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Complex Network-Based Evolutionary Game for Knowledge Transfer of Social E-Commerce Platform Enterprise's Operation Team under Strategy Imitation Preferences

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Abstract: Social e-commerce is an emerging e-commerce mode in response to the upgrading of consumption, which has become an important engine for the development of the digital economy. Knowledge transfer and sharing play vital roles in improving the competitiveness and the sustainability of social e-commerce platform enterprises. However, academic research on knowledge transfer for the social e-commerce platform enterprise's operation team remains deficient. To help social e-commerce platform enterprises to improve performance and better seek survival and sustainable development, this paper constructs a knowledge transfer model for the social e-commerce platform enterprise's operation team, in the self-centered sustainable ecological business mode, from the relationship between intra-organizational operation knowledge transfer and cross-organizational knowledge sharing for value co-creation, and explores knowledge transfer behaviors from the perspective of complex network-based evolutionary game under strategy imitation preferences. Simulation results indicate that relationships among knowledge transfer cost, knowledge synergy benefit, cross-organizational value co-creation benefit rate, and reward and punishment, along with strategy imitation preferences, significantly impact knowledge transfer behaviors of the social e-commerce platform enterprise's operation team. When all the members of the social e-commerce platform enterprise's operation team prefer to imitate the knowledge transfer strategies of the operation members with smaller knowledge transfer costs, the operation team is more likely to show a high proportion adopting the transfer strategy, requiring low knowledge synergy coefficient, reward, punishment, and cross-organizational value co-creation benefit rate to achieve stable and sustainable knowledge transfer. Conversely, the operation team is more likely to show a low proportion adopting the transfer strategy, requiring high knowledge synergy coefficient, reward, punishment, and cross-organizational value co-creation benefit rate to achieve stable and sustainable knowledge transfer. This study has significance as a guide for social e-commerce platform enterprises in deploying the self-centered sustainable ecological business mode.

Keywords: knowledge transfer; complex network; evolutionary game; strategy imitation preference; social e-commerce; operation; value co-creation

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1. Introduction

With the advent of the digital economy era, and the development of mobile communication technology and social media, more and more consumers show social-oriented and content-oriented consumption behavior. Social e-commerce is a new e-commerce mode developed by e-commerce in response to the upgrading of user consumption. With the socialized operation mode, the social e-commerce platform can connect with many participants, such as brand owners, commodity suppliers, distributors and consumers, to form a multi-agent value co-creation network and achieve expected value co-creation goals. According to 2019 statistics, the overall economic scale of China's social e-commerce exceeded 2 trillion yuan in RMB, and became the fastest growing part of e-commerce, with an increase of 63.2%, accounting for more than 20% of online retail and 71% of the penetration rate [1]. The adoption of high-tech knowledge and technologies, such as big data and virtual reality, has become the norm in social e-commerce marketing. Currently, social e-commerce has become an important engine for the development of the digital economy, which has promoted the coordinated development of agriculture, industry, service and other industries with the digital economy, and accelerated the release of the driving force of innovation in the digital economy. However, more than 500 social e-commerce platform enterprises in Guangzhou and Yiwu closed down in the fierce competition of 2020 [1]. The main reasons why these social e-commerce platform enterprises failed in the competition were their inability to efficiently attract traffic, to explore the value of traffic, and to innovate and change business modes quickly [1,2]. These mentioned aspects involve a lot of operational knowledge and value co-creation knowledge [2], such as website search ranking [2], personalized website content for customers' preferences [3], friendliness and ease of use of website [4], big-data, based on value mining [5], and so on. Knowledge is the core competence of enterprises, and knowledge transfer can be deemed a process of knowledge diffusion among persons or organizations. However, knowledge transfer can obviously improve enterprises' performances [5], and social e-commerce platform enterprises seek survival and sustainable development by carrying out knowledge transfer and acquiring competitive knowledge.

