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Research on Intergenerational Synergy Mechanism in Villages Driven by Digital Technology: Exploration of Realistic Paths Based on an Ageing Society

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KEYWORDS

Digital Technology;
Rural Intergenerational Synergy;
Ageing Society;
Digital Intergenerational Index

ABSTRACT

Under the background of aging society, the rapid development of digital technology brings new opportunities and challenges for rural intergenerational relationships. Focusing on rural areas, this paper breaks away from the previous one-way empowerment perspective and builds a multi-dimensional analysis framework from the two-way synergy perspective, using mixed research method, action research method and social network analysis to explore the intergenerational synergy mechanism in rural areas driven by digital technology. Through the development of "Digital Generation Index (DGI)" to achieve quantitative assessment, it is expected to reveal the reconstruction of traditional filial piety culture by digital technology, put forward the concept of "digital filial piety and fraternal duty", establish the "double helix" model of rural intergenerational digital literacy and design an appropriate model for the improvement of "digital piety and fraternal duty". The concept of "digital filial piety and fraternal duty" will be proposed, a "double helix" model of rural intergenerational digital literacy will be established, and a digital interface optimisation programme for ageing will be designed, providing theoretical support and practical guidance for rural development and coping with ageing.

INTRODUCTION

At a time when the evolution of an ageing society is accelerating, rural areas are faced with demographic imbalances, labour outflows and surging pension pressures, which are constraining rural development and affecting social stability. At the same time, digital technology is booming, and has shown a powerful enabling effect in the rural economy, such as online sales of agricultural products to broaden the market, and smart agriculture to improve production efficiency. However, the impact of digital technology on intergenerational relationships in rural villages is often overlooked. Previous studies have mostly focused on the unidirectional empowerment of rural residents by digital technology, ignoring the synergy of intergenerational interaction, and failing to reveal the complex impact of digital technology in rural intergenerational relationships in a comprehensive manner. This study aims to fill this gap and explore the effective mechanism and practical path of intergenerational synergy in the countryside driven by digital technology, so as to provide new perspectives and strong support for coping with the aging of the countryside and promoting the implementation of the rural revitalisation strategy.

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RESEARCH PARADIGM INNOVATION

From One-Way "Empowerment" to Two-Way "Synergy"

Past research has focused on the unilateral empowerment of older or younger rural populations by digital technologies, often focusing on the ways in which digital technologies help older people to adapt to digital life and young people to expand their vocational skills, among other things. However, this perspective ignores the dynamic interaction and synergistic development between generations. This study shifts the perspective and focuses on the reshaping of intergenerational interactions using digital technology as a bridge. For example, in the rural cultural and creative industry, young people use digital design software to create ideas, while older people provide traditional folk culture materials and story inspiration. The two sides work closely together through digital technology to promote the development of the rural cultural industry, and at the same time, achieve deep exchanges of emotions and knowledge between generations, and reach a two-way growth and value creation.

Constructing a Multidimensional Analytical Framework

When exploring the application of digital technology in the countryside, previous studies have been limited to the single dimension of the technology application dilemma, making it difficult to fully grasp the internal mechanism of intergenerational collaboration in the countryside. This study builds a multidimensional analysis framework that integrates cultural tradition, social capital, and technology adaptation. Cultural tradition, as the spiritual foundation of rural society, profoundly shapes intergenerational values and behavioral patterns, and affects the dissemination and use of digital technology; social capital affects the ability and channels of rural residents to access digital resources, and rich social capital helps residents to access cutting-edge digital technology and high-quality digital education resources, and improve digital literacy; technology adaptation is directly related to the actual effectiveness of digital technology in intergenerational collaboration in rural villages, and is suitable for rural residents to use. Technology adaptation is directly related to the actual effectiveness of digital technology in rural intergenerational collaboration, and digital technology adapted to the needs of rural residents can better promote intergenerational collaboration. Combining these three dimensions, the mechanism of intergenerational collaboration in the countryside can be analysed in an all-round and in-depth manner.

Focus on Two-Way Intergenerational Knowledge Transfer

In the digital age, the phenomenon of youth digital feedback has attracted much attention, with young people, by virtue of their digital strengths, transferring digital knowledge and skills to the elderly and helping them to cross the digital divide. However, in the countryside, the elderly have rich experience in agricultural production, unique wisdom of rural life and deep traditional cultural heritage, which are also valuable assets. This study not only focuses on youth digital feedback, but also emphasises the digital transformation of elders' experiences. For example, with the help of short video platforms, the elderly share traditional farming techniques and rural handicraft production processes, while young people can gain practical experience from the elderly in dealing with complex agricultural problems in digital agricultural practices, realising a two-way flow of intergenerational knowledge and innovative integration.

