
Explained variable	OSH	High-quality development of elderly care services	Entropy calculation
Explanatory variables	DIG	Digital technology	Entropy calculation
Mediating variables	CAP	Capital allocation efficiency	Income/capital investment
	LAB	Labor allocation efficiency	Income/Labor Input
Control variables	INF	Infrastructure level	Urban road area/permanent population
	GOV	Government intervention	Fiscal expenditure/regional GDP
	FDI	Economic openness	Total imports and exports/regional GDP
	TIR	The ratio of the tertiary industry	Output value of tertiary industry/GDP

Table 4
Descriptive statistics of variables.

variable	Sample size	Mean	Standard Deviation	Minimum	Maximum
OSH	240	0.219	0.073	0.0900	0.434
DIG	240	0.235	0.136	0.0200	0.740
INF	240	16.98	4.924	4.110	26.78
GOV	240	0.263	0.111	0.105	0.753
FDI	240	0.101	0.139	0.000	0.742
TIR	240	0.515	0.082	0.370	0.837

In Equation (1), CAP represents capital allocation efficiency. In Equation (2), LAB denotes labor allocation efficiency. β_1 is the effect of DT on capital allocation efficiency, while γ_1 is the effect of DT on labor allocation efficiency.

10. Results

10.1. Primary effect regression analysis

This paper presents the regression results from both Ordinary Least Squares (OLS) and Fixed Effects models, as shown in Table 5. In detail, Model 1 presents the regression results without controlling for province and time fixed effects, whereas Model 2 accounts for these fixed effects. The regression findings reveal that whether or not control variables are included, and regardless of whether province and time fixed effects are controlled, the regression coefficient for DT remains positively significant, with the coefficient passing the 1 % significance test. The development of DT has a strong promotional impact on ECS, enhancing both its quantity and quality. This advancement can facilitate the better development of the eldercare industry, enabling the elderly to more fully benefit from the advantages brought about by social progress. It has the potential to become a new driving force behind the enhancement of ECS.

The regression results indicate that for every one percentage point increase in the development level of DT, the high-quality development level of ECS is estimated to rise by approximately 21.5 percentage points. This demonstrates that DT plays a

Table 5
Primary effect analysis.

Variables	Model 1		Model 2	
	OSH	OSH	OSH	OSH
DIG	0.265***	0.181***	0.247***	0.215***
	(0.030)	(0.042)	(0.025)	(0.055)
FDI		0.024		−0.250**
		(0.034)		(0.099)
GOV		−0.299***		−0.044
		(0.037)		(0.139)
INF		0.000		0.001
		(0.001)		(0.002)
TIR		0.043		−0.103
		(0.079)		(0.158)
constant	0.156***	0.226***	0.161***	0.238***
	(0.008)	(0.042)	(0.006)	(0.069)
year	No	No	Yes	Yes
province	No	No	Yes	Yes
N	240	240	240	240
R^2	0.245	0.449	0.321	0.343

Note: ***, **, and * denote significance levels of 1 %, 5 %, and 10 % respectively, with the t-values provided in parentheses.

significant role in improving the quality of ECS service provision.

10.2. Indirect effect test

As depicted in Table 6, Model 1 presents the regression results of the baseline model for the first stage, indicating that DT significantly promotes the enhancement of the supply quality in ECS. Models 2 and 3 report on the indirect effects of capital allocation efficiency and labor allocation efficiency in the process by which DT drives the development of ECS supply quality. The significant positive coefficients of DT on capital allocation efficiency and labor allocation efficiency in Models 2 and 3 suggest that the advancement of DT effectively increases both capital and labor allocation efficiencies.

10.3. Regional heterogeneity analysis

By assessing the advancement of Digital Technology (DT) and the enhancement of Elderly Care Services (ECS) supply quality, it has become evident that there are pronounced regional variations in the advancement of DT and ECS in different regions across China. Zhao Yankun (2022) [73] highlighted that the disparities in digital economy development exert a differential impact on the level of service sector development in various regions. Thus, the driving effect of DT on the enhancement of ECS supply quality may also exhibit regional disparities. It is necessary to delve into further research and analysis by categorizing China's 30 provinces into eastern, central, and western regions for a regional disparity analysis. The results of this analysis are detailed in Table 7.

In analyzing the regression results, we observed that the eastern, central, and western regions all exerted a significant positive influence on the improvement of ECS service quality. Notably, the impact of DT was more pronounced in the eastern and central regions, with their coefficients of influence being higher than those in the western region. This suggests that DT played a stronger role in driving the development of ECS in the eastern and central regions. In the eastern region, where DT levels are higher, DT has been successfully integrated into ECS, effectively harnessing its strengths to enhance service quality. The central region, meanwhile, has demonstrated a late-mover advantage in DT development. By actively adopting DT from the eastern region, it has established a digital ECS network, improved resource integration and information flow efficiency, reduced operational costs, and increased the efficiency of service element allocation. This has progressively narrowed the gap with the eastern region and propelled ECS towards a higher level of service quality.

10.4. Robustness checks for variables

Firstly, authors conduct robustness checks on the variables. Given that the measurement of Digital Technology (DT) development level is not confined to the indicator system chosen in this paper, we have re-estimated the model using different indicator measurement systems to ensure the reliability of our research conclusions. Drawing inspiration from the study by Huang et al. (2019) [74], we have reconstructed the DT measurement index system by focusing on two aspects: the development of communication technology and the development of information technology and related services. As shown in Table 8, the coefficient signs and significance levels of DT in these robustness checks are largely consistent with the previous regression results, indicating that our findings are robust and reliable.