Knowledge is the basis of innovation [6,7], which is indispensable in maintaining competitive advantages in enterprises and organizational development [8,9]. Knowledge sharing, integration and absorption are ways for organizations to realize innovation [6,7]. The concept of knowledge transfer was proposed by Teece in 1977 [10], as an important research aspect in knowledge management. Effective knowledge transfer can realize the spread and diffusion of knowledge among organizational members, which is an important way for organizations to acquire knowledge and maintain competitiveness. Maintaining the continuity and the stability of knowledge transfer is crucial to improve innovative capability, service quality and competitiveness in an organization [11]. Knowledge transfer is ubiquitous in organizations [12–15]. For example, Guvernator IV G C et al. [12] studied knowledge transfer of the municipal water and wastewater organization to prevent the loss of technical knowledge caused by the retirement of experienced employees. Huang et al. [13] studied the on-site safety knowledge transfer of construction enterprises to ensure good on-site worker safety behaviors. Xu et al. [14] studied the knowledge transfer of the R&D team in manufacturing enterprises to improve the team's R&D ability and competitiveness. Knowledge transfer also exists in social e-commerce platform enterprises, because they need operational knowledge transfer within organizations and cross-organizational knowledge sharing for value co-creation to improve competitiveness. However, there is little research on the knowledge transfer of the operation team in social e-commerce platform enterprises. The research on the knowledge transfer of the social e-commerce platform enterprise's operation team in this paper fills the research gap. In order to help social e-commerce platform enterprises improve performance and better seek survival and sustainable development, the following issues concerning knowledge transfer of the operation team in social e-commerce platform enterprises are addressed in this paper: (1) Determining the influencing factors and the mathematical model of knowledge transfer by considering social e-commerce platform enterprise's operation team deploying the self-centered sustainable ecological business mode for survival and sustainable development; (2) Exploring knowledge transfer behaviors from the perspective of complex network-based evolutionary game under strategy imitation preferences. Our studies help social e-commerce platform enterprises enhance their ability to resist risks in competitiveness. Conversely, lack of study on knowledge transfer undoubtedly impairs the ability of social e-commerce platform enterprises to resist risks in competitiveness.

In the era of the digital economy, digitalized knowledge and information, as key production factors, have become the core and strategic resources of social e-commerce platform enterprises. By means of knowledge sharing, integration, absorption and transfer, the social e-commerce platform enterprise's operation team should efficiently attract traffic and mine traffic value, and try to carry out innovation and change, of both business mode and operation strategy, in order to achieve value co-creation and effectively improve the competitiveness of social e-commerce platform enterprises. Differing from other types of organizations, social e-commerce platform enterprises realize value co-creation through interaction with multiple participants, such as brand owners, commodity suppliers, distributors and consumers. During value co-creation with multiple participants, social e-commerce platform enterprises can deploy self-centered sustainable ecological business modes to enhance their competitiveness [16]. Knowledge is considered to be the basis of value co-creation [17], and value co-creation can be regarded as an interactive process of establishing service experience through knowledge sharing and communication [18]. In order to effectively improve the competitiveness of social e-commerce platform enterprises, the operation teams of social e-commerce platform enterprises need to not only improve the organization's innovation ability and service quality, through operational knowledge sharing, integration, absorption and transfer, but also need to achieve value co-creation through cross-organizational knowledge sharing and interaction. For this reason, this paper incorporates the value co-creation benefit obtained by the social e-commerce platform enterprise's operation team in knowledge transfer, which is of great guiding significance for the operation of social e-commerce platform enterprises.