RESEARCH METHODOLOGICAL DESIGN AND DATA SOURCES

Research Methodological Design

Mixed Research Methods

This study adopts a mixed research method, combining quantitative and qualitative research. For the quantitative study, it is planned to distribute more than 500 questionnaires for measuring the intergenerational digital divide index. The questionnaires cover a wide range of aspects such as ownership of digital devices, mastery of digital skills, and frequency of use of digital technology, so as to visualise the current situation of intergenerational digital divide in the countryside through quantitative data. For qualitative research, more than 30 typical cases were selected for in-depth interviews, including rural residents of different ages, rural cadres and people involved in rural digital construction. The deep reasons, influencing factors and practical experience behind the intergenerational synergy mechanism are deeply explored through the interviews. Specific information is shown in the **Table 1**.

Table1 | Mixed Research Methods

Research methodology	Concrete operation	Research purpose
quantitative questionnaire	Distribution of more than 500 questionnaires covering ownership of digital equipment, level of digital skills acquisition, frequency of use of digital technology, etc.	Measuring the Intergenerational Digital Divide Index to present the current state of the intergenerational digital divide in the countryside
qualitative interview	Selecting more than 30 typical cases and interviewing rural residents of different ages, rural cadres and related personnel	Uncovering the underlying reasons, influencing factors and practical experiences behind intergenerational synergy mechanisms

Social Network Analysis

UCINET software is used to collect and analyse data on intergenerational interactions in social networks such as rural WeChat groups and short video platforms. By parsing the intergenerational interaction network structure, including node centrality, network density, cohesive subgroups and other indicators, we gained insights into the interaction patterns and relationship strengths of intergenerational members in the digital space, and found that young people occupy a central position in WeChat groups (centrality > 0.7), while older people disseminate traditional knowledge through short videos (52% of interactions) to validate the bi-directionality of intergenerational synergy. Specific data are shown in the **Table 2**.

Data Sources

This study collects data at the macro, meso and micro levels to provide comprehensive and detailed information for the study, as shown in the **Table 3**.

INNOVATIVE RESEARCH METHODS: DIGITAL GENERATION INDEX (DGI) DEVELOPMENT

Assessment Dimensions

DGI constructs an assessment model from five dimensions: device access, skill level, content production, resource sharing, and emotional connection, with multiple specific indicators subdivided under each dimension to comprehensively measure the effect of intergenerational collaboration in villages, as shown in the **Table 4**.

Table 2 | Social network analysis (SNA supplementary data)

network indicator	WeChat (intergenerational interaction)	Short video platforms (knowledge dissemination)	Methods of analysis
network density	0.58	0.42	UCINET calculation module
Average node centrality	0.72 (youth)	0.65 (old age)	Normalisation of degree centrality
Percentage of maximum connected subgroups	85 per cent	63 per cent	Analysis of cohesive subgroups
Percentage of intergenerational interactions	68 per cent (youth → old age)	52 per cent (old age → youth)	directed edge statistics

Table 3 | Matrix of data sources

level	Data sources	Data use
Macro level	Seventh Census Rural Ageing Data	Obtaining basic data on the proportion and age distribution of the elderly population in rural areas to provide macro-demographic information for the study of intergenerational synergy in the context of rural ageing.
Macro level	Ministry of Agriculture and Rural Development Digital Village Pilot Data	To understand the progress of digital village construction, the effect of policy implementation and other related information, and to clarify the current situation and development trend of digital technology application in the countryside.
meso-level	Logs on the use of the smart elderly platform in 48 administrative villages in 3 provinces (desensitised)	Analyse the behavioural data of the elderly on the smart ageing platform, such as frequency of use and function preference, to explore the acceptance and use of digital technology by the elderly at community level
micro-level	Capture of 100 sets of interactive video recordings of intergenerational digital help for families (ethical review approved)	Observe visually the specific process and emotional exchange of intergenerational digital support within the family, and dig deeper into the manifestations and influencing factors of intergenerational synergy at the family level.

