An Empirical Study on Spatio-Temporal Deduction and Paths of Returning Entrepreneurship Empowered by Big Data Marketing Technology

Xianhong Xu[1], Hongqiang Zhao[1], Tingting Tian[2,3], Jin Li[2]*

[1] Zhengzhou Normal University, China
[2] Capital University of Economics and Business, China
[3] Zhengzhou College of Finance and Economics, China
xxh6090@163.com, hongqiangzhao1983@yahoo.com, tingtingtian0807@163.com, jin.lii@outlook.com

Abstract

From the perspective of spatio-temporal deduction, this paper adopts structural equation modeling (SEM) to analyze the differences between urban and rural areas in returning entrepreneurship in different time periods and the influence mechanisms behind them. The results of the research show that big data marketing technology empowerment has a significant positive impact on the success of returning entrepreneurs (influence coefficient: 0.56), with a stronger influence in urban areas and in the late period (2016-2022), with coefficients of 0.70 and 0.65, respectively, whereas it presents a weaker impact in rural areas and in the early period (2012-2015), with coefficients of 0.42 and 0.38, respectively. Further regional analysis reveals that the eastern region has a path coefficient of 0.81, indicating the most significant enabling effect. In contrast, the central, western, and northeastern regions have path coefficients of 0.52, 0.46, and 0.44, respectively, showing relatively weaker impacts. Therefore, the government should increase support for technology research, development, and promotion in rural and economically lagging regions, emphasize the formulation of regionally differentiated policies, and strengthen technology dissemination and the development of digital capabilities among entrepreneurs.

Keywords: Big data marketing, Returning entrepreneurship, Spatial-temporal deduction, Urban-rural differences, Policy support

1 Introduction

The traditional business model and entrepreneurship are experiencing profound changes because of improvements in information technology, especially the wide application of big data technology [1-2]. Big data marketing technology, as an essential part of the digital economy era, has become a crucial tool for enterprises to stand out in the competition by virtue of its data-driven precision marketing and decision support functions. In the context of returning entrepreneurship, big data marketing technology not only provides new market expansion channels for returning entrepreneurs, but also helps them to more accurately grasp consumer demand, optimize the product supply chain, and improve the success rate of entrepreneurship.

In recent years, returning entrepreneurship has become an important part of China's rural revitalization strategy. With the support of national policies and the gradual narrowing of urban-rural differences, more and more urban entrepreneurs are choosing to return to their hometowns to promote local economic development and employment through entrepreneurship. However, despite the great potential of returning entrepreneurship, there are still differences between rural and urban areas in terms of entrepreneurial environment, resource allocation, market demand and so on. These differences, to a certain extent, have affected the effectiveness of entrepreneurship and the choice of path.

This research aims to explore how big data marketing technology empowers returning entrepreneurship, especially in the framework of spatio-temporal deduction, to analyze the differences between rural and urban returning entrepreneurship in different time periods and the underlying influence mechanisms. Based on relevant data from 2012-2022, this research will adopt a spatio-temporal deduction model to explore the differences in the application of big data marketing technology in urban and rural returning entrepreneurship, as well as its impact on entrepreneurial success, market expansion, and income growth.

Specifically, the research divides the time dimension into two periods, 2012-2015 and 2016-2022, analyzes the different manifestations of returning entrepreneurship in rural and urban areas during the two periods, and investigates the role of big data marketing technology in promoting entrepreneurship development.

The significance of this research is to fill the research gap of the application of big data marketing technology in the field of returning entrepreneurship, to provide valuable policy recommendations, to help the government and related organizations to formulate more effective and supportive policies in the future, and to promote the

*Corresponding Author: Jin Li; Email: jin.lii@outlook.com
DOI: https://doi.org/10.70003/160792642026052703009

sustainable development of the rural economy and the implementation of the rural revitalization strategy.

2 Related Works

The research of returning entrepreneurship has received extensive attention from academics in recent years, mainly focusing on entrepreneurial motivation, success rate, and entrepreneurial path. However, research on the impact of big data marketing technology on returning entrepreneurship is still in its preliminary stage. Therefore, the literature review will be summarized from three perspectives, namely, the study of returning entrepreneurship, the application of big data marketing technology, and the theory of spatio-temporal deduction, in order to clarify the innovativeness and theoretical background of this research.