Secondly, Robustness Checks with Adjusted Sample Interval: This paper performs robustness checks by adjusting the sample interval. Liu et al. (2020) [75] argue that the history of digital economy development includes a nascent stage and a period of robust

Table 6
Indirect effect test.

Variables	Model 1	Model 2	Model 3
	OSH	CAP	LAB
DIG	0.215***	2.219***	2.209*
	(0.055)	(0.660)	(1.161)
INF	−0.250**	0.560	−0.568
	(0.099)	(1.196)	(2.103)
GOV	−0.044	−0.847	−2.661
	(0.139)	(1.676)	(2.946)
FDI	0.001	−0.016	0.034
	(0.002)	(0.021)	(0.038)
TIR	−0.103	−3.103	−3.189
	(0.158)	(1.903)	(3.345)
constant	0.238***	1.837**	5.332***
	(0.069)	(0.828)	(1.456)
year	Yes	Yes	Yes
province	Yes	Yes	Yes
N	240	240	240
r2	0.343	0.114	0.108

Note: ***, **, and * denote significance levels of 1 %, 5 %, and 10 % respectively, with the t-values provided in parentheses.

Table 7
Regional heterogeneity analysis.

Variables	Eastern region	Central region	Western region
	OSH	OSH	OSH
DIG	0.281***	0.475**	0.141**
	(0.094)	(0.219)	(0.058)
FDI	−0.251*	−1.994	0.462*
	(0.149)	(1.282)	(0.235)
GOV	0.182	−0.487	−0.193
	(0.259)	(0.591)	(0.126)
INF	0.005	−0.004	−0.001
	(0.003)	(0.008)	(0.002)
TIR	−0.370	−0.337	−0.142
	(0.337)	(0.344)	(0.176)
constant	0.299*	0.554**	0.284***
	(0.154)	(0.211)	(0.074)
year	Yes	Yes	Yes
province	Yes	Yes	Yes
N	104	48	88
R^2	0.406	0.444	0.400

Note: ***, **, and * denote significance levels of 1 %, 5 %, and 10 % respectively, with the t-values provided in parentheses.

Table 8
Endogeneity test.

Variables	Replace variables	Adjust sample interval	Instrumental variable method
	OSH	OSH	OSH
DIG	0.039***	0.198***	0.335***
	(0.009)	(0.061)	(0.054)
FDI	−0.241**	−0.259**	−0.123
	(0.098)	(0.128)	(0.121)
GOV	0.019	−0.119	0.183
	(0.142)	(0.163)	(0.160)
INF	0.001	0.002	−0.002
	(0.002)	(0.002)	(0.002)
TIR	−0.182	0.108	−0.034
	(0.162)	(0.195)	(0.165)
constant	0.267***	0.145	0.156*
	(0.070)	(0.091)	(0.080)
year	Yes	Yes	Yes
province	Yes	Yes	Yes
N	240.000	210.000	210.000
R^2	0.355	0.356	0.442

Note: ***, **, and * denote significance levels of 1 %, 5 %, and 10 % respectively, with the t-values provided in parentheses.

growth, and that measuring the level of digital economy development during the nascent stage is of limited significance. Consequently, following their approach, we adjusted the sample interval to 2015–2021 for regression analysis. The results, presented in Table 7, show that the impact coefficient of DT on the quality of ECS service supply remains significant and is largely consistent with the previous regression findings, thereby confirming the reliability of our research results.

Thirdly, an endogeneity test is conducted using the instrumental variable approach. DT has the capacity to enhance the service quality of ECS. However, the increased demand for DT due to the improved service quality of ECS might also boost the development of DT, potentially leading to endogeneity issues in the model caused by two-way causality. To address the potential endogeneity, this paper employs the first-lagged period of the explanatory variable DT as an instrumental variable in the model estimation [76,77]. The estimation results, as shown in Table 8, indicate that the regression coefficients and significance levels for DT are largely consistent with those previously reported, with an even stronger effect, thereby confirming the reliability of the research findings.

11. Discussion

This study highlights the pivotal role of DT in enhancing the service quality of ECS. The results indicate that, with or without controlling for province and time fixed effects, DT significantly boosts both the quantity and quality of ECS. Moreover, DT indirectly elevates the quality of ECS by optimizing the efficiency of capital and labor allocation, indicating its potential in resource distribution optimization. However, an analysis of regional disparities reveals that the eastern regions take the lead in DT application, followed by the central regions, with the western regions showing a weaker promotional effect, uncovering issues of regional development imbalance. The robustness of the research findings is confirmed through various testing methods, validating the consistent positive impact of DT on ECS. These insights provide a basis for formulating differentiated policies for ECS.

The findings of this study contribute to a deeper understanding of how DT facilitates the enhancement of service quality in ECS. The research clearly articulates the positive influence of DT within the ECS domain, corroborating the notion that technological advancement is a pivotal factor in driving innovation and efficiency gains. This perspective aligns with the Technology Acceptance Model (TAM) and the theory of information technology capability, emphasizing the importance of technology's ease of use and perceived usefulness in improving service quality. The study resonates with a body of literature in which scholars suggest that the integration of older adults into an information technology society is an essential measure to address aging, and that the development of assistive technologies can effectively meet their needs. However, the design of technology must place greater emphasis on usability to minimize barriers encountered by the elderly during usage [78]. The case study of Personal Health Records (PHR) systems reveals a widespread perception among patients and care providers that these systems enhance communication effectiveness, further emphasizing the role of technology in ECS as a supportive rather than a substitutive tool [79]. It is noteworthy that a report by McKinsey & Company (2023) [80] indicates that 73 % of respondents acknowledged the substantial benefits of related DT in the realm of clinical productivity. These findings further substantiate that the application of DT offers more intelligent and personalized solutions for ECS, significantly enhancing the responsiveness and precision of service delivery.

