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Study on The Impact of Network Structure on Digital Technology Diffusion in Regional Innovation Ecosystems: A Moderating Effect Based on Technological Compatibility

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Abstract

In order to study the diffusion of digital technology in regional innovation ecosystem, based on the analysis of the micro-mechanism of digital technology diffusion, a digital technology diffusion model of regional innovation ecosystem is constructed with threshold theory as the core. Through multi-dimensional dynamic simulation data, the influence of network structure on the diffusion of digital technology in regional innovation ecosystem and the moderating effect of technology compatibility are analyzed from the aspects of network average agglomeration coefficient, network average path length and network density. In addition, the simulation results are analyzed from the perspectives of digital technology diffusion speed and depth, and the corresponding research conclusions are drawn. The research shows that: (1) the average network agglomeration coefficient is negatively correlated with the depth of digital technology diffusion in the regional innovation ecosystem, and with the increase of the average network agglomeration coefficient, the negative correlation between the two is gradually significant. (2) The average path length of the network is negatively correlated with the depth and speed of digital technology diffusion in the regional innovation ecosystem. (3) Network density is positively correlated with the speed and depth of digital technology diffusion in regional innovation ecosystem, and within a certain network density range, the degree of digital technology diffusion in regional innovation ecosystem is accelerated.

Keywords

Regional innovation ecosystem; Digital technology diffusion; Network structure; Technology compatibility.

1. INTRODUCTION

Regional innovation ecosystem is an important carrier of regional economic development. Under the trend of regional economy seeking digital development by means of digital technology, it is also urgent to carry out digital transformation of regional innovation ecosystem, reconstruct its internal innovation structure, and promote the high-quality development of regional economy by forming an efficient digital regional innovation ecosystem. In this process, the diffusion of digital technology is a prerequisite for the success of the digital transformation of regional innovation ecosystem. On the one hand, only when the diffusion of digital technology reaches a certain degree, a stable digital innovation environment can be formed to promote technological innovation. On the other hand, the effective diffusion of digital technology can optimize the allocation of resources in the regional innovation ecosystem, and then promote resource sharing and information interaction, providing a solid foundation for the digital transformation of the regional innovation ecosystem. Therefore, it is of great significance to

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study the effective diffusion of digital technology in regional innovation ecosystem to promote the digital transformation process of regional innovation ecosystem.

The diffusion of digital technology in regional innovation ecosystem refers to the process of digital technology spreading among the subjects of regional innovation ecosystem over time. In recent years, scholars have conducted a series of studies on the diffusion of digital technology. Hossain et al. (2017) pointed out that enterprises will adopt digital technology to exert their potential advantages and gain competitiveness after being pressured by competitors [1]. Cai Xia et al. (2019) proposed that the more social networks formed by individual adopters, the more conducive to diffusion [2]. Qiu Zeqi and Huang Shiman (2021) proposed that the homogeneity and heterogeneity in the diffusion network of individuals will indirectly affect the channels and drivers of users' access to innovation [3]. Although the above research has laid a solid theoretical foundation for the study of digital technology diffusion, they still have the following shortcomings: On the one hand, most of the current research on digital technology diffusion is the influencing factors adopted at the individual level, and lacks the perspective of the overall network structure of the complex system of regional innovation ecosystem to analyze digital technology diffusion. On the other hand, in the past, scholars generally used linear regression [4], structural equation [5], evolutionary game [6] and other methods to analyze the causal relationship between variables, and digital technology diffusion is a complex dynamic process with nonlinear, high-order, multiple feedback and other characteristics. The traditional linear research method is not enough to analyze and grasp the nonlinear, holistic and complex characteristics of the digital technology diffusion system, which will be difficult to accurately reveal the mode and law of digital technology diffusion.