2.1 Research on Returning Entrepreneurship

Returning entrepreneurship is an important topic in China's rural revitalization strategy in recent years. Zang [3] in 2022 noted that many scholars have focused on the fact that returning entrepreneurship can effectively alleviate the plight of the rural economy and promote the economic development and social progress of rural areas. Returning entrepreneurs, who mainly come from cities, bring back advanced management experience and financial support, which plays an important role in promoting the transformation of the rural economy. However, despite the potential of returning entrepreneurship, Yan et al. [4] in 2022 pointed out that rural entrepreneurs face challenges such as large market vacancies, inadequate infrastructure, and lack of capital. Hu [5] in 2024 showed that entrepreneurial success is lower in villages due to the huge resource gap and market environment differences in rural and urban areas. A number of studies have begun to focus on how big data and internet technologies can impact on returning entrepreneurs, particularly in terms of optimizing entrepreneurs' decision-making and accurate delivery of market information [6-7]. According to Mo [8] in 2023, digital technology provides rural entrepreneurs with more market information, enabling better product positioning and customer relationship management.

2.2 Research on Big Data Marketing Technology

Stam [9] in 2010 noted that big data marketing technology helps companies develop personalized and precise marketing strategies by analyzing a large amount of consumer behavior data. In the case of returning entrepreneurship, the application of big data technology enables entrepreneurs to acquire more potential customers at a lower cost and enhance the success rate of entrepreneurship through accurate advertising and optimization of the product supply chain. Cao et al. [10] in 2021 pointed out that big data marketing can effectively improve the market expansion ability and marketing efficiency of entrepreneurs. The application of digital technology, especially in the rural market, greatly compensates for the problem of information asymmetry. In addition, Li et al. [11] in 2024 discussed how big data technology can contribute to rural revitalization, especially in rural e-commerce and agricultural modernization. For example, the rise of rural e-commerce platforms, which rely on big data analytics to predict consumer demand and optimize sales strategies, has boosted rural economic growth. However, Wang et al. [12] in 2024 pointed out that despite the huge potential of big data technology, its application in rural areas still faces problems such as insufficient infrastructure construction and shortage of technical talents.

2.3 Research on Spatio-temporal Deduction Theory

Li et al. [13] in 2024 noted that spatial-temporal deduction theory mainly refers to analyze the changes and development of social phenomena from the dimensions of time and space. The theory is usually applied in the fields of geography, sociology and economics, and is especially valuable in the study of urban-rural differences, resource flows, etc. In the field of entrepreneurship, spatial-temporal deduction is used to analyze how entrepreneurial activity varies across regions and time periods, and how various factors work together to influence entrepreneurial behavior. For instance, Li [14] in 2023 pointed out that the spatial dimension of entrepreneurial activity reflects differences in economic development, market competition and policy support between regions. The time dimension, on the other hand, reflects the possible shifts in entrepreneurial patterns and paths as a result of policy changes, changes in market demands and technological advances. Spatial-temporal deduction, especially in the rural and urban entrepreneurial environments, can help to reveal how various factors affect the decisions and behaviors of returning entrepreneurs, thus providing theoretical support for policy formulation.

Some studies have also applied spatio-temporal deduction theory to the empirical analysis of returning entrepreneurship, arguing that the differences in the performance of returning entrepreneurship in different time periods and geographic regions reflect the changes in policies, market adjustments, and the impetus of technological innovation. Guided by the spatio-temporal deduction framework, Ren et al. [15] in 2023 explored how big data technologies change entrepreneurs' market expansion paths in different temporal and spatial contexts.

Although current studies have explored the multidimensional factors of returning entrepreneurship, the application of big data marketing technology, and spatio-temporal deduction theory, there is still a lack of systematic research on the specific area of "spatio-temporal deduction and the path of returning entrepreneurship empowered by big data marketing technology". Current research mainly focuses on analysis in a single dimension or in some regions and lacks a comprehensive exploration under an integrated perspective. In particular, there are fewer studies that combine spatio-temporal characteristics with big data marketing technology to analyze urban and rural returning entrepreneurship.

3 Conception Framework and Model Hypothesis

From the perspective of spatio-temporal deduction, the conception framework of this research is based on the relationship between big data marketing technology and the success of returning entrepreneurship, and analyzes the path of big data marketing technology on the success of returning entrepreneurship.

