ISSN: 2692-7608 DOI: 10.6981/FEM.202308_4(8).0039

Impact of "Architect" on the Diffusion of Digital Technology in Innovation Ecosystem

-- Scale-free Network-based Simulation Study

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Abstract

In the context of innovation ecosystem, a scale-free network-based digital technology diffusion model is constructed with the market environment as the moderating variable, and a multi-agent simulation method is applied to dissect the complex mechanism of architects on digital technology diffusion in innovation ecosystem. The results show that architect size and architect innovativeness have a significant positive effect on the depth of digital technology diffusion in innovation ecosystems; the effect of architect size on the rate of digital technology diffusion tends to fluctuate up and down, while the effect of architect innovativeness has an inverted U-shaped relationship; and the volatility of the market environment has a moderating role in the relationship between architects and the rate of digital technology diffusion in innovation ecosystems. The findings further enrich the theories related to digital technology diffusion and provide a basis for decision making on the diffusion of digital technology.

Keywords

Architect; Digital Technology; Innovation Ecosystem; Simulation Analysis; Sustainable Innovation; Technology Diffusion.

1. Introduction

With the rapid development of digital technology, the characteristics of VUCA (volatile, uncertain, complex and ambiguous) of the external environment of enterprises are becoming increasingly prominent. To cope with this uncertainty, enterprises have chosen digital transformation strategies to reshape their innovation models and environments with the help of digital technologies and to maintain their competitive advantages by developing continuous digital innovation capabilities. It can be seen that the essence of digital transformation is innovation, and it is also based on innovation [1]. With the "ecosystem" transformation of corporate innovation in the Innovation 3.0 era, the innovation ecosystem has become the dominant form of corporate innovation activities and digital transformation, and the digital transformation of innovation ecosystem has become a hot topic for scholars. The digital transformation of innovation ecosystems has become a hot issue for scholars [2, 3]. The digital transformation of innovation ecosystems refers to the process by which the act of digital transformation among enterprises triggers changes in the structure, function, and operational mechanisms of the entire system [4]. In this process, effective diffusion of digital technologies is a prerequisite for the successful digital transformation of the innovation ecosystem. Only when digital technologies reach a certain level of diffusion and a stable and coordinated digital innovation environment is formed can the phenomenon of "backtracking" of traditional technologies be prevented. In addition, the diffusion of digital technologies can optimise the organisational structure of innovation ecosystems, thus promoting information interaction and resource sharing, and providing new momentum for the digital transformation of innovation

ISSN: 2692-7608 DOI: 10.6981/FEM.202308_4(8).0039

ecosystems. Therefore, the effective diffusion of digital technologies in the innovation ecosystem is of great practical significance in promoting the digital transformation of the innovation ecosystem and thus the high-quality development of the digital economy.

The diffusion of digital technology in innovation ecosystems refers to the process by which digital technologies are widely adopted by firms in an innovation ecosystem in a certain way within a specific period of time [5]. Currently, scholars have focused primarily on the influence of attributes of digital technology [6-8], the internal structure of enterprises [9, 10] and the external diffusion environment [11, 12] on the behaviour of adoption of digital technology by enterprises, laying the theoretical foundation for diffusion of digital technology in innovation ecosystems. However, the following aspects are still lacking: (1)scholars have mostly studied digital technology diffusion at the level of individual enterprises but lack a system-wide perspective to explore it. In reality, digital technology diffusion at the level of innovation ecosystem is not a simple superposition of individual adoption behaviour, but the result of complex nonlinear interactions of microentities emerging at the macro level. Exploring the diffusion of digital technologies in innovation ecosystems is crucial to understanding the patterns of diffusion of digital technologies in complex social systems. (2)Lack of attention by architects to the impact of the adoption and diffusion of digital technologies by subjects within innovation ecosystems, where architects play a key role in the diffusion of digital technologies in innovation ecosystems. In the initial stages of digital technology diffusion, influential leaders are particularly needed to drive the diffusion of digital technologies, and architects are the initial drivers and key innovation agents for the diffusion of digital technologies in innovation ecosystems due to their strong innovation and information acquisition capabilities. (3)Existing studies generally adopt linear analysis methods such as structural equation model and case studies to dissect the influence mechanisms of digital technology diffusion, and pay insufficient attention to the complex nonlinear interactions among adopters in the innovation ecosystem, which will affect the scientific and generalizability of the results of the overall diffusion model.

In addition, the development of innovation in firms is a dynamic interaction with the external environment, and the diffusion of digital technologies in innovation ecosystems is inevitably influenced by the external market environment [13-15]. In practice, due to the rapid evolution of digital technology, the digital interaction of a community of firms varies between different levels of turbulence in the market environment, and the diffusion of digital technology is subsequently facilitated or hindered. In order to study the impact of digital technology diffusion under different levels of turbulence in the market environment, this paper uses the degree of turbulence in the market environment as a moderating variable to investigate the role of architects on digital technology diffusion.

