Measurement Research on the Coupling and Coordinated Development of Digital Economy and Smart Pension -- A Case Study of Northwest China

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Abstract. By constructing entropy weight-improved TOPSIS model, coupling coordination degree model and grey relational degree mode, this study deeply analyzed the coupling coordination level of digital economy and smart elderly care in northwest China. The results show that the development level of digital economy and smart pension in northwest China shows a steady rise in general; At the same time, the coupling coordination degree of the two is also constantly improving, and the basic coordination stage will be reached in 2023. There is a strong correlation between the indicators of digital economy and smart elderly care. Through a detailed discussion of the coupling and coordination relationship between the digital economy and smart elderly care, this study further found that the digital economy has a significant role in promoting the high-quality development of smart elderly care. This finding provides a new idea for the application of digital economy in the field of smart elderly care, and has important reference value for national macro-control and local governments to formulate relevant policies.

Keywords: Digital economy, Intelligent elderly care, Coupling coordination degree model, Grey relational degree mode.

1 INTRODUCTION

By the end of 2023, the elderly population aged 60 and above in China will exceed 296 million, with a large elderly population base and a fast aging rate. It is urgent to solve the contradiction between supply and demand of elderly care and innovate the elderly care service system. For example, in 2021, the outline of the national "14th Five-Year Plan" will for the first time actively respond to the rise of population aging as a national strategy, and make systematic deployment on "accelerating the construction of digital

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society and helping the elderly to share digital life"; The report of the 20th National Congress of the Communist Party of China pointed out that it is necessary to implement the national strategy of actively responding to the aging population and develop the old-age service and the old-age service industry. The rapid development of the digital economy has injected vitality into elderly care services. Smart elderly care is an effective solution to the aging population from the macro decision-making level in the new era. How to promote the high-quality development of smart elderly care in the context of the digital economy era is worthy of in-depth discussion.

Smart elderly care is the use of modern technology to help the elderly to achieve more social participation, enhance independence as much as possible, and ultimately make the elderly live a happier and more dignified life. Liu et al. analyzed the current situation and problems of the smart elderly care industry from the perspective of demand, and proposed positive strategies to cope with the development of aging from the perspective of smart elderly care [1]. Wang et al. proposed to build a unified information platform, promote demand, expand supply, increase investment in the smart pension system, and combine social talents with smart pension [2]. Based on the analysis of the technology experiment of home smart elderly care in Singapore, Orlando Woods used four binary pairing concepts to define the relationship between smart elderly care and parallel sustainable mechanism [3]. At the same time, Bogataj David et al. proposed a measurement method for the social value created by the development of smart silver village, providing new perspectives and ideas for the diversified development path of smart elderly care [4].

At present, the research on digital economy and smart pension industry is mainly theoretical interpretation, and it is rare to carry out in-depth empirical analysis on the internal integration mechanism of digital economy and smart pension. Zeng analyzed the development status of the smart pension industry under the background of digital economy, and proposed corresponding solutions to the shortcomings in the development of the smart pension industry [5]. Dong proposed to set up a smart elderly care model based on digital technology and accelerate the layout of the smart and healthy elderly care industry to meet the increasingly urgent needs of the people for healthy elderly care [6].

2 MODEL

Based on the integration and analysis of existing research results [7], this study comprehensively considers the multiple factors affecting the coupling relationship between digital economy and smart elderly care, rejects potential adverse effects, follows the basic principles of scientific, systematic and data availability of index selection, and makes a breakthrough design of the coupling index system between digital economy and smart elderly care. An innovative "3×4" index is proposed to measure the development level of the digital economy, and a "2+1+2+1+3" index is proposed to measure the development level of smart elderly care. The coupling index system of digital economy and smart elderly care is shown in Table 1. This system not only reflects the depth

and breadth of the research, but also provides strong support for subsequent empirical analysis.