In view of this, based on the perspective of the overall network structure, this paper divides the overall network structure into network average agglomeration coefficient, network average path length and network density, and analyzes the impact of three complex network structure indicators on the digital technology diffusion of regional innovation ecosystem. In this process, enterprise technology compatibility in the regional innovation ecosystem network refers to the degree of matching between digital technology achievements and potential adopters in terms of existing technical conditions, organizational structure and cultural system [7]. It will adjust the relationship between the network structure of regional innovation ecosystem and the diffusion of digital technology by changing the interaction effect between enterprise adoption behaviors. For example, in the case of a high degree of matching of technical conditions, enterprises reduce the risk of incompatibility when enterprises adopt digital technology by interconnecting digital technology with existing technical equipment, and increase the demonstration effect of their neighboring enterprises. Therefore, this paper constructs a threshold model of digital technology diffusion based on adopter decision-making mechanism, and tries to use technology compatibility as a moderating variable. Through Netlogo simulation software, the speed and depth of digital technology diffusion are simulated and analyzed, so as to deeply reveal the influence relationship between network structure, technology compatibility and digital technology diffusion. Through the research of this paper, it not only expands the relevant theories of digital technology diffusion in regional innovation ecosystem, but also provides decision-making reference for local regions and governments to develop digital technology diffusion strategies.

2. BASIC CONCEPT

2.1. Regional Innovation Ecosystem

Since the innovation ecosystem was put forward, scholars have studied the innovation ecosystem and found that it is not perfect to analyze the innovation ecosystem only from the national level [8]. Because the efficiency of innovation depends on the connection and

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cooperation among the innovation subjects, the difference of regional innovation efficiency is more significant than that between countries, so scholars introduce the research results of ecology into the research of regional innovation. The regional innovation ecosystem refers to a system formed by the interaction and interdependence of innovative composite organizations and innovative composite environments in a certain spatial range through the flow of innovative materials, energy and information. Its social attributes, community agglomeration and short interaction distance are consistent with the structural characteristics of the small world network. Therefore, this paper uses the small world network to describe the network structure of the regional innovation ecosystem.

2.2. Regional innovation ecosystem network structure measurement indicators

(1) Average network agglomeration coefficient

The network clustering coefficient refers to the proportion of the actual number of connected edges of the adjacent nodes of a node in the network to the maximum possible number of connected edges of the adjacent nodes. In the regional innovation ecosystem, the network agglomeration coefficient reflects the agglomeration effect of enterprises. The higher the network agglomeration coefficient is, the higher the cohesion tendency of the regional innovation ecosystem is, as shown in Equation (1):

$$C_i = \frac{2E_i}{k_i(k_i-1)} \tag{1}$$

The average clustering coefficient of the network is the average value of the sum of the clustering coefficients of all nodes in the network, as shown in Equation (2):

$$\mathrm{C} = \frac{1}{N}\sum_{i=1}^{N} C_i \tag{2}$$

Where $0 \leq \mathrm{C} \leq 1$, when the C is larger, the network agglomeration of the whole regional innovation ecosystem is larger. According to the characteristics of the small-world network of regional innovation ecosystem, this paper sets the average network agglomeration coefficient as 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.5, 0.6 and 0.7.

(2) Average path length of network

The network path length refers to the shortest path between two connected nodes in the network. In the regional innovation ecosystem, the network path length describes the performance and efficiency of the inter-enterprise network. The shorter the network path length is, the easier it is for other enterprises to obtain diffusion information, such as (3):

$$\mathrm{L} = \frac{2}{N(N-1)}\sum_{m\neq n} L_{mn} \tag{3}$$

Where, L is the network average path length. Among them, the average path length of the small world network is shorter. According to the characteristics of the small-world network of regional innovation ecosystem, this paper sets the average network path length as 1.7, 1.8, 1.9, 2.0, 2.1, 2.3, 2.6, 3.5, 4.5 and 5.2.

(3) Network density

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Network density refers to the degree of connection between nodes in the network. In the regional innovation ecosystem, network density reflects the intensity and evolution trend of network relations, such as (4):

$$d = \frac{2Y}{N(N-1)} \tag{4}$$

Where, d is the network density. The greater the network density, the closer the relationship between network nodes, and the closer the relationship between enterprises in the regional innovation ecosystem. According to the characteristics of the small world network of the regional innovation ecosystem, the network density is set to 0.002,0.004,0.006,0.008,0.01,0.012,0.014,0.016,0.018 and 0.02, respectively.

3. MODEL CONSTRUCTION

At the micro level, the diffusion of digital technology in regional innovation ecosystem is the subject 's adoption process of digital technology. Based on this micro mechanism, this paper constructs a threshold model of digital technology diffusion in regional innovation ecosystem, and draws on the concept of Delre (2007) threshold model [9], the digital information transmission effect and demonstration effect of digital technology diffusion are considered in the threshold model, in which the digital information transmission effect is to let potential adopters understand the effect of digital technology, and the demonstration effect is to determine the individual 's adoption behavior of digital technology.