Based on the perspective of architects and using the market environment as the moderating variable, this paper uses multi-agent simulation to explore the impact of the scale of architects and the degree of innovativeness of architects on the speed and depth of digital technology diffusion in the innovation ecosystem. On the one hand, this paper provides insights into the influence of architects on the diffusion of digital technology in innovation ecosystems by setting up diverse simulation scenarios, complementing the theoretical research on the role of architects on the diffusion of digital technology in innovation ecosystems, and on the other hand, it provides a reference for decision-making for government departments and relevant core enterprises to promote the digital transformation of innovation ecosystems, improve the innovation performance of enterprises and achieve high-quality development of enterprises.

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2. Theoretical Foundations

2.1. Architect

The concept of architect was first introduced by Gulati and others to refer to the core agents that take the lead in innovation activities when they are carried out within an innovation ecosystem and are the key drivers for the adoption of innovations by other agents, thus driving the construction and evolution of the innovation ecosystem [19-21]. Architect is usually characterised by a strong capacity to innovate and integrate information, a lower sensitivity to demonstration effects, and a broader range of information dissemination channels, which contribute significantly to the diffusion of digital technologies. As the most important pioneer in the innovation ecosystem, Architect facilitates the diffusion of technology in the innovation ecosystem by coordinating the relationships between the various players in the innovation ecosystem and evolving collaboratively towards the set goals. The architects, which are the key organisations driving the diffusion of digital technologies, can be subdivided into internal architects and external architects. Internal architects refer to the core companies that adopt digital technologies, supplemented by other related industries, which are involved in the creation of digital technology value and provide energy for the diffusion of digital technologies in the innovation ecosystem; External architects refer to upstream players such as governments, universities, research institutions, and technology companies, supplemented by downstream actors such as consumers, who are not directly involved in the creation of digital technology value, but can provide dynamic support for the diffusion of digital technology in the innovation ecosystem.As the core enterprises in the innovation ecosystem are the core of the innovation strategy and digital resources, they are important innovation agents with strong innovation, coordination and resilience, able to absorb and lead other agents to implement innovation, and play a key role in the process of digital technology diffusion. Therefore, this paper focuses on the impact of the internal architects, that is, the core enterprises as innovation agents, on the diffusion of digital technology in the innovation ecosystem.

2.2. Innovation Ecosystems

Due to the innovation-driven nature of digital transformation and its systemic characteristics, innovation ecosystems have attracted widespread attention from scholars as a new type of innovation organization structure in response to the digital economy environment in the 3.0 era innovation paradigm. The concept of innovation ecosystem, first formally introduced by Ander in 2006, refers to a network structure that connects individual enterprises with organizations in the system to achieve value creation through interaction, and is essentially a collaborative mechanism with core enterprises as the mainstay [19]. As research progresses, scholars have interpreted the concept of innovation ecosystem from a network perspective, that is an innovation ecosystem refers to an open and dynamic network system in which firms connect and cooperate in innovation activities based on a common value proposition, resulting in synergy, interdependence, and coexistence [20]. The network structure of an innovation ecosystem differs from that of a regular or random network in that a small number of nodes have a large number of organisational connections, while the majority of nodes are few. The degree of the node of the network follows an obvious power-law distribution, which is highly consistent with the characteristics of a scale-free network structure [21]. Therefore, in this paper, a scale-free network model is chosen to simulate the evolution of the diffusion of digital technology in an innovation ecosystem when it is architect-oriented.

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3. Simulation Process for the Diffusion of Digital Technology in Innovation Ecosystems

3.1. Structural Setting of the Innovation Ecosystem

The scale-free network model was constructed according to the method proposed by Barabasi and Albert [22], and the scale-free network was generated by Netlogo software as follows: first, a fully coupled network with 10 nodes was constructed, and then one node was added in turn, and m0 = 3 old nodes were randomly selected to be connected to the new nodes according to the principle of degree priority, until the total number of nodes reached 500, the parameters of the generated scale-free network are shown in Table 1.

Table 1. Structural parameters of the scale-free network

Parameter name	Number of nodes	Average degree	Preference for number of dependent nodes	Average agglomeration factor	Average path length
Parameter values	500	6.06	3	0.07	4.804

A schematic representation of the generated scale-free network model is shown in Figure 1.