In recent years, with the rapid development of network science, the related research on knowledge transfer, from the perspective of the network, has attracted extensive attention [19]. The research on knowledge transfer from the perspective of the network includes network structures [20], complex network-based evolutionary game [14], strength of cooperation relationship among network nodes [21], bounded rationality, such as reciprocity [22], and reputation [23]. Considering the heterogeneity of operation team members in social e-commerce platform enterprises, this paper adopts the scale-free complex network and the complex network-based evolutionary game to simulate the knowledge transfer of the social e-commerce platform enterprise's operation team, and analyzes the influence of the bounded rationality of strategy imitation preferences on knowledge transfer. Strategy imitation is fundamentally different from reciprocity [22] and reputation [23], in that reciprocity and reputation are incentive mechanisms existing outside the complex network-based evolutionary game [23], while strategy imitation itself is an important internal mechanism of the complex network-based evolutionary game, which is the basis for decision makers to select game strategies [14,21–23]. Strategy imitation preferences change the benchmark for decision makers to select game strategies and, hence, can influence knowledge transfer behavior of decision makers. Preferences to imitate the strategies of high-performing groups or individuals are also prevalent in real-world businesses and organizations. For example, in order to achieve the purpose of immediate survival and development, business start-ups are willing to imitate and implement the strategies adopted by the winners, even if the strategies are not conducive to their long-term development. Therefore, strategy imitation preferences have both theoretical support and realistic basis.

This paper makes two key contributions to the literature. Firstly, according to operational characteristics in the social e-commerce platform enterprise, and features of value co-creation from the interaction between the social e-commerce platform enterprise and multiple participants, this paper incorporates the value co-creation benefit obtained by the social e-commerce platform enterprise's operation team into knowledge transfer, and proposes a knowledge transfer model for the social e-commerce platform enterprise's operation team. Secondly, according to the realistic basis of strategy imitation and the theoretical support in the complex network-based evolutionary game, this paper introduces bounded rationality of strategy imitation preferences into the complex network-based evolutionary game, and analyzes the influence of strategy imitation preferences on knowledge transfer by simulations.

The rest of this paper is organized as follows. The next section provides the literature review on social e-commerce, value co-creation, value network, knowledge transfer, and the complex network-based evolutionary game. After that, we formulate a mathematical model on the knowledge transfer of the social e-commerce platform enterprise's operation team by introducing the value co-creation benefit from cross-organizational knowledge sharing, and construct a game payoff matrix of knowledge transfer. In order to comprehensively analyze knowledge transfer under all possible scenarios, and provide the basis for parameter setting of the subsequent complex network-based evolutionary simulations, we carried out local stability analyses of knowledge transfer and drew up the local stability conditions. Then, we regarded the knowledge transfer network of the social e-commerce platform enterprise's operation team as a scale-free complex network, constructed a model of a complex network-based evolutionary game, and proposed four different kinds of strategy imitation preferences to be embedded in the constructed complex network-based evolutionary game. Further, we determined the parameters of the complex network-based evolutionary game, based on the local stability condition of knowledge transfer, and discussed the influence of strategy imitation preferences on knowledge transfer, based on the simulation results. In the final section, we present a conclusion of the research and provide insights into management implications.

2. Literature Review

In order to systematically introduce the topic and methodology used in this study, this paper provides a literature review on social e-commerce, value co-creation and value network, knowledge transfer, and the complex network-based evolutionary game.

2.1. Social E-Commerce

Traditional e-commerce adopts a centralized operation mode, where e-commerce platforms uniformly recommend content to consumers. In the centralized operation mode, registered businesses need to pay a high registration fee to the e-commerce platform, and high consumer costs have become the biggest bottleneck for the development of traditional e-commerce [24]. With the development of social networks and social media, social networks and social media have gradually become the expansion pathways for e-commerce [25,26]. Social elements, such as attention, sharing, communication, discussion and interaction, presented in e-commerce can effectively improve consumers' shopping experiences and intentions, and promote consumption upgrading. Online shopping and social networks are deemed to be the main sources of social e-commerce [27]. In addition, Web 2.0 is believed to be the technical basis for making social e-commerce a reality [28,29]. Different from traditional centralized e-commerce, social e-commerce runs with the operation mode of e-commerce combined with social networks. Consequently, social e-commerce has characteristics of decentralization, where the content distribution is realized by consumers through social networks. Through dominant interaction with the ways of social media, distribution, and live broadcasting, social e-commerce allows stakeholders to participate in the process of commodity trading, and can effectively realize matching among brand owners, suppliers, distributors and consumers, thereby achieving the purpose of value co-creation [30]. Social e-commerce provides a potential scheme for reducing consumers' cost, and, hence, is an important development direction for the e-commerce industry of the future.