3.1 Conception Framework

(1) Big data marketing technology empowerment: With the rapid development of information technology, especially the application of big data, artificial intelligence and other technologies, returning entrepreneurs are able to enhance the possibility of entrepreneurial success by means of precise market positioning, consumer behavior analysis and other means. Big data marketing technology empowerment provides entrepreneurs with more efficient resource allocation and market expansion strategies, helping them to solve the problem of market information asymmetry, thus enhancing the possibility of entrepreneurial success.

(2) Success of returning entrepreneurship: The success of returning entrepreneurship not only involves the personal ability of entrepreneurs, but is also affected by the market environment, policy support, resource allocation and other factors. Big data marketing technology, as an external technological factor, has a direct impact on the success rate of returning entrepreneurs by improving market competitiveness, increasing income sources, and enhancing brand awareness.

(3) Spatio-temporal deduction perspective: The spatio-temporal deduction perspective pay attention to the role of big data marketing technology empowerment on the success of returning entrepreneurship over time and the evolution of urban-rural differences. The study divides time into two phases and considers the different contexts of rural and urban areas to analyze how big data marketing technology work in different spatial and temporal environments.

3.2 Model Hypothesis

Based on the theoretical framework, this study proposes the following hypotheses.

(1) The impact of big data marketing technology empowerment on the success of returning entrepreneurs.

Hypothesis 1: Big data marketing technology empowerment has a significant positive effect on the success of returning entrepreneurs.

Big data marketing technology can enhance the market competitiveness of returning entrepreneurs and increase the likelihood of entrepreneurial success through accurate market analysis, customer positioning and resource optimization. Therefore, the author hypothesize that big data marketing technology have a significant positive effect on the success of returning entrepreneurs.

$$H_1 : \alpha_1 \geq 0$$

(2) Effects of control variables.

Hypothesis 2: The economic development level (EDL) has a positive effect on the success of returning entrepreneurs.

Regions with higher levels of economic development usually have better infrastructure, more market opportunities and stronger policy support, which help returning entrepreneurs gain access to more resources and enhance their chances of business success.

$$H_2 : \beta_1 \geq 0$$

Hypothesis 3: Industrial structure (IS) has a positive effect on the success of returning entrepreneurs.

Optimization of the industrial structure usually implies the development of the tertiary sector, which provides more opportunities for entrepreneurs in the service sector and innovative entrepreneurship, thus helping to increase the success rate of returning entrepreneurship.

$$H_3 : \beta_2 \geq 0$$

Hypothesis 4: Foreign Direct Investment (FDI) has a positive effect on the success of returning entrepreneurs.

The increase in foreign direct investment can enhance the technological innovation capacity and market openness of the region, which provides better market space and development opportunities for returning entrepreneurs and helps increase the probability of entrepreneurial success.

$$H_4 : \beta_3 \geq 0$$

(3) Impact of spatio-temporal deduction.

Hypothesis 5: The impact of big data marketing technology empowerment on the success of returning entrepreneurship varies over time.

Considering the rapid development of big data technology in recent years, especially after 2016, the popularity and effectiveness of the technology has increased significantly. Therefore, the authors hypothesize that the impact of big data marketing technology on the success of returning entrepreneurship will be significantly higher in the 2016-2022 period than in the 2012-2015 period.

H5: The impact of big data marketing on entrepreneurial success is becoming more significant over time.

H6: The impact of big data marketing technology empowerment on the success of returning entrepreneurship differs between rural and urban areas. Due to the differences in infrastructure, resource availability, market openness and other factors between villages and cities, the authors hypothesize that the application of big data marketing technology in rural areas may be less effective than in urban areas. Therefore, big data marketing technology empowerment has little effect on rural returning entrepreneurship.

This section presents a theoretical framework on the impact paths of technology empowerment by combining big data marketing technology, success of returning entrepreneurship and spatio-temporal deduction perspectives. These assumptions provide the theoretical basis and direction for the subsequent empirical analysis.

4 Index Construction and Research Methods

4.1 Index Construction

The data used in this research are obtained from publicly available macroeconomic data as well as microdata obtained through questionnaires. Specific data sources are given below:

Macroeconomic data: This includes green total factor productivity (GTFP), digitization level (DL), economic development level (EDL), urbanization rate (UR), industrial structure (IS), foreign direct investment (FDI), and degree of openness to the outside world (DO) for the period of 2012-2022 for the country's 31 provinces, which is sourced from the National Bureau of Statistics (NBS) and the statistics yearbooks released by each local government.