3.1. Basic model

According to the threshold theory, the regional innovation ecosystem digital technology diffusion model attributes the impact effect of digital information transmission to the digital impact itself, and the network platform only has the role of transmitting digital technology, and ultimately the threshold mechanism determines the adoption behavior of adopters. Therefore, the threshold model constructed in this paper includes a total of three parts, namely, the total utility evaluation model, the demonstration effect evaluation model and the technology preference utility evaluation model, as follows.

(1) Total utility evaluation model:

$$\begin{cases} Q_{i,t} \geq Q_{i,thre}, ZO_{i,t} = 1 \\ Q_{i,t} < Q_{i,thre}, ZO_{i,t} = 0 \end{cases} \tag{5}$$

$$Q_{i,t} = \gamma_i X_{i,t} + (1-\gamma_i) L_{i,j} \tag{6}$$

In the equation, $Q_{i,t}$ is the total utility obtained by enterprises adopting digital technology, $Q_{i,thre}$ is the adoption threshold of the enterprise, and $ZO_{i,t}$ indicates whether the enterprise adopts digital technology. $L_{i,j}$ is the effectiveness of digital technology compatibility and the performance of the technology itself for the enterprise, and $X_{i,t}$ is the demonstration effect brought by the adoption of digital technology by enterprises. γ_i is the importance of the impact of utility on the enterprise.

(2) Model for evaluation of demonstration effects:

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$$\begin{cases} B_{i,t} \geq x_{i,thre} \rightarrow X_{i,j} = 1 \\ B_{i,t} < x_{i,thre} \rightarrow X_{i,j} = 0 \end{cases} \quad (7)$$

In the equation, $B_{i,t}$ indicates the proportion of enterprises that have adopted digital technologies among their network neighbors. $x_{i,thre}$ represents the demonstration effect threshold of the enterprise.

(3) Technology preference utility evaluation model:

$$\begin{cases} q_j \geq l_{i,j} \rightarrow L_{i,j} = 1 \\ q_j < l_{i,j} \rightarrow L_{i,j} = 0 \end{cases} \quad (8)$$

In the equation, q_j represents the compatibility of digital technology. $l_{i,j}$ represents the preference threshold of enterprises for digital technology.

3.2. Model fixed parameter settings

Based on a large number of literatures and related cases, the fixed parameter settings of the model in this paper are shown in Table 1:

Table 1. Model fixed parameter settings

Name	Parameters	Value
Technology Preference	$\boldsymbol{l_{i,j}}$	$\mathbf{U}\sim(\mathbf{0},\mathbf{1})$
Demonstration weights	$\boldsymbol{\gamma_i}$	$\mathbf{N}\sim(\mathbf{0.65},\mathbf{0.01})$
Demonstration effect threshold	$\boldsymbol{x_{i,thre}}$	$\mathbf{N}\sim(\mathbf{0.3},\mathbf{0.01})$
Adoption Threshold	$\boldsymbol{Q_{i,thre}}$	$\mathbf{U}\sim(\mathbf{0},\mathbf{1})$
Enterprise network impact strength	Enterprise-network	0.003
Number of main bodies	Agent-number	1000
Number of running steps	Run-times	500

4. SIMULATION ANALYSIS

4.1. Network average agglomeration coefficient, technology compatibility and digital technology diffusion

(1) Diffusion depth of digital technology. As shown in Figure 1, with the increase of the average clustering coefficient of the network, the diffusion depth of digital technology first shows a flat trend and then shows a downward trend. This shows that there is a threshold in the process of digital technology diffusion. Within the threshold range, the average network agglomeration coefficient is negatively correlated with the depth of digital technology diffusion. With the increase of the average network agglomeration coefficient, the depth of digital technology diffusion in the regional innovation ecosystem will be reduced and the diffusion of digital technology will be hindered. In addition, high technology compatibility will reduce the degree of difference in the impact of network average agglomeration coefficient on the diffusion depth of digital technology in regional innovation ecosystem.