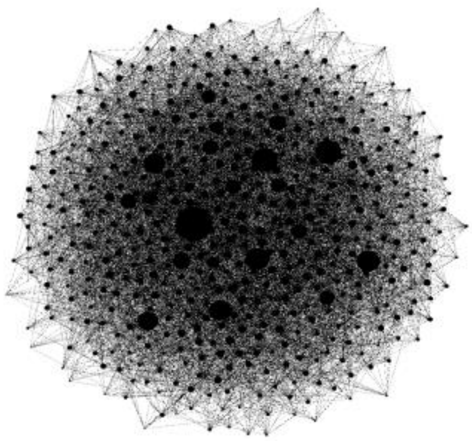

Figure 1. Schematic diagram of the scale-free network structure

3.2. Moderating Variables

Digital technology diffusion in innovation ecosystems is the process by which digital technologies are adopted by initial adopters and then integrated and distributed innovatively. In this process, the volatile market environment not only influences the frequency of digital technology updates but also the competitive environment for firms, which plays a moderating role in the diffusion of digital technologies in innovation ecosystems. Therefore, this paper divides the market environment into strong volatile market environment, weak volatile market environment, and medium volatile market environment, which lies between, to analyse the impact of architects on the diffusion digital technologies under different levels of turbulence in the market environment.

(1) Strong volatile market environment

Strong volatile market environment is one in which the demonstration effects of other firms in the system play a much greater role in the adoption behaviour of potential adopters than the characteristics of the digital technology itself in the diffusion of digital technologies in the innovation ecosystem. That is, when making decisions about digital technologies, potential

ISSN: 2692-7608 DOI: 10.6981/FEM.202308_4(8).0039

adopters place greater importance on whether they can maintain their own behaviour in line with that of other adopters when adopting the digital technology, and thus maintain their business operations without becoming disconnected from those that have already adopted the digital technology. In a strong volatile market environment, the advanced and efficient nature of digital technology is not overly valued by potential adopters, and the competitive pressure from other firms within the system to adopt digital technology is more pronounced, and the more volatile the market environment, the more eager firms are to innovate digitally.

(2) Weak volatile market environment

In weak volatile market environment, potential adopters take into account the characteristics of the digital technology itself, such as its sophistication, its complexity, and its suitability for the firm, when deciding whether to adopt it. The adoption behaviour of potential adopters depends on whether the characteristics of the digital technology itself meet the expectations of the potential adopters and is less influenced by the demonstration effect of other firms in the innovation ecosystem. Potential adopters may take into account the advice of other adopters when deciding whether to adopt a digital technology, but the degree of influence on their decision-making behaviour is weak, and the less volatile the market environment, the more muted the willingness of potential adopters to transform their businesses.

3.3. Threshold Model Construction

Among the many models of subjective decision-making, the threshold model better reflects human psychological preferences and decision-making behavioural mechanisms, and is a model often used in the field of social dynamics research, especially in the modelling of collective behaviour [22]. The threshold model in this paper is based on Granovette's threshold theory [23] and includes three main aspects: acquisition of digital technology information, evaluation of the utility of digital technology and digital technology adoption function. The model suggests that inter group adoption behaviour has a positive demonstration effect on the behaviour of other firms, and when the number of this behaviour reaches its own threshold, firms will adopt digital technology due to the demonstration effect, which in turn creates a stronger demonstration effect. The threshold model describes the interaction of positive feedback between groups.

3.3.1. Acquisition of Digital Technology Information

Firms in the innovation ecosystem generally access information on digital technologies through innovation promotion agencies and apply digital technologies to enhance their innovation capabilities in order to build their competitive advantage. As the first adopters of digital technologies in the innovation ecosystem, architects are more proactive in accessing relevant information, initiating innovative thinking to adopt digital technologies, and promoting the diffusion of digital technologies within the system, i.e. IAi-ol=1. The presence of architects broadens the access of potential adopters to information about digital technologies, i.e. if an architect in the innovation ecosystem knows or applies a digital technology, other firms in the system will also have access to information about that digital technology, i.e. IAi-fol=1.

$$IA_{i-o1} = \begin{cases} 1 & \text{Innovation Promotion Agencies} \\ 0 & \text{No access to digital technology information} \end{cases} \tag{1}$$

$$IA_{i-fo1} = \begin{cases} 1 & \text{Innovation Promotion Agencies and Architects} \\ 0 & \text{No access to digital technology information} \end{cases} \tag{2}$$

ISSN: 2692-7608 | DOI: 10.6981/FEM.202308_4(8).0039

3.3.2. Evaluation of the Utility of Digital Technology

After obtaining information about a digital technology, companies will assess whether to adopt the technology based on its potential usefulness, including the characteristics of the technology itself and the demonstration effect of adoption by other companies in the system.