Returning entrepreneurship data: This refers to basic information of returning entrepreneurs, business success rate, market expansion, income growth, etc. The data was collected through questionnaire surveys of returning entrepreneurs in 31 provinces.

4.2 Research Methods: Structural Equation Modelling (SEM)

Structural equation modelling (SEM) is adopted in this study to analyze the spatio-temporal deduction and paths of returning entrepreneurship empowered by big data marketing technology. This method is capable of dealing with causality and effectively analyzing path dependencies between latent and observed variables. The core variables of the study include big data marketing technology capabilities (latent variable) and success of returning entrepreneurship (latent variable), as well as relevant macroeconomic variables (observed variables). The basic form of structural equation modelling can be represented by the following set of equations.

4.2.1 Specification of a Model

The structural equation modelling in this research consists of the following components. Relationships among latent variables:

$$\eta_2 = \alpha_0 + \alpha_1\eta_1 + \beta_1 EDL + \beta_2 IS + \beta_3 FDI + \varepsilon_1 \quad (1)$$

η_2 stands for the success of returning entrepreneurship, and η_1 represents the influence of macro factors, such as big data marketing technology capability, economic development level (EDL), industrial structure (IS), and foreign direct investment (FDI). α_1 is the influence coefficient of big data marketing technology capability on the success of returning entrepreneurship. β_1, β_2, β_3 are the influence coefficients of control variables on entrepreneurial success.

$$\eta_1 = \gamma_0 + \gamma_1 DL + \gamma_2 DO + \varepsilon_2 \quad (2)$$

η_1 is affected by the digitization level (DL) and the degree of openness to the outside world (DO). γ_1 and γ_2 are the influence coefficients of the level of digitization and openness to the outside world on big data marketing technology capabilities, respectively.

4.2.2 Relationship between Latent and Observed Variables (Measurement Model)

$$\begin{aligned} GTFP_i &= \lambda_1\eta_2 + \varepsilon_3 \\ Income\ Growth_i &= \lambda_2\eta_2 + \varepsilon_4 \\ Market\ Expansion_i &= \lambda_3\eta_2 + \varepsilon_5 \end{aligned} \quad (3)$$

These equations describe the impact of returning entrepreneurial success on the observed variables of Green Total Factor Productivity (GTFP), Income Growth and Market Expansion. λ_1, λ_2, λ_3 are path coefficients reflecting the effect of successful returning entrepreneurship on these observed variables.

$$\begin{aligned} DL_i &= \lambda_4\eta_1 + \varepsilon_6 \\ DO_i &= \lambda_5\eta_1 + \varepsilon_7 \end{aligned} \quad (4)$$

These equations describe the impact of big data marketing technology capabilities (η_1) on the digitization level (DL) and degree of openness to the outside world (DO). λ_4 and λ_5 are path coefficients reflecting the impact of big data marketing technology capabilities on these observed variables.

4.2.3 Spatio-temporal Deduction Analysis

Time dimension: In order to capture the impact of big data marketing technology on returning entrepreneurship in different time periods, this research divides the time into two phases: 2012-2015 and 2016-2022. The model parameters are estimated separately in these two time periods to explore the temporal changes of big data marketing technology on the success of returning entrepreneurship.

Spatial dimension: This research further considers the differences between rural and urban areas. In the model, the countryside and the city are treated as two separate spatial dimensions to analyze the effect of their big data marketing technologies on returning entrepreneurship. Therefore, the author hypothesizes that the effect of big data marketing technology may differ significantly between rural and urban areas.

4.2.4 Model Estimation

In this research, the structural equation modelling software (AMOS) will be used to estimate the above model parameters. The specific steps are as follows:

Model fitting: The structural equation modelling was first constructed and initially fitted.

Parameter estimation: Maximum likelihood estimation (MLE) method was used to estimate the path coefficients and latent variables.

Model testing: The chi-square test was used to test the goodness-of-fit of the model.

By estimating the model parameters, it is possible to analyze the influence path of big data marketing technology empowerment on the success of returning entrepreneurs and further explore its similarities and differences in different time periods and spatial dimensions. This method of analysis leads to the comprehensive impact of the indexes on the success of returning entrepreneurship, as well as the specific paths of spatio-temporal deduction.