Table 1. Digital economy and smart pension coupling index system

Primary index	Secondary index	Label
Digital infrastructure	Mobile phone penetration	A_{11}
	Optical cable line length	A_{12}
	Number of Domains	A_{13}
	Number of Internet broadband access users	A_{14}
Digital industrialization	Express volume	A_{21}
	Total volume of telecommunication service	A_{22}
	Share of software revenue in regional GDP	A_{23}
	Share of software product revenue in regional GDP	A_{24}
Industrial digitization	Number of websites owned by the enterprise	A_{31}
	Share of e-commerce sales in regional GDP	A_{32}
	Proportion of enterprises with e-commerce transaction activities	A_{33}
	Digital Financial Inclusion Index	A_{34}
Economic development status	Per capita disposable income	B_{11}
	Per capita consumption expenditure	B_{12}
Elderly care service personnel	Number of professional health technicians	B_{21}
Smart elderly care facilities and equipment	Number of pension institutions	B_{31}
	Number of community hospitals	B_{32}
Informatization level of elderly care	Intelligent informatization level	B_{41}
Humanistic care	Income from social endowment insurance funds for urban and rural residents	B_{51}
	Number of endowment insurance participants	B_{52}
	Social assistance number	B_{53}

2.1 Constructing Entropy Weight - Improving TOPSIS Model

In this study, entropy weight - improved TOPSIS model is constructed to measure the development level of digital economy and smart elderly care. Entropy method is an objective valuation method that can determine the weight of multidimensional indica-

tors [8]. TOPSIS method evaluates the quality of each sample by calculating the distance between the evaluation object and the positive and negative ideal solution [9]. However, in the actual calculation, the distance between the positive ideal solution and the negative ideal solution will be very close, resulting in numerical overflow or precision loss. To solve the above problems, the improved TOPSIS method improves the accuracy and stability of the model by introducing a small adjustment factor ε.

2.2 Constructing Coupling Coordination Degree Model

Calculate the coupling correlation degree of digital economy and smart elderly care *C*.

$$C = \frac{2\sqrt{S_1 \times S_2}}{S_1 + S_2} \tag{1}$$

Among them, S_1 and S_2 respectively represent the comprehensive evaluation index of digital economy and smart elderly care.

Calculate the coupling coordination degree *D* of digital economy and smart elderly care. In this study, $\alpha_1=\alpha_2=0.5$ is taken.

$$T = \alpha_1 S_1 + \alpha_2 S_2 \tag{2}$$

$$D = \sqrt{C \times T} \tag{3}$$

2.3 Constructing Grey Relational Degree Model

Calculate the grey correlation coefficient $\xi_{\lambda k}$(t) among each index.

$$\xi_{\lambda k}(t) = \frac{min_\lambda min_k|\Delta| + \rho max_\lambda max_k|\Delta|}{|\Delta| + \rho max_\lambda max_k|\Delta|} \tag{4}$$

Where, $\Delta=X_\lambda(t)-Y_k(t)$, $X_\lambda(t)$ represents the standardized value of the λth indicator of digital economy, $Y_k(t)$ represents the standardized value of the KTH indicator of smart pension, and $\xi_{\lambda k}(t)$ represents the gray correlation coefficient between the λth indicator of digital economy and the KTH indicator of smart pension in year t; ρ is the resolution coefficient, which is used to control the differentiation of the gray correlation coefficient. ρ is generally 0.5 [10].

Calculate the grey correlation degree among the indicators $o_{\lambda k}$. Where, $0 < o_{\lambda k} \leq 1$, the closer to 1 indicates the stronger the correlation between indicators.

$$o_{\lambda k} = \frac{1}{m}\sum_{t=1}^{m} \xi_{\lambda k}(t) \tag{5}$$

3 EXPERIMENT

Based on the constructed coupling index system of digital economy and smart elderly care, the index weights calculated. Through objective analysis and reference to the existing research [11], the subjective verification, the weight distribution is more reasonable.

3.1 Analysis of the Coupling Coordination Degree Between Digital Economy and Intelligent Old-Age Care

The coupled coordination degree model is used to calculate the coupled coordination degree value of digital economy and smart elderly care in 5 provinces in Northwest China, and the calculation results are shown in Table 2.

Table 2. Digital economy and smart pension coupling coordination degree value

Province	2017	2018	2019	2020	2021	2022	2023
Shaanxi	0.61	0.68	0.74	0.79	0.76	0.77	0.77
Gansu	0.59	0.69	0.80	0.86	0.80	0.79	0.79
Qinghai	0.64	0.71	0.77	0.81	0.75	0.75	0.75
Ningxia	0.65	0.68	0.73	0.78	0.72	0.73	0.73
Xinjiang	0.58	0.63	0.69	0.76	0.74	0.75	0.75
Mean value	0.62	0.68	0.76	0.77	0.75	0.76	0.76