(1) Evaluation of characteristics of digital technology

Regardless of whether a potential adopter i within the innovation ecosystem is an architect or a follower, when the potential adopter's expectations of the digital technology j are met, i.e., when the digital technology characteristics qj are greater than or equal to the potential adopter's preference threshold for the digital technology innovativeness pi,j, the potential adopter develops a utility preference for the digital technology with a utility value of 1. Otherwise, the potential adopter does not develop a preference for the digital technology, and the digital technology itself does not provide any utility to the potential adopter with a utility value of 0. Since the information integration ability of the architect is stronger than that of the followers, the model makes the following assumptions: the architect is able to accurately judge the characteristics of digital technology after acquiring information about the innovativeness of digital technology, that is, qj-ol=0.5, and the followers can only accurately judge the characteristics of digital technology accordingly when other firms in the system adopt the innovation of digital technology, that is, qj-fol=0.5, if no other firm in the innovation ecosystem adopts this digital technology, the followers will reduce their evaluation of the characteristics of digital technology due to teaching of the weak information integration ability, that is, qj-fol=0.

$$q_{j-ol} = \begin{cases} 0.5 & \text{Innovation Promotion Agencies} \\ false & \text{No access to digital technical information} \end{cases} \quad (3)$$

$$q_{j-fol} = \begin{cases} 0.5 & \text{Innovation promotion agencies, architects and other enterprises} \\ 0 & \text{Innovation promotion agencies and architects} \\ false & \text{No access to digital technical information} \end{cases} \quad (4)$$

$$\text{Architect digital technology utility functions} \quad \begin{matrix} q_{j-ol} \geq p_{i-ol,j} \Rightarrow p_{i-ol,j} = 1 \\ q_{j-ol} < p_{i-ol,j} \Rightarrow p_{i-ol,j} = 0 \end{matrix} \quad (5)$$

$$\text{Follower digital technology utility functions} \quad \begin{matrix} q_{j-fol} \geq p_{i-fol,j} \Rightarrow p_{i-fol,j} = 1 \\ q_{j-fol} < p_{i-fol,j} \Rightarrow p_{i-fol,j} = 0 \end{matrix} \quad (6)$$

(2) Evaluation of the demonstration effect

Potential adopters are affected by the demonstration effect if the ratio of the number of firms in the innovation ecosystem that have adopted digital technologies to the total number of firms is greater than or equal to the demonstration effect threshold for potential adopters ni,thre and has a value of 1. Otherwise, potential adopters are not affected by the demonstration effect and have a demonstration effect value of 0. The rules for evaluating architects and followers are the same with respect to the demonstration effect.

$$\text{Architect demonstration effect function} \quad \begin{matrix} A_{i-ol} \geq n_{i,thre} \Rightarrow N_{i-ol} = 1 \\ A_{i-ol} < n_{i,thre} \Rightarrow N_{i-ol} = 0 \end{matrix} \quad (7)$$

$$\text{Follower demonstration effect function} \quad \begin{matrix} A_{i-ol} \geq n_{i,thre} \Rightarrow N_{i-fol} = 1 \\ A_{i-fol} < n_{i,thre} \Rightarrow N_{i-fol} = 0 \end{matrix} \quad (8)$$

(3) Total utility evaluation

ISSN: 2692-7608 DOI: 10.6981/FEM.202308_4(8).0039

The total utility of architects and followers is the sum of the characteristics of the digital technology itself and the demonstration effect of the firms that have adopted it. Since architects are less sensitive to the demonstration effect than followers, the weighting factor of the demonstration effect for architects is lower at ai.

$$U_{i-ol} = \alpha_{i-ol}N_{i-ol} + (1-\alpha_{i-ol})p_{i-ol,j} \tag{9}$$

$$U_{i-fol} = \alpha_{i-fol}N_{i-fol} + (1-\alpha_{i-fol})p_{i-fol,j} \tag{10}$$

Whereαi-ol<αi-fol.

3.3.3. Digital Technology Adoption Function

Potential adopters in the innovation ecosystem decide whether to adopt a digital technology based on its utility value and adoption threshold. Potential adopters adopt a digital technology when its utility value Ui is greater than or equal to its adoption threshold Ui,thre; otherwise, they do not adopt the digital technology. The adoption threshold is negatively related to the innovation of the firm, with architects being more innovative than followers and, therefore, having a lower adoption threshold than followers.

$$AC_{i-ol} = \begin{cases} 1 & U_{i-ol} \geq U_{i-ol,thre} \\ 0 & U_{i-ol} < U_{i-ol,thre} \end{cases} \tag{11}$$

$$AC_{i-fol} = \begin{cases} 1 & U_{i-fol} \geq U_{i-fol,thre} \\ 0 & U_{i-fol} < U_{i-fol,thre} \end{cases} \tag{12}$$