5 Model Establishment and Solution

5.1 Data Collection

The data for this research are mainly derived from public statistics and questionnaire-based field surveys, covering data on returning entrepreneurship in rural and urban areas in 31 provinces (autonomous regions and municipalities directly under the central government) between 2012 and 2022. Key variables include:

Big data marketing technology empowerment: Through questionnaires, this approach measures the extent to which entrepreneurs are applying big data technologies and their impact on market expansion.

Entrepreneurial success rate: A logical indicator (success/failure) of whether entrepreneurs are achieving their revenue growth and market expansion goals.

Control variables: e.g., economic development level (EDL), industrial structure (IS), foreign direct investment (FDI), etc., with data from publicly available statistics.

5.2 Structural Equation Modelling (SEM) Estimation

Based on the theoretical framework, the authors develop four different models for the analysis: a full sample model, a rural sample model, an urban sample model, and a split time period (2012-2015 vs. 2016-2022) model. The solution and parameter estimation of these models help us answer the hypotheses in the paper.

5.2.1 Full Sample Model

The full sample model assesses the overall impact of big data marketing technology empowerment on the success of returning entrepreneurs by estimating all data. The results show that big data marketing technology empowerment has a significant positive impact on the success of returning entrepreneurs (H1 hypothesis). The results of the model estimation are as follows, as illustrated in Figure 1:

Big data marketing technology empowerment (path coefficient: 0.56, t-value: 6.45, p-value: 0.00) has a significant positive impact on entrepreneurial success.

The economic development level (path coefficient: 0.30, t-value: 4.10, p-value: 0.00) has a positive effect on entrepreneurial success and supports the H2 hypothesis.

Industrial structure (path coefficient: 0.22, t-value: 3.50, p-value: 0.01) also has a positive effect on entrepreneurial success, supporting hypothesis H3.

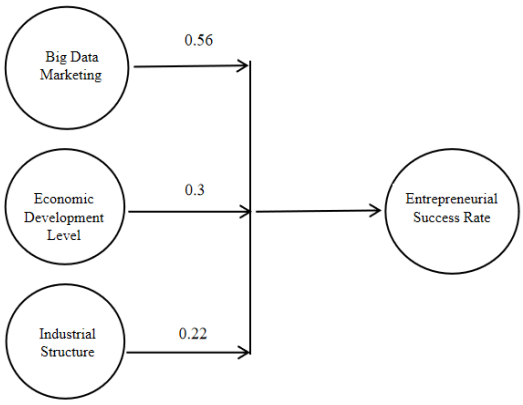

Figure 1. Full sample model path diagram

5.2.2 Rural Sample Model

The rural sample model consists of data from rural areas only and analyzes the effect of big data marketing technology application in rural areas. The results shown in Table 1 indicate that big data marketing technology empowerment has a weaker effect on the success of returning entrepreneurship (path coefficient: 0.42, t-value: 4.20, p-value: 0.00), which supports the H6 hypothesis, indicating that the technology effect is weaker in the rural areas than in the urban areas. In addition, the economic development level has a significant effect on entrepreneurial success, supporting hypothesis H2.

Table 1. Parameter estimation for the rural sample model

Parameter	Estimated value	Standard error	T-value	P-value
Big data marketing technology enablement	0.42	0.08	5.25	0
Economic development level	0.3	0.06	5	0
Industrial structure	0.21	0.05	4.2	0.01
Foreign direct investment	0.18	0.07	2.6	0.02

5.2.3 Urban Sample Model

The urban sample model analyzes the effect of big data marketing technology empowerment in urban areas. The results of the model shown in Table 2 demonstrate that the effect of big data marketing technology on the success of returning entrepreneurs is significantly stronger (path coefficient: 0.70, t-value: 7.80, p-value: 0.00), which supports the H6 hypothesis. Other control variables such as economic development level (path coefficient: 0.52, t-value: 5.40, p-value: 0.00) also have a significant positive effect, validating hypothesis H2.