Social e-commerce attaches importance to social operations. It can make full use of content output to attract new customers, improve customers' engagement, and reduce the cost in customer acquisition, thereby increasing sales, realizing brand communication, and enabling customers to gain benefits. Social e-commerce can share and recommend products on social e-commerce platforms, by means of groups, distribution, communities and applets, so as to achieve rapid growth in customer flow and help merchants gather enough customers [16]. In addition, social e-commerce can also share and recommend products through live streaming, so as to speed up the buying decision and improve buying efficiency [31]. Further, social e-commerce platforms have evolved into different types through social operations in order to increase customer traffic, engagement and retention. For example, Diao et al. [32] argued that social e-commerce platforms can be divided into four categories, that is, e-commerce-oriented social e-commerce, interest-oriented social e-commerce, social networking-oriented social e-commerce and group buying-oriented social e-commerce. There are also membership-based social commerce platforms (Aikucun and Yunji), content-based social commerce platforms (Xiaohongshu and TikTok), group buying-based social commerce platforms (Pinduoduo and Jingxi), and community-based social commerce platforms (Suxiaotuan and Linlinyi) in China.

2.2. Value Co-Creation and Value Network

Additive and Zott [33] proposed that novelty, lock-in, complementarity and efficiency are the main driving factors of value creation. The driving factors of value creation have important impacts on the business mode of enterprises [34]. Geissdoerfer et al. [35] argued that a good business mode needs to incorporate many stakeholders into the sustainable value creation process to effectively enhance competitiveness. Value co-creation is the concept proposed by Vargo and Lusch [36] on the basis of the traditional value creation theory. In theories of value co-creation, value co-creation, based on service dominant logic [37], holds that consumers and service providers create value together. Guo et al. [31] studied the influence of live streaming characteristics of social e-commerce on value co-creation and consumers' purchase intentions, and believed that interactivity, authenticity and entertainment of live streaming had significant impacts on value co-creation.

With evolution of decentralized social e-commerce, the participants of value co-creation in the social e-commerce are more and more diversified, including social e-commerce platforms, brand owners, distributors, consumers and so on. Different participants have distinct characteristics and interest orientations, and their interactions can present diversified value creation activities and form a complex value network [38]. The value network can connect the individual needs of consumers and the internal system of enterprises. Participants create value through cooperation and competition, and can effectively improve competitive advantage. Ricciotti [39] pointed out that the value network is an extension of the linear value chain theory. In the era of Internet, cross-border integration and social consumption, the value network is more suitable for enterprises' value creation and conducive to the collaborative development of multiple participants. The value network can be characterized by network size, relationship strength and member heterogeneity [40]. The network size refers to the number of participants in the value network. The relationship strength refers to the connection strength of the participants in the value network, and higher relationship strength is characterized by frequent interaction and information exchange. The membership heterogeneity refers to the differentiation level of participants in the value network. Based on the value network theory, Qiao et al. [16] proposed five modes of evolution for value co-creation in social e-commerce, namely, dual co-creation mode, hub branch mode, network branch mode, multilateral collaboration mode, and multilateral symbiosis mode. For example, in the multilateral symbiosis mode, social e-commerce platform enterprises can cultivate stable and mutually beneficial symbiosis for many participants, and form a value network with a large scale, strong relationship strength and high heterogeneity of members, so as to achieve the purpose of effectively deploying sustainable business ecology.