3.4. Simulation Parameter Settings

In this paper, the simulation parameters are set according to the relationship between architects and digital technology diffusion, in which the demonstration effect weights of architects are 0.81, 0.51, and 0.21 in order from the strongly turbulent market environment to the weakly turbulent market environment, and those of the followers are 0.90, 0.60, and 0.30, with the lower limit uniformly set at 0.01. In addition, the digital technology characteristics are 0.5, and the intensity of the media influence is 0.003. The specific simulation parameters were set as follows:

Table 2. Model parameter settings based on the weights of the demonstration effects of the three market environments

Volatile market environment	Architect		Follower	
	Parameters	Parameter values	Parameters	Parameter values
Strong volatile market environment	α_{i-ol}	N~(0.81, 0.01)	α_{i-fol}	N~(0.90, 0.01)
Medium volatile market environment	α_{i-ol}	N~(0.51, 0.01)	α_{i-fol}	N~(0.60, 0.01)
Weak volatile market environment	α_{i-ol}	N~(0.21, 0.01)	α_{i-fol}	N~(0.30, 0.01)

(1) Architect size, market environment, and digital technology diffusion simulation parameter setting

ISSN: 2692-7608 DOI: 10.6981/FEM.202308_4(8).0039

This section focuses on the impact on the speed and depth of digital technology diffusion when the size of the architects changes. Simulations will be conducted in three market environments: strong volatile market environment, medium volatile market environment, and weak volatile market environment. Where architects have an adoption threshold of 0-0.8 and followers have an adoption threshold of 0-1. To explore the dynamics between architect size and market environment and digital technology diffusion, architect size is set to 5, 10, 20, 30, 40, 50, 60, 70, 80, 100, 120 and 145 for each of the three simulation scenarios.

(2) Architect innovativeness, market environment, and digital technology diffusion simulation parameter setting

This section examines the impact on the speed and depth of digital technology diffusion when architects differ in their degree of innovativeness. Simulations will be carried out in three environments: strong volatile market environment, medium volatile market environment, and weak volatile market environment. The number of subjects of architects is 300 and the number of subjects of followers is 700. To explore the dynamics between architect innovativeness and market environment and digital technology diffusion, architect innovativeness parameters are set to U~(0, 0.85), U~(0, 0.80), U~(0, 0.75), U~(0, 0.70), U~(0, 0.65), U~(0, 0.60), U~(0, 0.55), U~(0, 0.50), U~(0, 0.45), U~(0, 0.40), U~(0, 0.35), and U~(0, 0.30) for a total of twelve reference groups.

4. Simulation Results of Digital Technology Diffusion in Innovation Ecosystem

4.1. Architect Size, Market Environment and Digital Technology Diffusion

The simulation model was analyzed using Netlogo software, and 100 simulations were carried out for each parameter condition. In order to eliminate the influence of random parameter settings on the simulation results to the greatest extent possible, the mean value was chosen as the final simulation result in this paper, and the simulation data were collated, plotted, and analyzed in terms of both the speed and depth of diffusion of digital technology, with the following results:

(1) Depth of digital technology diffusion

As shown in the figure, the diffusion depth curve of digital technology shows a general upward trend with increasing architect size in these three market environments. When ol<100, the depth of diffusion of digital technology is greater in the medium turbulent market environment, followed by the weak turbulent market environment, and least in the strong turbulent market environment, given the same architect size. When ol=100, the diffusion depth of digital technology in the strong turbulent market environment is slightly higher than that in the weak turbulent market environment, while as the architect size increases, the diffusion depth of digital technology in different market environments in order from high to low is medium turbulent market environment, weak turbulent market environment and strong turbulent market environment. When ol<70, the depth of diffusion of digital technology increases more slowly, when ol>70, the depth of diffusion of digital technology varies relatively more with increasing architect size in medium turbulent market environment and strong turbulent market environment, while the depth of diffusion of digital technology tends to vary slowly with increasing architect size in weak turbulent market environment.

ISSN: 2692-7608 DOI: 10.6981/FEM.202308_4(8).0039

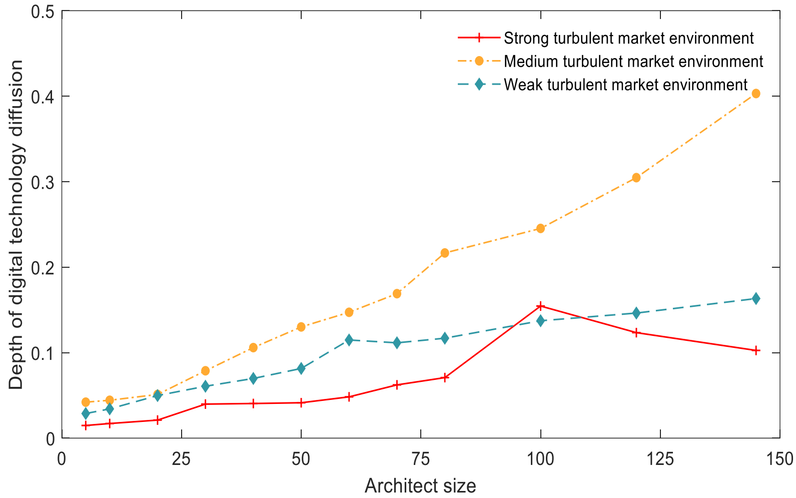

Figure 2. Simulation drawing of the relationship between digital technology diffusion depth and architect scale