Secondly, the application of digital technology (DT) indirectly promotes the quality of elderly care services (ECS) by enhancing the efficiency of capital and labor allocation. This not only optimizes service processes but also reduces service costs, thereby enhancing the sustainability of ECS. This finding provides empirical support for both the resource dependence theory and the dynamic capabilities theory, suggesting that firms can better integrate internal and external resources through the effective use of DT, thereby improving service quality and efficiency. In this context, scholarly research further illuminates the role of digital tools (e.g., social media, applications, chatbots, big data) in transforming the consumer value creation process. These tools facilitate the integration of new distribution channels under a omnichannel perspective, establishing deeper relationships with consumers [81]. Additionally, the research by Xings et al. (2023) [82], emphasize the transformative role of DT in the manufacturing industry, where resource integration has led to increased production efficiency and service quality. These research outcomes indicate that the in-depth application of DT is not only an effective means to elevate service levels in the ECS domain but also a crucial tool for building stronger consumer relationships.

Furthermore, the analysis of regional disparities reveals that the impact of DT is not uniformly distributed, which is closely related to factors such as regional economic development levels, technological infrastructure, and market maturity. The leading position of the eastern regions reflects their advantages in DT application, while the western regions require policy support and resource allocation to bridge this gap. This finding underscores the need to consider inter-regional differences and specific needs in the process of driving the nationwide enhancement of ECS quality. The robustness of the findings indicates that the promotional effect of DT on ECS is stable and reliable, providing strong evidence for policymakers and industry practitioners.

The application of DT in ECS has been found to significantly boost economic growth, a viewpoint supported by numerous studies. For instance, Abujamra and Randall (2019) [83] discovered that smart health devices and remote health monitoring have enhanced the efficiency and quality of ECS, thereby reducing medical expenditures and promoting economic benefits. Additionally, the research by Peng and Tao (2022) indicates that digital transformation has driven the development of the ECS industry and related technology sectors, stimulating economic growth across the entire industrial chain [84]. Litwin (2021) further notes that the application of DT has created a substantial number of emerging professions, thereby reducing unemployment rates and stimulating the economy [85]. At the same time, Batabyal and Nijkamp (2016) emphasize that the introduction of DT aids in narrowing the regional gap in areas with lagging economic development, promoting coordinated regional economic growth through the enhancement of service quality and the development of related industries [86].

The innovation of this paper is reflected in its systematic investigation into how DT enhances the service quality of ECS through an empirical analysis of China's provincial balanced panel data from 2014 to 2021, offering new empirical evidence for supporting related theories. Specifically, it delineates the meanings of DT and the improvement of service quality in ECS, thoroughly analyzes the mechanism by which DT promotes the enhancement of ECS service quality, and examines its influence on resource allocation and service standards. The study refines the theoretical framework for DT' s role in improving ECS service quality and presents a new perspective for comprehending its intrinsic dynamics; it addresses the empirical gap in existing research with its analysis, thereby reinforcing the empirical foundation of the theory. The results provide policymakers with a theoretical framework for optimizing ECS resource allocation and elevating service quality.

Nevertheless, the research does not adequately address the long-term effects, concerns regarding data privacy protection, and the digital divide that exists. Future studies should concentrate on prolonging the observation period to evaluate the enduring impact of DT and carry out cross-national or regional comparative analyses to investigate the generalization of the findings. Additionally, pinpointing the DT that most effectively contributes to the improvement of ECS will be instrumental in guiding targeted investments and policy decisions. Based on these insights, policymakers and stakeholders must grasp the opportunities offered by digitization, striving to build a thorough and effective ECS system that guarantees high service quality, inclusiveness, and long-term sustainability, thereby meeting the challenges posed by an aging society.

12. Conclusions and implications

This paper focuses on how DT enhances the service quality of ECS. It begins by theoretically explaining the intrinsic mechanisms through which DT promotes the improvement of ECS service quality. Then, using panel data from China's 30 provinces from 2014 to

2021, it empirically tests the direct and indirect enabling effects of DT on enhancing ECS service quality, leading to the following conclusions: Nationally, DT plays a positive role in promoting the improvement of ECS service quality; in terms of specific pathways, DT optimizes the efficiency of resource allocation, thereby enhancing the service quality of ECS. Regionally, DT has a stronger promotional effect in the eastern and central regions of China.

The important implications of these conclusions are as follows: In the new era of digital economy development, we should seize the opportunities presented by DT to promote the deep integration of DT and ECS, and to enhance the contribution of DT to the improvement of ECS service quality. Traditional industries will focus on breaking through bottlenecks and reshaping service models, with DT and other emerging elements becoming the core driving force for generating new momentum and business forms. Under the empowerment of DT, the pace of integrating DT with ECS applications will accelerate. The results indicate that DT can significantly promote the improvement of ECS service quality. In the process of advancing ECS service quality, we should seize the opportunity of integrating DT with the real economy, accelerate and deepen the integration of new technologies such as big data, robotics, the Internet of Things, and 5G/6G, guide DT to permeate every link of the ECS production process, accelerate the transformation of DT application results, and promote the digital construction and service quality improvement of ECS. This will realize precision, diversified, and high-quality supply of ECS, allowing the elderly to enjoy a higher quality of life in their later years.