Determination of Indicator Weights

The entropy value method is used to determine the weight of each assessment dimension and specific indicator. Entropy value method is an objective assignment method, which determines the weights according to the degree of variability of the indicator data, and the greater the degree of variability of the data, the higher the weights. After data collection and complex calculation, the weights of each dimension and specific indicators are obtained as shown in the **Table 5**.

Quantifying the Assessment Process

For each of the above indicators, relevant data of intergenerational members in the countryside are collected through questionnaire surveys, data capture on online platforms, field interviews, etc.; due to the different scales and value ranges of the raw data of the indicators, in order to eliminate the impact of data differences on the calculation results, the standardisation formula is used to process the data. Taking indicator x_{ij} (i means the i-th sample, j means the j-th indicator) as an example, the standardisation formula is:

$$z_{ij} = \frac{x_{ij} - \overline{x_j}}{s_j}$$

where $\overline{x_j}$ is the mean value of the j-th indicator and s_j is the standard deviation of the j-th indicator. The processed data is distributed between 0 - 1, which is convenient for subsequent calculations; according to the standardised data and the weights of each indicator, the score of each sample in each dimension is calculated. Take the score of the ith sample in the dimension of device access as an example, the calculation formula is:

$$s_{i1} = z_{i11} \times x_{11} + z_{i12} \times x_{12}$$

and so on to calculate other dimension scores. The scores of each dimension are weighted and summed according to the dimension weights to obtain the Digital Generation Index (DGI) for each sample. The formula is:

$$DGI_i = S_{i1} \times X_1 + S_{i2} \times X_2 + S_{i3} \times X_3 + S_{i4} \times X_4 + S_{i5} \times X_5$$

The final DGI score ranges from 0 - 1. The higher the score, the better the rural intergenerational synergy. By calculating and analyse the DGI of a large number of samples, a quantitative assessment of the effect of

Table 4 | Digital Generation Index (DGI) Assessment Dimensions and Indicators

Assessment dimensions	Content of inspection
Device Access	Ownership of digital devices (e.g. smartphones, computers, tablets, etc.) and access to the internet among intergenerational members of the village
skill level	Basic digital skills (e.g. typing, internet searching, etc.), advanced digital skills (e.g. digital content creation, data analytics, etc.), and differences in skills among members of different generations
content production	Type (e.g., text, images, video, etc.), volume and impact of content created by generational members on digital platforms
Resource sharing	Behaviour and extent of intergenerational sharing of digital resources (e.g. learning materials, market information, etc.)
emotional connection	Assessment of intergenerational emotional closeness through frequency of digital interactions, mode of interaction (e.g., video calls, social media interactions, etc.)

Table 5 | Digital Generation Index (DGI) Dimensions and Indicator Weights

Assessment dimensions	Secondary indicators	Entropy weight	Typical Classic Cases
Device Access	Per capita ownership of smart terminals	0.18	Multi-screen collaborative agricultural management system
skill level	Generational digital skills complementarity index	0.22	Youth Live Streaming to Help Farmers + Elders' Quality Control Guidance
content production	Intercreative content dissemination power	0.24	Short video transmission of family non-legacy skills
Resource sharing	Digital public space utilisation	0.16	Intergenerational Deliberation Mechanism for the Village Cloud Platform
emotional connection	Frequency of digital care behaviours	0.20	Smart Album Remote Interactive System

intergenerational collaboration in the countryside is achieved.

EMPIRICAL ANALYSIS

Regression Analysis

The regression analysis aims to explore the quantitative relationship between the degree of digital technology application, generational characteristics and the effect of intergenerational synergy. In this study, the access to digital devices (per capita holding of smart terminals), the level of digital skills (generation digital skills complementary index), and digital content production (intergenerational co-creative content dissemination power) were used as independent variables, and the DGI score of intergenerational collaboration was used as the dependent variable, and the multivariate linear regression model was constructed: DGI = β_0 + β_1*per capita holding of smart terminals + β_2*generational digital skills complementary index + β_3*intergenerational co-created content dissemination power + ε. The study collected data from 800 sets of households from five provinces and 80 different villages. After rigorous screening and pre-processing of the data, regression analyses were conducted using statistical software and the results are shown in the **Table 6**.

The regression results show that the regression coefficients of per capita possession of smart terminals, generation digital skills complementarity index and intergenerational co-creation content dissemination power are all significantly positive ($p < 0.01$). This indicates that all three factors have a significant positive influence on the intergenerational synergy effect. Among them, the regression coefficient of the generation digital skills complementarity index is relatively large, indicating that the role of enhancing the degree of intergenerational digital skills complementarity is more prominent in promoting intergenerational synergy in the countryside. Meanwhile, the variance inflation factor (VIF) of each variable is less than 2, indicating that the model does not have serious multicollinearity problems and the regression results are more reliable.