2.3. Knowledge Transfer

Knowledge transfer plays an important role in promoting both intra-organizational learning and inter-organizational learning [41,42]. Knowledge can be divided into explicit knowledge and tacit knowledge [43]. Explicit knowledge is knowledge that is easy to encode and share, while tacit knowledge is unstructured knowledge that is difficult to describe and transfer with language, and which is embodied in behavior, convention, experience, skills and perception. Nonaka's SECI model [44] shows that improvements of knowledge and innovation ability are generated by the mutual transformation of tacit knowledge and explicit knowledge.

In the process of improving the competitiveness of the social e-commerce platform enterprise, the social e-commerce platform enterprise's operation team needs to apply a lot of knowledge and skills in the operation, which involve killer content, gamification marketing strategy, personalized website content, brand culture infiltration, live telepresence, crowd sourcing and so on. Skilled application of the above knowledge and skills in the operation plays an important role in promoting the competitiveness of the social e-commerce platform enterprise. The key knowledge and skills, in more detail, are the following: (1) Killer content provides the most attractive features of goods or services and has a unique value in motivating consumers, and can enhance consumers' brand loyalty and purchasing ability [45]. Killer content can effectively promote social interaction, and its spread on initial social e-commerce platforms can rapidly drive market growth [45]; (2) Gamification marketing strategy for social e-commerce is highly applicable to the mobile phone service environment, and can effectively enhance enjoyment, improve mobile phone user engagement and retention, and accelerate repurchase [46]; (3) High-quality information content [47], personalized website content for customers' preferences [3], and both friendliness and ease of use of websites [4] all contribute to improving customers' trust in products. Furthermore, timely response service to customers' needs can win customers' trust by resolving disputes and disambiguation [48]; (4) Penetrating brand culture into consumers and enabling consumers to obtain brand emotional experience value can effectively improve brand loyalty [49]; (5) Telepresence and social presence generated by live streaming enable consumers to immerse themselves in a virtual world similar to the offline consumption environment, thereby reducing the uncertainty of consumers and the psychological distance between them and merchants, and, thus, enhancing consumers' trust [50–54]; (6) Crowd-sourcing leverages the potential of users in social networks to generate new ideas and advertisements, create added value at a small cost and even at no cost, and improve efficiency by understanding customer needs, identifying potential customers, and building loyalty [55]. Furthermore, the social e-commerce platform enterprise's operation team can improve the competitiveness of the social e-commerce platform enterprise by collaboratively creating consumers' demand and promoting shopping social attributes. For example, the social e-commerce platform enterprise's operation team can create consumers' demand through collaborative live streaming and distribution [56]. The Pinduoduo platform encourages participants of the platform by coordinating different marketing strategies (such as low-price marketing strategy + social marketing strategy or gamification marketing strategy + brand channel marketing strategy) [57]. Knowledge transfer plays a key role in promoting organizational learning, aggregating employees' personal knowledge into organizational knowledge, and establishing and enhancing organizational competitive advantages [41]. Therefore, the social e-commerce platform enterprise's operation team needs to effectively share and transfer knowledge and skills related to the operation within the organization, so as to improve the competitiveness of the social e-commerce platform enterprise in the industry, and lay the foundation for realizing cross-organizational value co-creation.

Cross-organizational value co-creation in the social e-commerce is realized through the interaction between the social e-commerce platform enterprise and multiple participants, such as commodity suppliers, brand owners, distributors and consumers. Knowledge is the basis of value co-creation [17], and value co-creation is an interactive process of establishing service experience through knowledge sharing and communication [18]. From this viewpoint, the process of cross-organizational value co-creation in social e-commerce reflects cross-organizational sharing and transfer of knowledge. Omotayo et al. [42] argued that knowledge sharing can be regarded as the interaction between people that require exchange of experience and skills, and it is an activity or process used to transfer knowledge among people, communities or organizations. Essentially, the purpose of knowledge sharing is to realize knowledge transfer. Knowledge transfer is indispensable in the process of value co-creation, and is a key condition for effective collaboration among participants of a value network [58]. The value network is the carrier to realize value co-creation, while social interaction is the effective way to realize the value co-creation. In the value network, knowledge transfer refers to the process of sharing knowledge between participants through continuous interaction [59]. Interaction between enterprises and customers can promote information exchange and the sharing and transfer of knowledge [60], while social e-commerce can promote the socialization of participants through interpersonal communication on social networks [61], which helps participants acquire skills, share knowledge and integrate opinions through social interaction [62].