At the same time, we should formulate differentiated development strategies to promote the coordinated development of ECS across different regions. The results show that there are differences in the contribution of DT to the improvement of ECS service quality among the eastern, central, and western regions, with a stronger promotional effect in the eastern and central regions. Therefore, to promote regional balanced development strategies and the goal of building a digital China, regions with relatively developed economies and higher levels of DT should accelerate the research and development, application promotion, and deep integration of DT with ECS, further expand the application scope of DT in the ECS field, and strengthen its leading and boosting role in the improvement of ECS service quality. For regions with lower levels of economic and DT development, it is necessary to increase financial support for DT development, invest more in DT research and development, and cultivate digital talent, accelerate the cultivation of digital industries, and thus provide a favorable environment for the digital construction of ECS, improving its digital development level and promoting the service quality improvement of ECS.

CRediT authorship contribution statement

Jiaxin He: Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Dangchen Sui:** Writing – review & editing, Writing – original draft, Validation, Project administration, Funding acquisition, Data curation, Conceptualization. **Lingpeng Li:** Writing – review & editing, Writing – original draft, Visualization, Resources, Methodology, Investigation, Data curation, Conceptualization. **Xinyan Lv:** Methodology, Investigation.

Informed consent

Not applicable, as no human participants were involved in the research.

Data and code availability statement

Data will be made available on request.

The data utilized in this article were sourced from the China Statistical Yearbook and the China National Statistical Yearbook, which are publicly available on government websites. For detailed calculations and data organization, interested parties may contact the corresponding author via email for further information.

Human and animal research

This article does not report on any studies involving human participants or animals, as it is based on the analysis of data from the China Statistical Yearbook and the China National Statistical Yearbook.

Animal rights

Not applicable, as no animals were used in this research.

Duplicate publication and plagiarism

The authors confirm that this article has not been published elsewhere and is not under consideration by another journal. All authors have agreed to the content of the manuscript and there is no plagiarism or substantial similarity with any work which is in press or published or under consideration for publication elsewhere.

Funding

This research is led by Sui Dangchen and is financially supported by the Humanities and Social Sciences Project of the Ministry of

Education. The project is titled “Study on the Internal Mechanism and Realization Path of High-Quality Development of Elderly Care Services Empowered by Digital Technology”, with the grant number 22YJA840009.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to express our sincere gratitude to Professor Sui Dangchen for his financial support, which was instrumental in conducting this research. We also extend our thanks to Li Lingpeng for his dedication and hard work in collecting and organizing the data during his master’s program. Additionally, we are deeply appreciative of the valuable suggestions and comments provided by the Editor-in-Chief and the editorial board. Their meticulous attention to detail and high level of academic dedication have significantly enhanced the quality of this manuscript.

Appendix

Construction of econometric model

First, in order to test the direct impact of digital technology on the high-quality development of elderly care services, the following benchmark regression model is constructed:

$$OSH_{i,t} = \alpha_0 + \alpha_1 DIG_{i,t} + \delta X_{i,t} + A_{i,t} + B_{i,t} + \varepsilon_{i,t} \tag{1a}$$

In formula (1), OSH is the high-quality development level of elderly care services, DIG is the development level of digital technology, and X is the control variable of this paper. A is the individual fixed effect, which controls the factors that do not change over time at the provincial level, such as geographical location; B is the time fixed effect. ε It represents the random error term.

Secondly, in order to further test the indirect role of factor allocation optimization in enabling high-quality development of elderly care services through digital technology, the following model is established based on the research of Jiang Ting:

$$CAP_{i,t} = \beta_0 + \beta_1 DIG_{i,t} + \rho X_{i,t} + C_{i,t} + D_{i,t} + \mu_{i,t} \tag{2a}$$

$$LAB_{i,t} = \gamma_0 + \gamma_1 DIG_{i,t} + \sigma X_{i,t} + E_{i,t} + F_{i,t} + \varphi_{i,t} \tag{3}$$

In formula (2), CAP represents capital allocation efficiency, and in formula (3), LAB represents labor allocation efficiency. β_1 is the effect of digital technology on capital allocation efficiency, and γ_1 is the effect of digital technology on labor allocation efficiency.

References

[1] A. Sestino, M.I. Prete, L. Piper, G. Guido, Internet of Things and Big Data as enablers for business digitalization strategies, Technovation 98 (2020) 102173, https://doi.org/10.1016/j.technovation.2020.102173.
[2] L. Shen, X. Zhang, H. Liu, Digital technology adoption, digital dynamic capability, and digital transformation performance of textile industry: moderating role of digital innovation orientation, Manag. Decis. Econ. 43 (6) (2022) 2038–2054, https://doi.org/10.1002/mde.3507.
[3] A. Aoun, A. Ilinca, M. Ghandour, H. Ibrahim, A review of Industry 4.0 characteristics and challenges, with potential improvements using blockchain technology, Comput. Ind. Eng. 162 (2021) 107746, https://doi.org/10.1016/j.cie.2021.107746.
[4] S.Y.Y. Tun, S. Madanian, F. Mirza, Internet of things (IoT) applications for elderly care: a reflective review, Aging Clin. Exp. Res. 33 (2021) 855–867, https://doi.org/10.1007/s40520-020-01545-9.
[5] D. Lee, S.N. Yoon, Application of artificial intelligence-based technologies in the healthcare industry: opportunities and challenges, Int. J. Environ. Res. Publ. Health 18 (1) (2021) 271, https://doi.org/10.3390/ijerph18010271.
[6] W. Li, T. Yigitcanlar, I. Erol, A. Liu, Motivations, barriers and risks of smart home adoption: from systematic literature review to conceptual framework, Energy Res. Social Sci. 80 (2021) 102211, https://doi.org/10.1016/j.erss.2021.102211.
[7] S. Hermes, T. Riasanow, E.K. Clemons, et al., The digital transformation of the healthcare industry: exploring the rise of emerging platform ecosystems and their influence on the role of patients, Bus Res 13 (2020) 1033–1069, https://doi.org/10.1007/s40685-020-00125-x.
[8] J. Pirhonen, L. Lolich, K. Tuominen, O. Jolanki, V. Timonen, “These devices have not been made for older people’s needs”–Older adults’ perceptions of digital technologies in Finland and Ireland, Technol. Soc. 62 (2020) 101287, https://doi.org/10.1016/j.techsoc.2020.101287.
[9] T.H. Jo, J.H. Ma, S.H. Cha, Elderly perception on the internet of things-based integrated smart-home system, Sensors 21 (4) (2021) 1284, https://doi.org/10.3390/s21041284.
[10] S. Baraković, J. Baraković Husić, J. Van Hoof, O. Krejcar, P. Maresova, Z. Akhtar, F.J. Melero, Quality of life framework for personalised ageing: a systematic review of ICT solutions, Int. J. Environ. Res. Publ. Health 17 (8) (2020) 2940, https://doi.org/10.3390/ijerph17082940.
[11] C. Bianchi, Exploring how internet services can enhance elderly well-being, J. Serv. Market. 35 (5) (2021) 585–603, https://doi.org/10.1108/JSM-05-2020-0177.
[12] F.O. Oderanti, F. Li, M. Cubric, X. Shi, Business models for sustainable commercialisation of digital healthcare (eHealth) innovations for an increasingly ageing population, Technol. Forecast. Soc. Change 171 (2021) 120969, https://doi.org/10.1016/j.techfore.2021.120969.