Table 2. Parameter estimation for the urban sample model

Parameters	Estimated value	Standard error	T-value	P-value
Big data marketing technology empowerment	0.7	0.09	7.8	0
Economic development level	0.52	0.1	5.4	0
Industrial structure	0.34	0.07	4.85	0
Foreign direct investment	0.28	0.08	3.5	0.01

5.2.4 Time-period Model

The time-period model divides the data into two periods (2012-2015 and 2016-2022) to analyze the impact of big data marketing technology on returning entrepreneurship in different time periods. As demonstrated in Table 3, the impact of big data marketing technology is significantly higher in the period of 2016-2022 than in the period of 2012-2015 (path coefficient: 0.65 vs. 0.38), supporting hypothesis H5.

Table 3. Model parameter estimation by time period

Parameters	2012-2015	2016-2022
Big data marketing technology enablement	0.38	0.65
Economic development level	0.32	0.48
Industrial structure	0.2	0.35
Foreign direct investment	0.14	0.22

5.2.5 Sub-regional Model

According to the analysis of the impact of big data marketing technology empowerment on the success of returning entrepreneurship in different regions, Table 4 presents that the path coefficient in the eastern region is 0.81, which is significantly higher than that in other regions. As shown in Table 4, the path coefficient in the central region is 0.52, while it is 0.46 in the western region and 0.44 in the northeast region. Overall, the empowering effect of big data marketing technology is most significant in the eastern region, while its impact is relatively weak in other regions. Hypothesis H7 is supported.

Table 4. Model parameter estimation by sub-region

Parameters	Eastern region	Central region	Western region	Northeastern region
Big data marketing technology enablement	0.81	0.52	0.46	0.44
Economic development level	0.41	0.31	0.28	0.26
Industrial structure	0.24	0.2	0.19	0.18
Foreign direct investment	0.31	0.26	0.24	0.2

5.3 Model Evaluation and Testing

To ensure that the model developed has a good fit, the following three tests are used. The first one is the goodness-of-fit, and the chi-square statistic (χ^2) is used to assess the fit of the model. The second is the path coefficient significance test, which tests the significance of each path through t-values and p-values to ensure the validity of each hypothesis. The third is model comparison, which compares the full-sample, rural, urban, and time-period models to analyze the differences in the effects of big data marketing technology empowerment.

Table 5. Summary of Goodness-of-Fit indexes

Model scenarios	Chi-square statistic (χ^2)	df	RMSEA	CFI	SRMR
Early rural	125.36	56	0.045	0.92	0.05
Late rural	137.89	60	0.048	0.94	0.04
Early urban	142.22	58	0.047	0.91	0.05
Late urban	120.45	54	0.044	0.93	0.04
Full sample model	156.78	62	0.046	0.95	0.03

As can be seen from Table 5, the goodness-of-fit indexes of the models meet the standard requirements, indicating that the models have a good fit. Among them, the ratios of chi-square to degrees of freedom are all less than 3, indicating that the models can explain the differences between the observed and predicted values of the data better. In addition, the root mean square error approximation (RMSEA) values are all less than 0.08, and the comparative fit index (CFI) and standardized root mean square residual (SRMR) satisfies the criteria of CFI>0.9 and SRMR<0.08, respectively, further verifying the reasonableness and robustness of the model fit. These results indicate that the structural equation modelling constructed in this research has high credibility and can effectively support the subsequent empirical analysis and testing of research hypotheses.

The estimation results of the four models verify the significant influence of big data marketing technology empowerment on the success of returning entrepreneurship.

Specifically, big data marketing technology empowerment shows a stronger influence in urban areas and later periods (2016-2022), while rural areas and earlier periods (2012-2015) show a weaker influence, which suggests that the role of spatio-temporal factors in technological efficacy should not be ignored.

6 Conclusions

This study systematically explores the impact of big data marketing technology empowerment on the success of returning entrepreneurs and its dynamic evolution pattern through full sample modeling, urban-rural comparison, regional heterogeneity analysis, and time-period modeling. The study draws the following main conclusions:

(1) Big data marketing technology empowerment has a significant positive impact on the success of returning home entrepreneurship, and its effect is significantly moderated by the level of economic development, industrial structure and regional digitization. This suggests that technological empowerment, economic foundation and industrial structure optimization are the key factors driving the success of returning entrepreneurship.

(2) The difference between urban and rural areas is significant. The enabling effect of big data marketing technology in the urban sample (path coefficient of 0.70) is significantly higher than that in the rural sample (path coefficient of 0.42), highlighting the differences in technology application conditions and resource endowment between urban and rural areas.