(2) Speed of digital technology diffusion

As shown in the figure, the diffusion speed of digital technology increases with the increase in architect size in all three market environments, but not always with the increase in architect size; the diffusion speed fluctuates with the increase in architect size. In weak and medium volatile market environments, the diffusion speed of digital technologies tends to increase and then decrease as the architect size increases. In strong turbulent market environment, the diffusion speed of digital technology increases with the increase in architect size. Under the same architect size condition, when ol<40, the diffusion speed of digital technology in the weak turbulent market environment is higher than that of the medium turbulent market environment and the strong turbulent market environment; when 40≤ol≤100, the diffusion speed of digital technology is highest in the medium turbulent market environment, followed by the strong turbulent market environment and the weak turbulent market environment; when ol>100, the diffusion speed of digital technology is higher in the strong turbulent market environment than in the medium turbulent market environment, and lowest in the weak turbulent market environment.

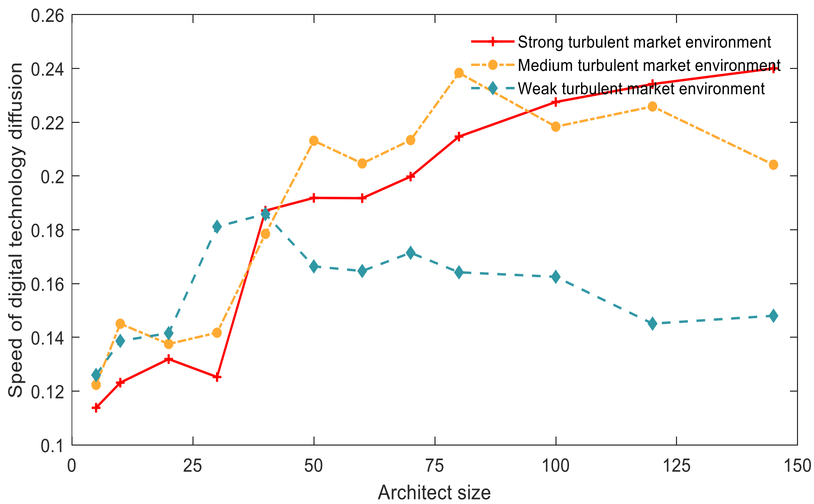

Figure 3. Simulation drawing of the relationship between digital technology diffusion speed and architect scale

ISSN: 2692-7608 DOI: 10.6981/FEM.202308_4(8).0039

4.2. Architect Innovativeness, Market Environment and the Proliferation of Digital Technologies

The simulation model was analyzed using Netlogo software, and 100 simulations were carried out for each parameter condition. To eliminate the influence of random parameter settings on the simulation results to the greatest extent possible, the mean value was chosen as the final simulation result in this paper, and the simulation data were collated, plotted, and analyzed in terms of both the speed and depth of diffusion of digital technology, with the following results:

(1) Depth of digital technology diffusion

In the study of digital technology diffusion, scholars generally use adoption thresholds to measure the innovativeness of potential adopters. The lower the adoption threshold of a potential adopter, the easier it is to adopt digital technology, representing a higher level of innovativeness. In this paper, the adoption threshold parameter Ui,thre-ol is set to follow a uniform distribution with values ranging from 0 to μ, and the value of μ is the mean value of the innovativeness of the architects. The lower the value of μ, the lower the average adoption threshold of the architects, that is, the more innovative the architects. The figure shows that the depth of diffusion of digital technologies increases with the level of innovativeness of the architects in the three market environments. The depth of diffusion of digital technology innovation increases fastest with architect innovativeness in the strong turbulent market environment, and then increases the slowest in the weak turbulent market environment. As can be seen from the graph, the depth of diffusion of digital technology innovation increases faster when the innovativeness of the architect is high, that is, when $\mu \leq 0.55$, and increases fastest in the strong turbulent market environment, followed by the medium turbulent market environment and finally the weak turbulent market environment, and increases slower when $0.6 \leq \mu$, although it is still the lowest in the weak turbulent market environment and the highest in the strong turbulent market environment.