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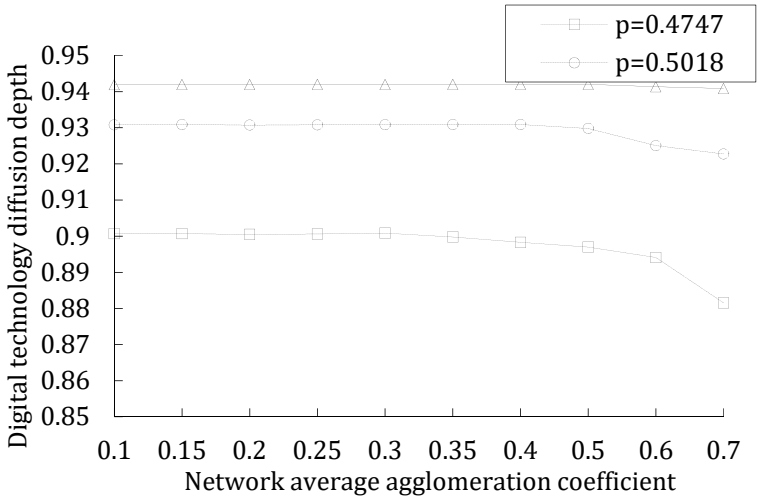

Figure 1. Simulation results of diffusion depth of digital technology

(2) Digital technology diffusion speed. As shown in Figure 2, with the increase of the average clustering coefficient of the network, the diffusion speed of digital technology generally shows a trend of increasing first and then decreasing. This shows that the relationship between the two is not a simple linear relationship, but has periodic characteristics. When the network agglomeration coefficients are 0.3,0.25 and 0.15, the diffusion rate of digital technology reaches the maximum. This shows that there is a threshold, so that the average agglomeration coefficient of the network can improve the speed of digital technology diffusion within a certain range. When the average agglomeration coefficient of the network reaches a critical point, digital technology is difficult to spread in the regional innovation ecosystem. In addition, technology compatibility is positively correlated with the speed of digital technology diffusion. With the increase of technology compatibility, the speed of digital technology diffusion in regional innovation ecosystem also increases accordingly.

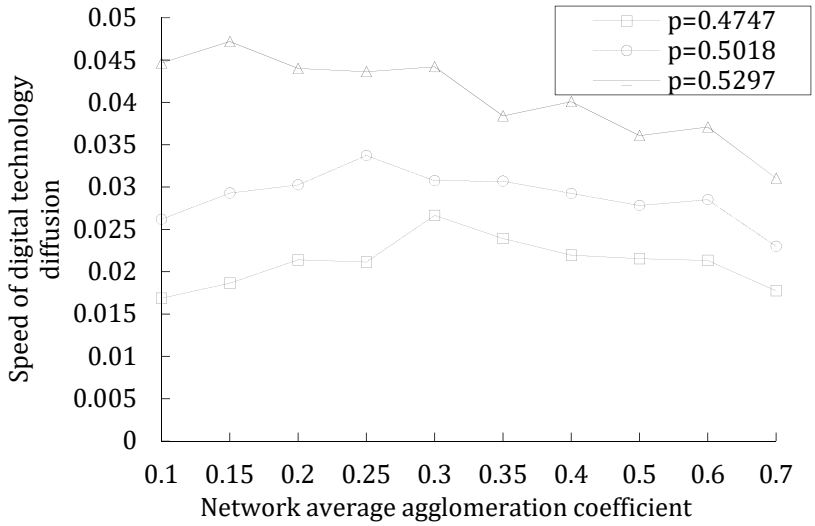

Figure 2. Simulation results of diffusion rate by digital technology

4.2. Network average path length, technology compatibility and digital technology proliferation

(1) Diffusion depth of digital technology. It can be seen from Figure 3 that with the increase of the average path length of the network, the diffusion depth of digital technology shows a

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downward trend. It can be judged that the average path length of the network has an impediment to the depth of digital technology diffusion in the regional innovation ecosystem. And when the average path length of the network reaches 2.1, the decline in the depth of digital technology diffusion increases, indicating that there is a threshold, so that the average path length of the network has no obvious effect on the depth of digital technology diffusion within the threshold range. In addition, increasing the intensity of technology compatibility can improve the blocking strength of the average path length of the network to the depth of digital technology diffusion, thus promoting the diffusion of digital technology in the regional innovation ecosystem.