[13] S.Y. Shin, D. Kim, S.A. Chun, Digital divide in advanced smart city innovations, Sustainability 13 (7) (2021) 4076, https://doi.org/10.3390/su13074076.
[14] E.M. Solomon, A. van Klyton, The impact of digital technology usage on economic growth in Africa, Util. Pol. 67 (2020) 101104, https://doi.org/10.1016/j.jup.2020.101104.
[15] Y. Xue, C. Tang, H. Wu, J. Liu, Y. Hao, The emerging driving force of energy consumption in China: does digital economy development matter? Energy Pol. 165 (2022) 112997 https://doi.org/10.1016/j.enpol.2022.112997.
[16] W. Pan, T. Xie, Z. Wang, L. Ma, Digital economy: an innovation driver for total factor productivity, J. Bus. Res. 139 (2022) 303–311, https://doi.org/10.1016/j.jbusres.2021.09.061.
[17] J. Su, K. Su, S. Wang, Does the digital economy promote industrial structural upgrading?—a test of mediating effects based on heterogeneous technological innovation, Sustainability 13 (18) (2021) 10105, https://doi.org/10.3390/su131810105.
[18] M. Núñez-Merino, J.M. Maqueira-Marín, J. Moyano-Fuentes, P.J. Martínez-Jurado, Information and digital technologies of Industry 4.0 and Lean supply chain management: a systematic literature review, Int. J. Prod. Res. 58 (16) (2020) 5034–5061, https://doi.org/10.1080/00207543.2020.1743896.
[19] K. Sen, G. Prybutok, V. Prybutok, The use of digital technology for social wellbeing reduces social isolation in older adults: a systematic review, SSM-population health 17 (2022) 101020, https://doi.org/10.1016/j.ssmph.2021.101020.
[20] B.J. Blažič, A.J. Blažič, Overcoming the digital divide with a modern approach to learning digital skills for the elderly adults, Educ. Inf. Technol. 25 (2020) 259–279, https://doi.org/10.1007/s10639-019-09961-9.
[21] X. Xu, Y. Zhao, J. Zhou, S. Xia, Quality-of-life evaluation among the oldest-old in China under the "active aging framework", Int. J. Environ. Res. Publ. Health 19 (8) (2022) 4572, https://doi.org/10.3390/ijerph19084572.
[22] X. Wang, C. Qin, Y. Liu, C. Tanasescu, J. Bao, Emerging enablers of green low-carbon development: do digital economy and open innovation matter? Energy Econ. 127 (2023) 107065 https://doi.org/10.1016/j.eneco.2023.107065.
[23] C. Xu, S. Zhu, B. Yang, B. Miao, Y. Duan, A review of policy framework research on promoting sustainable transformation of digital innovation, Sustainability 15 (9) (2023) 7169, https://doi.org/10.3390/su15097169.
[24] S. Liang, Q. Tan, Can the digital economy accelerates China's export technology upgrading? Based on the perspective of export technology complexity, Technol. Forecast. Soc. Change 199 (2024) 123052, https://doi.org/10.1016/j.techfore.2023.123052.
[25] A. Di Vaio, R. Palladino, A. Pezzi, D.E. Kalisz, The role of digital innovation in knowledge management systems: a systematic literature review, J. Bus. Res. 123 (2021) 220–231, https://doi.org/10.1016/j.jbusres.2020.09.042.
[26] L. Ma, B. Zhang, K. Liang, Y. Cheng, C. Yi, Digital enabled innovation ecosystems: a dual case study of knowledge flows in intellectual property platforms, Eur. J. Innovat. Manag. (2024).
[27] I. Blau, T. Shamir-Inbal, O. Avdiel, How does the pedagogical design of a technology-enhanced collaborative academic course promote digital literacies, self-regulation, and perceived learning of students? Internet High Educ. 45 (2020) 100722 https://doi.org/10.1016/j.iheduc.2019.100722.
[28] A. Kulal, H.U. Rahiman, H. Suvarna, N. Abhishek, S. Dinesh, Enhancing public service delivery efficiency: exploring the impact of AI, Journal of Open Innovation: Technology, Market, and Complexity 10 (3) (2024) 100329, https://doi.org/10.1016/j.joitmc.2024.100329.
[29] W. Pan, T. Xie, Z. Wang, L. Ma, Digital economy: an innovation driver for total factor productivity, J. Bus. Res. 139 (2022) 303–311, https://doi.org/10.1016/j.jbusres.2021.09.061.
[30] Y. Zhang, M. Zhang, H. Hu, X. He, Spatio-temporal characteristics of the supply and demand coupling coordination of elderly care service resources in China, Int. J. Environ. Res. Publ. Health 19 (16) (2022) 10397, https://doi.org/10.3390/ijerph191610397.
[31] A. Grigorescu, E. Pelinescu, A.E. Ion, M.F. Dutcas, Human capital in digital economy: an empirical analysis of central and eastern European countries from the European Union, Sustainability 13 (4) (2021) 2020, https://doi.org/10.3390/su13042020.
[32] Y. Tim, L. Cui, Z. Sheng, Digital resilience: how rural communities leapfrogged into sustainable development, Inf. Syst. J. 31 (2) (2021) 323–345, https://doi.org/10.1111/isj.12312.