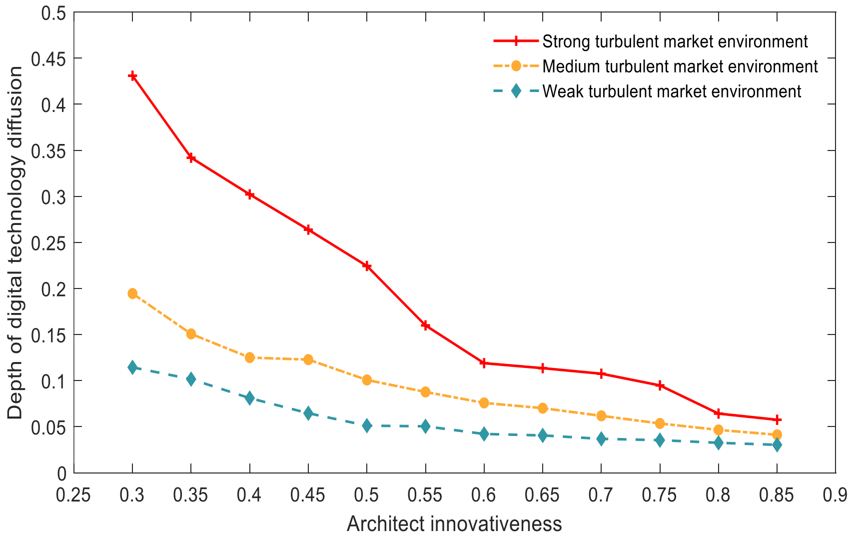

Figure 4. Simulation drawing of the relationship between digital technology diffusion depth and architect innovativeness

(2) Speed of digital technology diffusion

As shown in the figure, the diffusion speed of digital technologies tends to increase overall with the degree of innovativeness of the architects in the three market environments. As the innovativeness of architects increases, the diffusion speed of digital technologies rises fastest in medium and strong turbulent market environments, especially when $0.45<\mu<0.65$, where

ISSN: 2692-7608 **DOI: 10.6981/FEM.202308_4(8).0039**

the diffusion speed curve is steepest. The diffusion speed of digital technology rises flatly in weak turbulent market environment, and the diffusion speed of digital technology in weak turbulent market environment is at a lower level compared to the speed of diffusion in strong turbulent and medium turbulent market environments. Additionally, the diffusion of digital technologies is highest in medium volatile markets when 0.4<μ<0.7. When architects are more or less innovative, that is,μ≤0.35 or μ≥0.7, digital technologies diffuse faster in strong turbulent market environment, followed by medium turbulent market environment and slower in weak turbulent market environment.

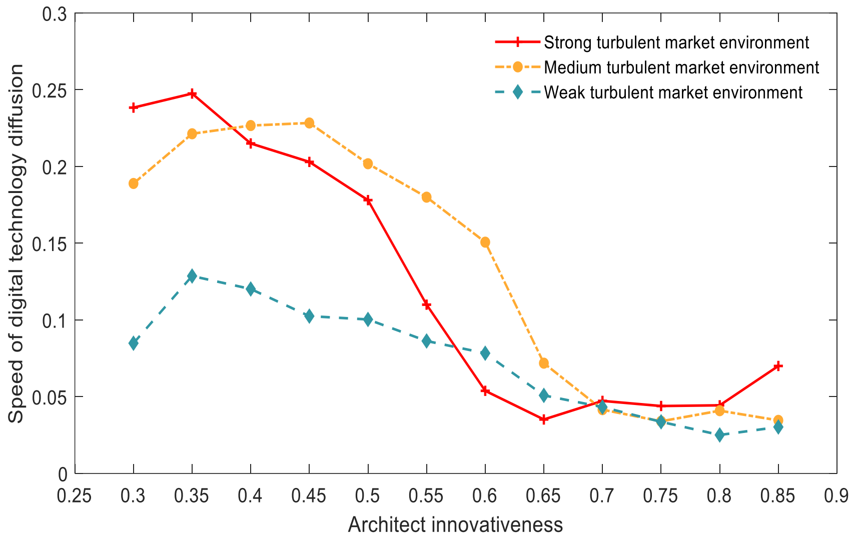

Figure 5. Simulation drawing of the relationship between digital technology diffusion speed and architect innovativeness

5. Conclusion and Insights

5.1. Research Findings

This paper investigates the complex nonlinear influence relationship between the architect size and architect innovativeness and the digital technology diffusion in innovation ecosystems, using three different levels of turbulence in the market environment as moderating variables, and constructs a simulation model of digital technology diffusion in innovation ecosystems using a multi-agent simulation approach, and finds that:

Architect size has an overall positive impact on the depth of diffusion of digital technologies, while the impact on the speed of digital technology diffusion tends to fluctuate up and down with the increase in architect size. In general, architect size positively contributes to the depth of diffusion of digital technology in the innovation ecosystem, and the degree of influence on the depth of diffusion of digital technology increases with the increase in architect size. For the diffusion speed of digital technology in the innovation ecosystem, when the architect size is small, the diffusion speed of digital technology in the innovation ecosystem increases more slowly with increasing architect size; when the architect size is large, the diffusion speed of digital technology in strong turbulent market environment tends to increase overall, but in medium turbulent market environment and weak turbulent market environment, the diffusion speed of digital technology architect decreases with increasing size.