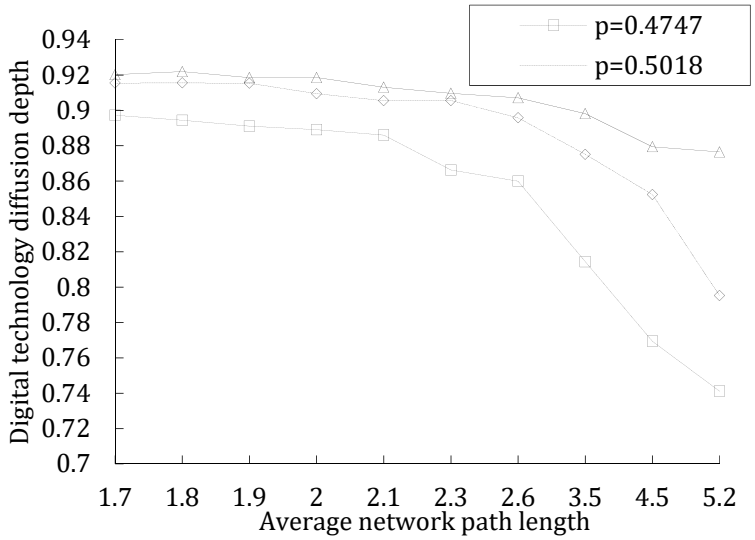

Figure 3. Simulation results of diffusion depth of digital technology

(2) Digital technology diffusion speed. As shown in Figure 4, with the gradual increase of the average path length of the network, the overall speed of digital technology diffusion shows a downward trend. It shows that there is a significant negative correlation linear relationship between the average path length of the network and the speed of digital technology diffusion. The increase of the average path length of the network will hinder the speed of digital technology diffusion in the regional innovation ecosystem. In addition, technology compatibility promotes the diffusion of digital technology. With the increase of technology compatibility, the diffusion speed of digital technology in regional innovation ecosystem also increases accordingly.

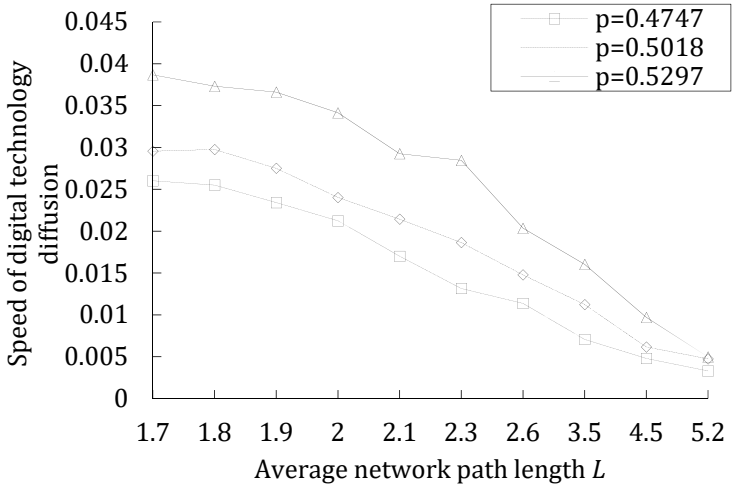

Figure 4. Simulation results of diffusion rate by digital technology

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4.3. Network Density, Technology Compatibility and Digital Technology Diffusion

(1) Diffusion depth of digital technology. It can be seen from Figure 5 that with the increase of network density, the diffusion depth of digital technology increases first and then tends to be gentle. In a certain range, the diffusion depth of digital technology increases rapidly, and with the continuous increase of network density, the diffusion depth of digital technology gradually tends to be gentle. It can be seen that there is a threshold, and the increase of network density within the threshold range has a significant promoting effect on the diffusion depth of digital technology in regional innovation ecosystem. In addition, there is not a simple linear relationship between technology compatibility and digital technology diffusion depth. In the threshold range, the diffusion depth of digital technology is positively correlated with technology compatibility. Outside the threshold range, the diffusion depth of low technology compatibility will exceed the diffusion depth of medium technology compatibility.