[33] S. Quach, P. Thaichon, K.D. Martin, S. Weaven, R.W. Palmatier, Digital technologies: tensions in privacy and data, J. Acad. Market. Sci. 50 (6) (2022) 1299–1323, https://doi.org/10.1007/s11747-022-00845-y.
[34] L. Tedersoo, R. Küngas, E. Oras, K. Köster, H. Eenmaa, Ä. Leijen, T. Sepp, Data sharing practices and data availability upon request differ across scientific disciplines, Sci. Data 8 (1) (2021) 192, https://doi.org/10.1038/s41597-021-00981-0.
[35] P. Dong, Y. Zhu, S. Duan, M. Wu, J. Bao, How does the digital economy promote a culture of business innovation? A study based on human capital allocation perspective, Sustainability 15 (8) (2023) 6511, https://doi.org/10.3390/su15086511.
[36] S. Carlisle, S. Ivanov, C. Dijkmans, The digital skills divide: evidence from the European tourism industry, J. Tourism Futur. 9 (2) (2023) 240–266, https://doi.org/10.1108/JTF-07-2020-0114.
[37] V. Zander, R.M. Johansson-Pajala, C. Gustafsson, Methods to evaluate perspectives of safety, independence, activity, and participation in older persons using welfare technology. A systematic review, Disabil. Rehabil. Assist. Technol. 15 (4) (2020) 373–393, https://doi.org/10.1080/17483107.2019.1574919.
[38] H. Wang, P.C. Coyte, W. Shi, X. Zong, R. Zhong, Social governance and sustainable development in elderly services: innovative models, strategies, and stakeholder perspectives, Sustainability 15 (21) (2023) 15414, https://doi.org/10.3390/su152115414.
[39] S. Wyciślak, P. Pourhejazy, Supply chain control tower and the adoption of intelligent dock booking for improving efficiency, Front. Energy Res. 11 (2023) 1275070, https://doi.org/10.3389/fenrg.2023.1275070.
[40] S.G.S. Shah, D. Nogueras, H.C. Van Woerden, V. Kiparoglou, The COVID-19 pandemic: a pandemic of lockdown loneliness and the role of digital technology, J. Med. Internet Res. 22 (11) (2020) e22287, https://doi.org/10.2196/22287.
[41] W. Qian, H. Liu, F. Pan, Digital economy, industry heterogeneity, and service industry resource allocation, Sustainability 14 (13) (2022) 8020, https://doi.org/10.3390/su14138020.
[42] G. Secundo, S.R. Shams, F. Nucci, Digital technologies and collective intelligence for healthcare ecosystem: optimizing Internet of Things adoption for pandemic management, J. Bus. Res. 131 (2021) 563–572, https://doi.org/10.1016/j.jbusres.2021.01.034.
[43] F. Mubarak, R. Suomi, Elderly forgotten? Digital exclusion in the information age and the rising grey digital divide, Inquiry: The Journal of Health Care Organization, Provision, and Financing 59 (2022) 00469580221096272, https://doi.org/10.1177/00469580221096272.
[44] M.M. Hasan, L. Yajuan, A. Mahmud, Regional development of China's inclusive finance through financial technology, Sage Open 10 (1) (2020) 2158244019901252, https://doi.org/10.1177/2158244019901252.
[45] D. Hodapp, A. Hanelt, Interoperability in the era of digital innovation: an information systems research agenda, J. Inf. Technol. 37 (4) (2022) 407–427, https://doi.org/10.1177/02683962211064304.
[46] Y. Liu, Y. Yang, H. Li, K. Zhong, Digital economy development, industrial structure upgrading and green total factor productivity: empirical evidence from China's cities, Int. J. Environ. Res. Publ. Health 19 (4) (2022) 2414, https://doi.org/10.3390/ijerph19042414.
[47] D. Rohn, P.M. Bican, A. Brem, S. Kraus, T. Clauss, Digital platform-based business models–An exploration of critical success factors, J. Eng. Technol. Manag. 60 (2021) 101625, https://doi.org/10.1016/j.jengtecman.2021.101625.
[48] A. Rangaswamy, N. Moch, C. Felten, G. Van Bruggen, J.E. Wieringa, J. Wirtz, The role of marketing in digital business platforms, J. Interact. Market. 51 (1) (2020) 72–90, https://doi.org/10.1016/j.intmar.2020.04.006.
[49] P. Li, X. Li, G. Yuan, Cross-regional allocation of human capital and sustainable development of China's regional economy—based on the perspective of population mobility, Sustainability 15 (12) (2023) 9807, https://doi.org/10.3390/su15129807.
[50] L. Mewes, T. Broekel, Technological complexity and economic growth of regions, Res. Pol. 51 (8) (2022) 104156, https://doi.org/10.1016/j.respol.2020.104156.
[51] T. Ciarli, M. Kenney, S. Massini, L. Piscitello, Digital technologies, innovation, and skills: emerging trajectories and challenges, Res. Pol. 50 (7) (2021) 104289, https://doi.org/10.1016/j.respol.2021.104289.
[52] P. Bejaković, Ž. Mrnjavac, The importance of digital literacy on the labour market, Employee Relat. 42 (4) (2020) 921–932, https://doi.org/10.1108/ER-07-2019-0274.