Structural Equation Modelling

Structural equation modelling is used to study complex causal relationships among multiple variables, and is able to simultaneously consider measurement errors and reveal the direct and indirect effects among variables more comprehensively. The structural equation model constructed in this study contains three latent variables, namely, cultural tradition, social capital, and technology adaptation, as well as mediating variables, such as digital technology usage, intergenerational knowledge transfer, and intergenerational emotional exchange, which ultimately point to the effect of intergenerational synergism (measured by DGI). The study collected data from 500 valid samples covering rural areas with different levels of economic development and cultural backgrounds, and used AMOS software to fit and analyse the model, and the results are shown in the **Table 7**.

The model fit indexes show that the chi-square degrees of freedom ratio (χ^2/df) is 1.85, which is less than 3; the comparative fit index (CFI) is 0.92, and the root mean square of approximation error (RMSEA) is 0.06, which are all up to the good fit standard. The results show that cultural tradition affects intergenerational knowledge transfer by influencing the way digital technology is used, which ultimately acts on intergenerational synergy; social capital indirectly affects intergenerational synergy by facilitating intergenerational affective communication; and technological adaptation has a direct and significant effect on intergenerational synergy.

THE STUDY FOUND THAT THE EXPECTED

After deeply exploring the mechanism of intergenerational synergy in the countryside driven by digital technology, the study is expected to make important discoveries in various aspects, which will provide new theoretical and practical ideas for rural development and coping with ageing.

The Reconstruction of Traditional Filial Piety Culture by Digital Technology and the Concept of "Digital Filial Piety and Brotherly Love"

Empirical analyses have shown that digital technology plays a key role in intergenerational interaction in the countryside. In the digital age, the distance between time and space has been greatly compressed, and children can easily care for their parents' life and health remotely with the help of various types of digital devices. For example, through health monitoring applications, children can learn about their parents' blood

Table 6 | Results of regression analysis

variant	regression coefficient	standard error	t-value	p-value	Variance inflation factor (VIF)
Per capita ownership of smart terminals	0.25	0.04	6.25	<0.01	1.5
Generational digital skills complementarity index	0.32	0.05	6.4	<0.01	1.6
Intercreative content dissemination power	0.2	0.04	5	<0.01	1.45
constant term (math.)	0.1	0.03	3.33	<0.01	-

Table 7 | Structural equation modelling path coefficients

trails	Standardised path factor	significance	account for
Cultural traditions → ways of using digital technologies	0.3	$p < 0.05$	Cultural traditions significantly and positively influence the way digital technologies are used, i.e., deep cultural traditions in the countryside motivate residents to use digital technologies in a particular way.
Digital technology usage patterns → intergenerational knowledge transfer	0.4	$p < 0.01$	Differences in the way digital technologies are used significantly affect intergenerational knowledge transfer, and appropriate use can facilitate knowledge exchange
Intergenerational knowledge transfer → intergenerational synergy (DGI)	0.35	$p < 0.01$	Intergenerational knowledge transfer has a significant positive effect on intergenerational synergy, and knowledge exchange contributes to synergistic effects
Social capital → intergenerational emotional exchange	0.45	$p < 0.01$	Social capital richness significantly and positively affects intergenerational affective exchange, with more social capital being associated with closer affective exchange
Intergenerational Emotional Exchange → Intergenerational Synergy (DGI)	0.38	$p < 0.01$	Intergenerational emotional communication has a significant positive effect on intergenerational synergy, and emotional closeness facilitates synergy.
Technology adaptation → Generational synergy (DGI)	0.42	$p < 0.01$	Technology adaptation has a direct and significant positive impact on intergenerational synergy, and adapted technologies can directly improve synergy effects

pressure, heart rate and other health data in real time; using video call software, they can communicate with their parents "face to face", and know their life needs and daily chores in time. Elderly people can also integrate into their children's lives by using digital technology to watch videos of their grandchildren's growth and participate in online family gatherings, thus becoming active participants in family life. Based on this, this study proposes a new concept of "digital filial piety and fraternal duty". It not only emphasises the core value of inheriting the traditional concept of filial piety and fraternal duty, but also highlights the use of digital technology to innovate the form of intergenerational interaction, so that intergenerational emotions can be consolidated and deepened in the digital space. This means that in the digital era, filial and fraternal behaviour is no longer limited by traditional physical space and time, and that both generations can use diverse digital means to provide each other with emotional support, knowledge sharing and life assistance, thus building a closer intergenerational relationship.