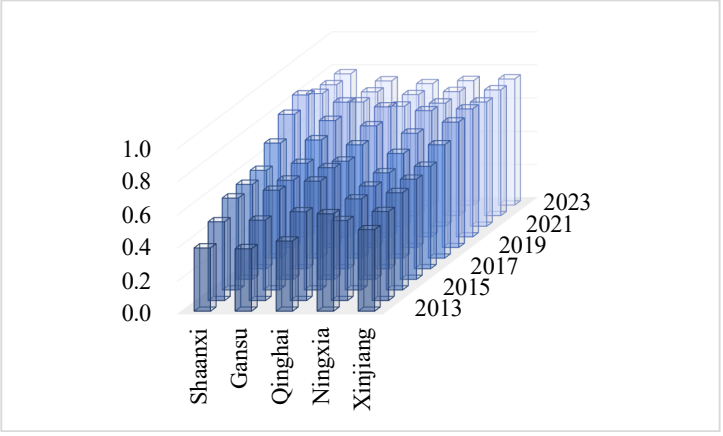

Fig. 1. Digital economy and smart pension coupling coordination degree

From Table 2 and Fig 1, it can be seen that the coupling coordination degree of digital economy and smart elderly care in northwest China showed an upward trend from 2017 to 2023, but there were still some differences between regions. In the future, government departments should continue to increase investment and support for the

smart elderly care industry, promote coordinated development among regions, and improve the well-being of elderly groups. At the same time, strengthen the deep integration of digital economy and smart elderly care services, and innovate service models to meet the growing needs of elderly care.

3.2 Digital Economy and Smart Elderly Care Grey Relational Degree Analysis.

From Fig 2, it can be seen that the correlation between digital economy and smart elderly care in northwest China is relatively high, with an average correlation of 0.612, which indicates that all indicators in the evaluation index system have a significant impact on the development of digital economy and smart elderly care, and there is good synergy between them and indicating a high correlation between the indicators. This shows that in Northwest China, the construction of information and communication infrastructure and the popularization of digital services play an important role in improving the quality of elderly care services and the economic status of residents.

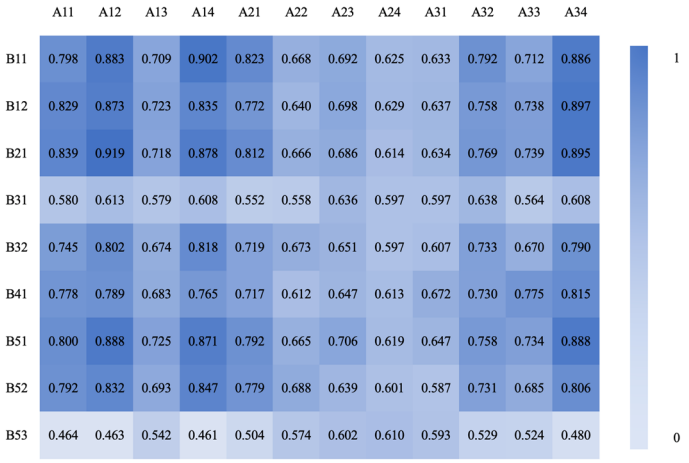

Fig. 2. Digital economy and smart pension related degree matrix

4 CONCLUSION

Based on the sample data of 5 provinces in Northwest China from 2017 to 2023, this study measures the development level of digital economy and smart elderly care by constructing the entropy-improved TOPSIS model. Through the construction of coupling coordination degree model, the coupling coordination level of digital economy and smart elderly care is analyzed. Through the construction of grey correlation degree model, the interaction between digital economy and smart pension indicators is analyzed, and then the influence mechanism of digital economy on smart pension is studied.

The results show that: First, from the perspective of direct impact, the improvement of the development level of digital economy can promote the improvement of the development level of smart elderly care, and the development level of both will reach the maximum in 2020, and then decrease slightly, but still increase gently, which may be related to the characteristics of rapid self-innovation and replication of digital technology in a short time, and such impact has regional heterogeneity. Second, from the perspective of regional coordinated development, the law of the global effect of digital economy and smart elderly care in all provinces in Northwest China is similar, and the coupling coordination degree of digital economy and smart elderly care is generally on the rise, from 0.618 in 2017 to 0.756 in 2022 in Northwest China, the overall level of coordination is basic, and regional differences are shrinking. Third, from the perspective of correlation order analysis, there is a good correlation between the indicators of digital economy and smart elderly care, which indicates that the digital economy plays a driving role in promoting the development of smart elderly care.

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