The degree of innovativeness of architects is significantly and positively related to the depth of digital technology diffusion in innovation ecosystems, but the effect on the speed of digital technology diffusion has a 'threshold' relationship. In general, the depth of diffusion of digital technology in the innovation ecosystem increases with the degree of innovativeness of architect,

ISSN: 2692-7608 DOI: 10.6981/FEM.202308_4(8).0039

and the higher the degree of architect innovativeness, the greater the subsequent increase in the depth of diffusion of digital technology. The degree of architect innovativeness has an inverted U-shaped relationship with μ=0.35 as the cut-off point for the speed of diffusion of digital technology in the innovation ecosystem. In addition, the curves for the diffusion depth and diffusion speed of digital technologies increase significantly when the degree of innovativeness of architects is higher, indicating that a higher degree of innovativeness of architects has a significant contribution to the diffusion efficiency of digital technologies.

There is a moderating role for the degree of market environment in the relationship between architects and the efficiency of digital technology diffusion in innovation ecosystems. The efficiency of digital technology diffusion fluctuates significantly with the size of the architect and the degree of innovativeness of the architect in medium and strong volatile market environments, suggesting that the architect has a more significant impact on the efficiency of digital technology diffusion in innovation ecosystems in both market environments. When the architect size is small, the volatility of the market environment does not play a significant moderating role, while when the architect size is large, the effect of architect size on the speed of diffusion of digital technology is more significant in medium and strong volatile market environments. The diffusion efficiency of digital technologies is highest in strong volatile market environment and lowest in weak volatile market environment when the innovativeness of the architects is low or high. When architects are moderately innovative, the diffusion speed of digital technology is highest in medium volatile market environment, while its depth of diffusion remains highest in strong volatile market environment.

5.2. Management Insights

Based on the analysis of the simulation results, the management insights presented in this paper are as follows:

Give financial support to proactively cultivate architects. The overall results of the simulation show that the diffusion efficiency of digital technologies in the innovation ecosystem of companies increases with the size of the architects. To promote the effective diffusion of digital technologies, it is important to increase the size of architect in the innovation ecosystem and actively cultivate them. There is a wasted cost for companies to adopt digital technologies for innovation, so architects in the innovation ecosystem tend to be stronger companies. To increase the size of architects in the innovation ecosystem, the government should provide financial support to architects, encourage the adoption of digital technologies, and promote collaborative innovation among potential adopters in the innovation ecosystem. Companies should also strengthen their awareness of the innovation ecosystem and enhance their innovation capabilities through the adoption of digital technologies to promote the effective and rapid diffusion of digital technologies within the innovation ecosystem, thus contributing to the overall positive development of the innovation ecosystem.

Focusing on the use of digital technologies to increase the innovativeness of architects. The more innovative the architects in an innovation ecosystem are, the more efficient the diffusion of digital technologies will be, and the higher the adoption rate of corporate managers' decisions will be, facilitating the diffusion of digital technologies in the innovation ecosystem. Therefore, the architects in the innovation ecosystem should focus on digital technologies that are in line with the company's development and explore new ways to improve performance according to their own resource base and corporate strategic orientation. To enhance the expertise and participation of innovation ecosystem architects in the digital technologies they adopt, promote interaction between architects and between architects and other enterprises, realise collaborative innovation and co-evolution with other enterprises in the innovation ecosystem, and accelerate the digital transformation of the innovation ecosystem.

Adopt a digital technology diffusion strategy that is appropriate to the degree of volatility in the market environment. When the size and innovativeness of the architects in the innovation ecosystem are certain, managers should consider the volatility of the market environment of the innovation ecosystem when innovating digital technologies. When architects are small or less innovative, the diffusion efficiency of digital technology in the medium volatile market environment is relatively high, so managers should choose the medium volatile market environment as the digital technology diffusion environment, while when architects are large or more innovative, they should choose the strong volatile market environment as the digital technology diffusion environment. The choice of the market environment for the adoption and diffusion of digital technology by enterprise managers according to the size of the architects and the degree of innovativeness of the architects is conducive to the diffusion of digital technology, improving the level of innovation performance of companies, and promoting the high-quality development of the digital economy.

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