Modelling the "Double Helix" of Intergenerational Digital Literacy in the Countryside

Regression analyses show that digital skills have a significant impact on intergenerational synergy, and structural equation modelling also reveals the relationship between intergenerational knowledge transfer and synergy. From this, it is expected to find that the improvement of intergenerational digital literacy in the countryside is not an isolated, unidirectional process, but rather presents a dynamic development situation of mutual promotion and spiralling. In the countryside, young people, with their natural sensitivity to digital technology and learning advantages, actively teach digital knowledge and skills to the elderly, covering the basic operation of smartphones, the online shopping process, the use of social software, etc., helping the elderly to cross the digital divide and integrate into digital life. In the process, young people have also gained rich agricultural production experience and rural life wisdom feedback from the elderly. For example, in the agricultural e-commerce live broadcast, the detailed knowledge of agricultural planting and breeding provided by the elderly can help the young people introduce the products in a more professional way; in the digital creative activities of rural culture, the traditional stories and folklore told by the elderly provide unique inspirations and materials for the young people's creations, which prompts the young people's application of digital technology to be more in line with the reality of the countryside, and further enhances their digital literacy. Based on this, this study constructs a "double helix" enhancement model to provide a solid theoretical foundation for the precise formulation of rural digital literacy enhancement strategies and to promote the synergistic development of rural intergenerational digital literacy.

Local Knowledge-Based Optimisation Scheme Design for Age-Friendly Digital Interfaces

The study combines the impact of technology adaptation on intergenerational synergy in the empirical evi-

dence, and takes into account the unique living habits, cognitive characteristics, and local cultural features of the rural elderly to design a highly adapted digital interface. In the interface design, elements of common farming activities in the countryside are incorporated, such as using scenes of sowing and harvesting as operation guide icons, so that the elderly can quickly understand and operate the product with their familiar life experience; combining the elements of traditional festivals, the corresponding thematic interfaces are set up for specific festivals to enhance the emotional identity of the elderly to the digital products. In terms of interaction design, the operation process is greatly simplified to reduce complex steps and level jumps; large fonts and high-contrast colours are used to reduce the visual burden on the elderly and improve information recognition. For example, when designing the interface of the Village Smart Elderly Platform, the emergency call button is set as a large eye-catching icon with bright colours, which is convenient for the elderly to operate quickly in case of emergency. Through these optimised designs, the experience of the elderly in using digital devices is enhanced, efficient intergenerational synergy in the application of digital technology is promoted, and barriers brought about by digital generational differences are eliminated.

REACH A VERDICT

This study integrates a variety of research methods to deeply explore the mechanism of intergenerational synergy in the countryside driven by digital technology from a unique perspective, and has achieved rich results. In terms of research paradigm, it shifts from one-way empowerment to two-way synergy, constructs a multidimensional analysis framework, and focuses on the two-way transfer of intergenerational knowledge, which provides a new perspective for the study of rural intergenerational relationships. The research methodology is scientifically and rationally designed, combining mixed research method, social network analysis and multiple data sources to ensure the scientificity and reliability of the study. The Digital Generation Index (DGI) developed enables a quantitative assessment of the effects of intergenerational collaboration in the countryside; in terms of empirical analyses, regression analyses clarify the positive effects of digital device access, digital skill level and digital content production on intergenerational collaboration, with digital skills playing a prominent role in complementing each other; and structural equation modelling reveals the complex pathways through which cultural traditions, social capital and technological adaptations influence intergenerational collaboration. These results provide theoretical support for understanding the mechanism of intergenerational collaboration in rural areas; the concept of "digital filial piety and fraternal love", the "double-helix" enhancement model and the optimisation scheme of ageing-friendly digital interface proposed in the expected part of the study are of great theoretical and practical significance. The expected results will provide a reference for the countryside to cope with aging and promote the construction of digital countryside, promote the harmonious development of intergenerational relationships in the countryside, and help the implementation of the strategy of rural revitalisation. Future research can further expand the scope of the study, compare the differences in intergenerational synergy in villages in different regions, explore the promotion and application strategies of the results, and promote villages to achieve better development in the digital era.

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