[53] F. Kitsios, I. Giatsidis, M. Kamariotou, Digital transformation and strategy in the banking sector: evaluating the acceptance rate of e-services, Journal of Open Innovation: Technology, Market, and Complexity 7 (3) (2021) 204, https://doi.org/10.3390/joitmc7030204.
[54] U. Rani, M. Furrer, Digital labour platforms and new forms of flexible work in developing countries: algorithmic management of work and workers, Compet. Change 25 (2) (2021) 212–236, https://doi.org/10.1177/1024529420905187.
[55] T. Le, H.Q. Nguyen, M. Vu, Robot revolution and human capital accumulation: implications for growth and labour income, J. Evol. Econ. 34 (1) (2024) 89–126, https://doi.org/10.1007/s00191-024-00854-w.
[56] D. Shi, T. Wang, Regional Differences and Spatial Convergence of High-Quality Development Levels: Based on the Perspective of New Development Concepts, Research on Technology Economics and Management, 2022, pp. 103–109, 8, https://kns.cnki.net/kcms2/article/abstract?v=sMQVub3UVPix3Uc1ZI-u7FLKDHEuMTpKao8ttJ54zM9aEUUGkOdDqjiT_xVDUV8L7lv019qIyJ0jEEzYd9pAEK7SsAhHOJNYMbPdwWBsQ8AKuEc6OF_S65eWoY1DMt5C187Kzvme3Wnv81e7xHW2ue_cMlRIVHpqTspfx44C-U79zOxC0Q4QYA==&uniplatform=NZKPT&language=CHS.
[57] X.J. Wang, J.P. Si, Construction of institutional ECS supply evaluation indicators based on the concept of high-quality development, Chinese Journal of Gerontology 40 (8) (2020) 1789–1792. https://kns.cnki.net/kcms2/article/abstract?v=sMQVub3UVPgIezM_w5KUDe960eHCo_8qJKjmfWTGLNczSlKjuFp84C8Jcz5zpymjntGr6jvVTjm2ODBqEheV92lgYim-wSfjiUVN8ckizT1k2Z84Jnqvp-QuT-QJRXLRTebwr4skT8e–RVDDJgdxzJmJBsAbOTI-K2n7iqjhKNxo89Y-LuiZt7tQn7c9_F–8VUWbb9ducnir9TUMTjy_R_GsVtO1NgAmsMeyuo-kGV-x3tAkzqu3Tkz7NoeetgM8KjLgndXb-DYYKxNA4Bqg==&uniplatform=NZKPT&language=CHS.
[58] T. Chen, W. Guo, X. Gao, Z. Liang, AI-based self-service technology in public service delivery: user experience and influencing factors, Govern. Inf. Q. 38 (4) (2021) 101520, https://doi.org/10.1016/j.giq.2020.101520.
[59] D. Martinho, J. Carneiro, J.M. Corchado, G. Marreiros, A systematic review of gamification techniques applied to elderly care, Artif. Intell. Rev. 53 (7) (2020) 4863–4901, https://doi.org/10.1007/s10462-020-09809-6.
[60] H. Yangming, L. Sha, L. Hui, Y. Yanda, Study on the measurement of coupling and coordinated development level between China's internet and elderly care services and its influencing factors, BMC Publ. Health 24 (1) (2024) 920, https://doi.org/10.1186/s12889-024-18291-6.
[61] H. Zhu, Spatial matching and policy-planning evaluation of urban elderly care facilities based on multi-agent simulation: evidence from Shanghai, China, Sustainability 14 (23) (2022) 16183, https://doi.org/10.3390/su142316183.
[62] Y. Han, Y. He, J. Lyu, C. Yu, M. Bian, L. Lee, Aging in China: perspectives on public health, Global Health Journal 4 (1) (2020) 11–17, https://doi.org/10.1016/j.glohj.2020.01.002.
[63] L. Sun, C. Su, X. Xian, Assessing the sustainability of China's basic pension funding for urban and rural residents, Sustainability 12 (7) (2020) 2833, https://doi.org/10.3390/su12072833.
[64] A. Čajková, P. Čajka, Challenges and sustainability of China's socio-economic stability in the context of its demographic development, Societies 11 (1) (2021) 22, https://doi.org/10.3390/soc11010022.
[65] J.E. Devesa-Carpio, B. Rosado-Cebrian, J. Álvarez-García, Sustainability of public pension systems, in: Economic Challenges of Pension Systems: A Sustainability and International Management Perspective, 2020, pp. 125–154, https://doi.org/10.1007/978-3-030-37912-4_6.
[66] Z. Feng, E. Glinskaya, H. Chen, S. Gong, Y. Qiu, J. Xu, W. Yip, Long-term care system for older adults in China: policy landscape, challenges, and future prospects, Lancet 396 (10259) (2020) 1362–1372, https://doi.org/10.1016/S0140-6736(20)32136-X.
[67] J. Lubitz, L. Cai, E. Kramarow, H. Lentzner, Health, life expectancy, and health care spending among the elderly, N. Engl. J. Med. 349 (11) (2003) 1048–1055, https://doi.org/10.1056/NEJMsa020614.
[68] S.N. Li, Digital technology empowers productivity of services industry: theoretical mechanisms and empirical evidence, Research on Economics and Management 40 (10) (2021) 51–67, https://doi.org/10.13502/j.cnki.issn1000-7636.2021.10.004.