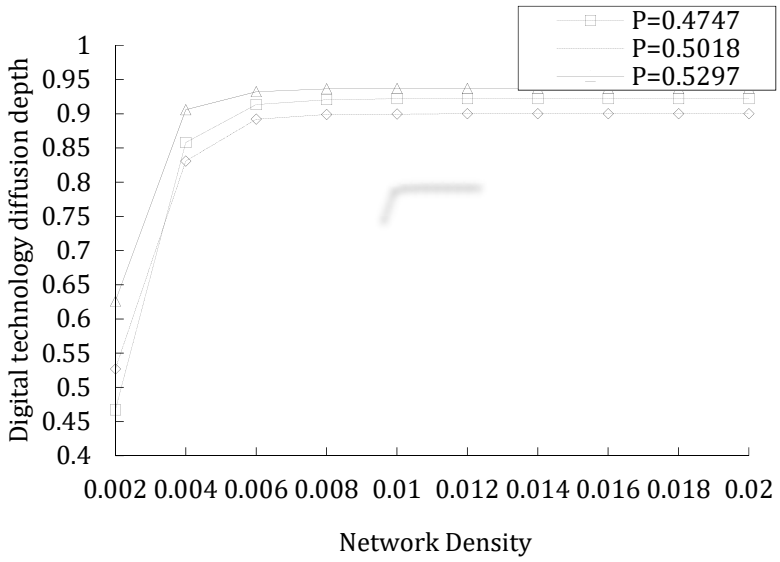

Figure 5. Simulation results of diffusion depth of digital technology

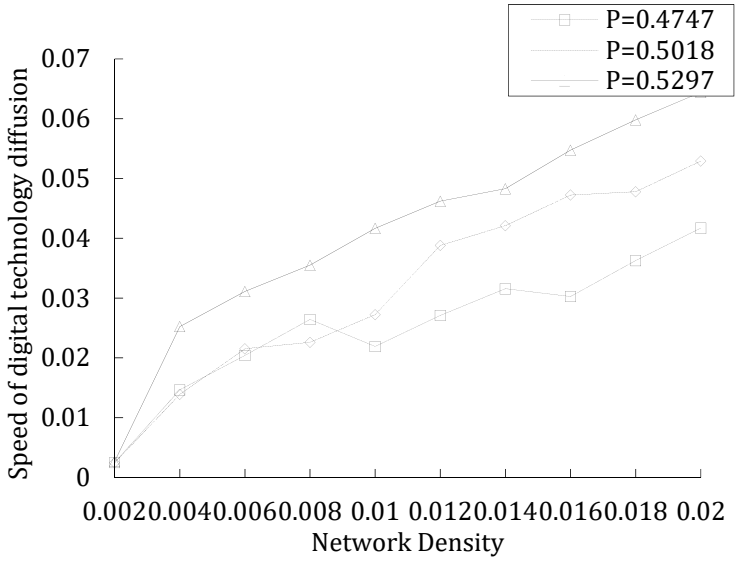

Figure 6. Simulation results of diffusion rate by digital technology

(2) Digital technology expansion speed. As shown in Figure 6, the speed of digital technology diffusion increases with the increase of network density. This shows that the increase of

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network density has a significant role in promoting the diffusion speed of digital technology in regional innovation ecosystem. In addition, when the network density is within a certain range, the diffusion speed of low technology compatible digital technology is always higher than that of medium technology compatible digital technology. It can be seen that for network density, there is not a simple linear relationship between technology compatibility and digital technology diffusion speed, but there is a threshold range. Within the threshold range, digital technology diffusion speed is positively correlated with technology compatibility. Outside the threshold range, the diffusion rate of low technology compatibility will exceed the diffusion rate of medium technology compatibility.