(3) Regional heterogeneity is obvious. The eastern region has the most significant technology-enabling effect (path coefficient of 0.81) due to its high level of economic development and well-developed digital infrastructure, while the central, western and northeastern regions have progressively diminishing impact coefficients (0.52, 0.46 and 0.44, respectively), reflecting the imbalance in the effect of technological empowerment among regions.

(4) The technology-enabling effect has increased significantly over time. The path coefficient for big data marketing technology is significantly higher for the period of 2016-2022 (0.65) than for the period of 2012-2015 (0.38), suggesting that technological advances are increasingly driving the entrepreneurial ecosystem.

Based on the above conclusions, this study proposes the following policy recommendations: first, the government should increase its efforts to develop and promote technology in rural and economically lagging regions to narrow the gap in the effectiveness of technology empowerment between regions; secondly, policymaking should focus on regionalization and differentiation, and targeted entrepreneurship support policies should be formulated taking into account the level of economic development and digitization in the region; third, with the rapid development of technology, policies should be adjusted in a timely manner, focusing on the popularization of technology and the enhancement of entrepreneurs' digital competence in order to maximize the positive effects of technological empowerment.

This study adopts various empirical methods, such as full-sample model, sub-sample model, and time-period analysis, to systematically analyze the mechanism of the influence of big data marketing technology on the success of returning entrepreneurship. The results of the study show that big data marketing technology has a significant positive impact on the success of returning entrepreneurs, but there is significant heterogeneity in the degree of its impact, which is manifested in significant differences across regions, time periods, and between urban and rural areas. This finding provides a solid empirical basis for the development of differentiated and targeted policies.

Different from previous studies focusing on traditional factors such as resource endowment and policy environment, this study for the first time incorporates big data marketing technology into the analytical framework of the influencing factors of the success of returning entrepreneurship. Based on the theory of spatio-temporal deduction, this study deeply explores its role mechanism in terms of urban-rural differences, time dimension changes and regional differences. This study not only expands the theoretical boundaries of the study of returning entrepreneurship, but also enriches the theoretical system of the study of technology empowerment and entrepreneurship. At the same time, the study reveals the heterogeneity and dynamic evolution law of the effect of technology empowerment, which provides a new theoretical perspective for understanding the regional differences and temporal changes of technology empowerment, and makes up for the shortcomings of the existing studies in the spatio-temporal dimension.

At the practical level, this study provides an important decision-making basis for the government and related organizations to formulate scientific and precise entrepreneurship support policies. In particular, this study is of great practical guidance in promoting the digital transformation of villages and narrowing the urban-rural and regional gap. In particular, this study is an important practical guide in promoting the digital transformation of villages and narrowing the urban-rural and regional gap.

Acknowledgement

This work was supported by the Key Project of Henan Provincial Education Science Planning, "Research on Value Reconstruction and Effectiveness Evaluation of College Students' Returning Entrepreneurship in the Context of New Quality Productivity" (No. 2025JKZD36), and the Annual Project of Philosophy and Social Science Planning of Henan Province, "Research on the Path of High-quality Development of Entrepreneurship under the Background of Rural Revitalization" (No. 2023BJJ101).

References

[1] S. Chen, Z. Weng, H. Ding, J. Huang, Experiment on the Effectiveness of Air-Space Numerical Intelligence Modeling for National Security Strategic Information Needs, *2024 IEEE 24th International Conference on*

Software Quality, Reliability, and Security Companion, Cambridge, United Kingdom, 2024, pp. 1188-1196. https://doi.org/10.1109/QRS-C63300.2024.00156

[2] Y. Cao, L. Hao, Z. Hua, X. Kang, Centralization or Decentralization? How Can Digital Transformation Empowers Firm Performance?, *2024 IEEE 24th International Conference on Software Quality, Reliability, and Security Companion*, Cambridge, United Kingdom, 2024, pp. 1258-1266. https://doi.org/10.1109/QRS-C63300.2024.00164

[3] X. Zang, Accessibility Analysis Model of College Students' Employment Education Resources Based on Mobile Search Algorithm, *Journal of Interconnection Networks*, Vol. 22, No. Supp04, Article No. 2146010, June, 2022. https://doi.org/10.1142/S0219265921460105

[4] J. Yan, M. Zhou, Y. Chen, Evaluation Model of College English Education Effect Based on Big Data Analysis, *Journal of Information & Knowledge Management*, Vol. 21, No. 3, Article No. 2250046, September, 2022. https://doi.org/10.1142/S0219649222500460

[5] J. Hu, Developing a Green Health-Oriented Talent Cultivation System through Industry-Education Integration in Universities, *Journal of Commercial Biotechnology*, Vol. 29, No. 1, pp. 263-278, January, 2024.