[69] T.G. Stavropoulos, A. Papastergiou, L. Mpaltadoros, S. Nikolopoulos, I. Kompatsiaris, IoT wearable sensors and devices in elderly care: a literature review, Sensors 20 (10) (2020) 2826, https://doi.org/10.3390/s20102826.
[70] D.M. Xu, Q. Wu, C.Q. Tao, How digital technology affects the high-quality development of manufacturing, Journal of Jiangxi Normal University (Natural Science Edition) 36 (6) (2022) 585–593, https://doi.org/10.16357/j.cnki.issn1000-5862.2022.06.05.
[71] S.H. Li, X.E. Qu, Digital economy empowers high-quality development of manufacturing industry: theoretical mechanism and empirical test, Exploration of Economic Issues (10) (2022) 105–117. https://kns.cnki.net/kcms2/article/abstract?v=sMQVub3UVPgLVHS6rA3GDd7RwO1lJisKeMhe7dA-8bBZoISshUKx5gLduomS8uSJNY1KSkOJ7fgembuar_vS5LBhkkKM0NquOYRaxR_matqNwMDha__b5S_0-9so-bDDtPlVdoIRyeNKDHQM1aDwPW_ZPYdfdShjvLK5QWUQfAuONl0RGDjZ_gijZxhH9xuuKtk5TPtTcdTfYmL1HhlqyxV18F_ufuDH&uniplatform=NZKPT&language=CHS.
[72] T. Jiang, Mediating effects and moderating effects in causal inference, China Industrial Economics (5) (2022) 100–120, https://doi.org/10.19581/j.cnki.ciejournal.2022.05.005.
[73] Y.K. Zhao, Mechanism of digital economy on the optimization of service industry structure, Wuhan University of Technology Journal (Social Science Edition) 35 (2) (2022) 116–125. https://kns.cnki.net/nzkhtml/xmlRead/trialRead.html?dbCode=CJFD&tableName=CJFDTOTAL&fileName=WHJT202202016.
[74] Q.H. Huang, Y.Z. Yu, S.L. Zhang, Internet development and productivity growth in manufacturing industry: internal mechanism and China experiences, China Industrial Economics 39 (8) (2019) 5–23, https://doi.org/10.19581/j.cnki.ciejournal.2019.08.001.
[75] J. Liu, Y.Y. Yang, S.F. Zhang, Measuring and analyzing the drivers of China's digital economy, Shanghai Economic Research (6) (2020) 81–96, https://doi.org/10.19626/j.cnki.cn31-1163/f.2020.06.008.
[76] J. Li, H. Ding, Y. Hu, G. Wan, Dealing with dynamic endogeneity in international business research, J. Int. Bus. Stud. 52 (2021) 339–362, https://doi.org/10.1057/s41267-020-00398-8.
[77] F. Caselli, J. Reynaud, Do fiscal rules cause better fiscal balances? A new instrumental variable strategy, Eur. J. Polit. Econ. 63 (2020) 101873, https://doi.org/10.1016/j.ejpoleco.2020.101873.
[78] I. Iancu, B. Iancu, Designing mobile technology for elderly. A theoretical overview, Technol. Forecast. Soc. Change 155 (2020) 119977, https://doi.org/10.1016/j.techfore.2020.119977.
[79] A.A. Ozok, H. Wu, M. Garrido, P.J. Pronovost, A.P. Gurses, Usability and perceived usefulness of personal health records for preventive health care: a case study focusing on patients' and primary care providers' perspectives, Appl. Ergon. 45 (3) (2014) 613–628, https://doi.org/10.1016/j.apergo.2013.09.005.
[80] Generative AI in healthcare: Adoption trends and what's next. Retrieved September 3, 2024, from https://www.mckinsey.com/industries/healthcare/our-insights/generative-ai-in-healthcare-adoption-trends-and-whats-next.
[81] M. Matarazzo, L. Penco, G. Profumo, R. Quaglia, Digital transformation and customer value creation in Made in Italy SMEs: a dynamic capabilities perspective, J. Bus. Res. 123 (2021) 642–656, https://doi.org/10.1016/j.jbusres.2020.10.033.
[82] X. Xing, T. Chen, X. Yang, T. Liu, Digital transformation and innovation performance of China's manufacturers? A configurational approach, Technol. Soc. 75 (2023) 102356.
[83] R. Abujamra, D. Randall, Blockchain applications in healthcare and the opportunities and the advancements due to the new information technology framework, in: Advances in Computers, vol. 115, Elsevier, 2019, pp. 141–154, https://doi.org/10.1016/bs.adcom.2018.12.002.
[84] Y. Peng, C. Tao, Can digital transformation promote enterprise performance?—from the perspective of public policy and innovation, Journal of Innovation & Knowledge 7 (3) (2022) 100198, https://doi.org/10.1016/j.jik.2022.100198.
[85] A.S. Litwin, Technological change and frontline care delivery work: toward the quadruple aim, in: The Contributions of Health Care Management to Grand Health Care Challenges, Emerald Publishing Limited, 2021, pp. 99–142, https://doi.org/10.1108/S1474-823120210000020005.
[86] A.A. Batabyal, P. Nijkamp, Digital technologies, knowledge spillovers, innovation policies, and economic growth in a creative region, Econ. Innovat. N. Technol. 25 (5) (2016) 470–484, https://doi.org/10.1080/10438599.2015.1073485.