5. CONCLUSION

Based on the analysis of the micro-mechanism of digital technology diffusion in regional innovation ecosystem, this paper constructs a multi-agent model of digital technology diffusion in regional innovation ecosystem with threshold theory as the core. Taking Netlogo as the simulation platform, through multi-dimensional dynamic simulation data, this paper deeply analyzes the influence of network structure on digital technology diffusion in regional innovation ecosystem from the aspects of network average agglomeration coefficient, network average path length and network density, and the adjustment effect of technology compatibility. The study found that:

(1) The average network agglomeration coefficient is negatively correlated with the depth of digital technology diffusion. In addition, the average agglomeration coefficient of the network and the diffusion speed of digital technology show a trend of rising first and then falling. There is a threshold in the process of digital technology diffusion in regional innovation ecosystem, which can promote the speed of digital technology diffusion within the threshold range. When the average network agglomeration coefficient reaches a critical point, it is difficult for digital technology to diffuse in regional innovation ecosystem, and the threshold range will gradually shrink with the increase of technology compatibility until the threshold disappears. It can be seen that technology compatibility plays a regulatory role in the influence of average network agglomeration coefficient on digital technology diffusion in regional innovation ecosystem. (2) There is a negative correlation between the average path length of the network and the depth and speed of digital technology diffusion. Increasing the average path length of the network will hinder the degree of digital technology diffusion in the regional innovation ecosystem. (3) There is a positive correlation between network density and the speed and depth of digital technology diffusion, and within a certain network density range, the upward trend of the speed and depth of digital technology diffusion in the regional innovation ecosystem is accelerated. In addition, the degree of digital technology diffusion is not a simple linear relationship with technology compatibility. The depth of digital technology diffusion under the influence of high-tech compatibility and low-tech compatibility is greater than that under the influence of medium-tech compatibility. This shows that technology compatibility has a certain regulatory effect on the degree of digital technology diffusion in regional innovation ecosystems in network density. Based on the above analysis, the following suggestions are put forward:

(1) Enterprises with lower average network agglomeration coefficient and shorter average network path length are selected for promotion. There are more communication opportunities between the enterprise and other enterprises, which can break the barriers of information islands, facilitate the exchange of information on digital technology among enterprises, and accelerate the diffusion of digital technology in the regional innovation ecosystem.

(2) Select enterprises with high network density for promotion. The greater the network density, the closer the relationship between network nodes, the closer the trade between

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enterprises, and the more vulnerable to the adoption behavior of neighboring enterprises, which is conducive to the adoption of digital technology by enterprises.

(3) Enterprises should choose target enterprises with high technology compatibility for promotion, which can accelerate the efficiency of digital technology diffusion in regional innovation ecosystem.

(4) Enterprises should constantly explore innovative talents of digital technology, absorb and draw on the achievements of cutting-edge digital technology innovation, enhance their own innovation ability, establish an innovative platform, and promote the diffusion of technological innovation within the platform.

REFERENCES

[1] M.A. Hossain, C. Standing, et al. The development and validation of a two-staged adoption model of RFID technology in livestock businesses, Journal of Information Technology & People, vol. 30 (2017) No.4, p.785-808.

[2] X. Cai, Z. Song, X.L. Geng. The impact of social network structure and adopter innovativeness on innovation diffusion--a small world network as an example, Journal of Soft Science, vol. 33 (2019) No.12, p.60-65.

[3] Z.C. Qiu, S.M. Huang. Acquaintance society, external market, and imitation and innovation in rural e-commerce entrepreneurship, Journal of Sociological Research, vol. 36 (2021) No.4, p.133-158.

[4] K.B. Shi, Y.C. Yang, S. Bai, et al. Technology diffusion or efficiency priority: An exploration of O2O e-commerce spatial penetration in China based on "Meituan.com", Journal of Geography Research, vol. 37 (2018) No.4, p.783-796.

[5] X.D. Li, J.T. Chen. Study on the driving path of FDI on the evolution of regional innovation system--an analysis based on structural equation modeling, Journal of Science and Technology Management, vol. 35 (2014) No.8, p.39-48.

[6] Y.H. Ma, X. Su, Y. Zhao. Evolutionary game analysis of industrial common technology diffusion, Journal of Control Theory and Applications, vol. 36 (2019) No.1, p.22-31.

[7] W.X. Chen, X. Wu. A study of patterns, characteristics and optimal paths of generic digital technology diffusion, Journal of Economic Research Reference, (2020) No.18, p.5-17.

[8] P. Cooke, M.H. Uranga, G. Etxebarria. Regional innovation systems: institutional and organisational dimensions, Journal of Research Policy, vol. 26 (1997) No.4.

[9] S.A. Delre, W. Jager, M.A. Janssen. Diffusion dynamics in small-world networks with heterogeneous consumers, Journal of Computational and Mathematical Organization Theory, vol. 13 (2007), No.2.