[6] A. Zakzouk, B. Oumran, H. Hasan, ALLI: A High-Performance Approach to Data Deduplication in Hadoop using Enhanced Hashing and Two-Level Indexing Techniques, *International Journal of Performability Engineering*, Vol. 20, No. 12, pp. 741-752, December, 2024. https://doi.org/10.23940/ijpe.24.12.p4.741752

[7] K. Chivukula, L.-N. Pattanaik, Effects of Industry 4.0 Technologies on Lean Manufacturing and Organizational Performances: An Empirical Study using Structural Equation Modelling, *International Journal of Performability Engineering*, Vol. 20, No. 6, pp. 355-366, June, 2024. https://doi.org/10.23940/ijpe.24.06.p3.355366

[8] X. Mo, IoT-Based Model for Student Ability Segmentation in Higher Education: A Technology and Innovation Management Approach, *Journal of Commercial Biotechnology*, Vol. 28, No. 4, pp. 259-270, October, 2023.

[9] E. Stam, Entrepreneurship, evolution and geography, in: R. Boschma, R. Martin (Eds.), *The handbook of Evolutionary Economic Geography*, Edward Elgar Publishing, 2010, pp. 307-348.

[10] G. Cao, N. Tian, C. Blankson, Big Data, Marketing Analytics, and Firm Marketing Capabilities, *Journal of Computer Information Systems*, Vol. 62, No. 3, pp. 442-451, 2022. https://doi.org/10.1080/08874417.2020.1842270

[11] H. Li, P. Li, Integrating Real-World Biotech Challenges into Entrepreneurship Education: A Pathway to Accelerating Student Startups in Digital Health, *Journal of Commercial Biotechnology*, Vol. 29, No. 2, pp. 178-188, May, 2024.

[12] J. Wang, L. Li, Analysis of the impact of college students' innovation and entrepreneurship on human resource index of science and technology enterprises based on logistic regression model, *Applied Mathematics and Nonlinear Sciences*, Vol. 9, No. 1, Article No. 00237, January, 2024. https://doi.org/10.2478/amns.2023.2.00237

[13] Z. Li, Y. Deng, Comprehensive evaluation of college students' engineering entrepreneurship ability based on improved TOPSIS model, *Journal of Commotional Methods in Science and Engineering*, Vol. 24, No. 3, pp. 2037-2047, May, 2024. https://doi.org/10.3233/JCM-230022

[14] F. Li, Research On The Management System Of College Students' Innovation and Entrepreneurship Education Based On B/S Architecture, *Journal of Applied Science and Engineering*, Vol. 26, No. 5, pp. 597-604, August, 2023. https://doi.org/10.6180/jase.202305_26(5).0002

[15] Z. Ren, N. Zhao, Z. Shi, Construction of a Model for College Students' Innovation and Entrepreneurship Quality Based on Artificial Intelligence Technology, *Informatica*, Vol. 47, No. 10, pp. 79-92, December, 2023. https://doi.org/10.31449/inf.v47i10.5174

Biographies

Xianhong Xu obtained a Ph.D. from Capital University of Economics and Business in 2017. Currently, she is employed by Zhengzhou Normal University. Her research mainly focuses on applied statistics, big data analytics and innovation and entrepreneurship management.

Hongqiang Zhao obtained a Ph.D. from Jilin University in 2011, Currently, he is employed by Zhengzhou Normal University. His research focuses on macroeconomics, business cycle, econometrics, game theory, regional economy, etc.

Tingting Tian obtained a Master's degree from Zhengzhou University in 2018. Currently, she is a doctoral student at Capital University of Economics and Business, and she is employed by Zhengzhou College of Finance and Economics. Her research focuses on auditing, big data analytics, and innovation and entrepreneurship management.

Jin Li obtained a Master's degree from University College London in 2018. Currently, she is a doctoral student at Capital University of Economics and Business. Her research focuses on income distribution, common prosperity and big data analytics.