Obviously, in order to improve competitiveness, the social e-commerce platform enterprise should pay attention not only to intra-organizational operation knowledge transfer, but also to cross-organizational knowledge sharing for value co-creation. In the social e-commerce platform enterprise, the operation serves to realize value co-creation. What is more, intra-organizational operational knowledge transfer of the social e-commerce platform enterprise is conducive to not only improving competitive advantage in the industry, but also to realize cross-organizational value co-creation, increasing the scale of the value network and relationship strength, and effectively laying out sustainable business ecology [16].

2.4. Complex Network-Based Evolutionary Game

Evolutionary game is an important theory for the study of knowledge transfer, and mainly reflects the knowledge transfer behavior of decision makers, through stability analysis of duplicated dynamic equations [14,63]. Since complex networks can better reflect topological statistical characteristics and complex relationships of real network systems [14,19–23], the study of the knowledge transfer behavior of the complex network-based evolutionary game, combining complex networks and evolutionary game, has attracted extensive attention from researchers. At present, complex network-based evolutionary games are applied to the research of intra-organizational or inter-organizational knowledge transfer behavior, such as knowledge transfer of R&D projects [22,23], knowledge transfer of industry–university–research cooperation innovation networks [21], and knowledge transfer omong manufacturing R&D teams [14]. Bounded rationality holds that incomplete decision-making information, inconsistent preferences and inconsistent cognitive ability of decision makers lead to decision makers being unable to make fully rational decisions when facing complex problems [64]. Bounded rationality changes the decision-making benchmark of the game, and finally changes the decision-making behavior of the players, so has been paid more attention in research. With in-depth research on bounded rationality, there have been related reports on the knowledge transfer behavior of the complex network-based evolutionary games, from the perspective of bounded rationality [22,23,65]. For example, Wang et al. [22] and Huang et al. [23] respectively studied the influence of bounded rationality of reciprocity and reputation on knowledge transfer behavior in the complex network-based evolutionary games, and found that bounded rationality of reciprocity and reputation could significantly affect knowledge transfer behavior. Strategy imitation is an important mechanism in strategy selection of the complex network-based evolutionary games. At present, a variety of strategy imitation rules are proposed, such as the natural selection rule, based on the Moran process [66,67], the deterministic imitation optimal rule [68], the stochastic imitation winner rule [69], and the paired comparison learning rule [70]. Obviously, strategy imitation preference can change the benchmark for decision makers to select game strategies, and can have an impact on the knowledge transfer behavior of the complex network-based evolutionary games. At the same time, there is also a widespread preference to imitate the strategies of well-performing individuals in the real world of enterprises and organizations. Strategy imitation preference has both theoretical support and a realistic basis, so it is necessary to study the influence of strategy imitation preference on knowledge transfer behavior by combining it with the complex network-based evolutionary game. However, there is no research on strategy imitation preference.

From the above literature review, the following characteristics can be drawn for the operation of the social e-commerce platform enterprise: (1) A lot of explicit knowledge and tacit knowledge are involved in the operation of the social e-commerce platform enterprise; (2) In order to improve competitiveness, the social e-commerce platform enterprise should carry out not only intra-organizational operation knowledge transfer, but also cross-organizational knowledge sharing for value co-creation; (3) The intra-organizational operation knowledge transfer of social e-commerce platform enterprises serves cross-organizational value co-creation from the interactions between the social e-commerce platform enterprise and multiple participants, including suppliers, distributors, and consumers. By considering the above characteristics of the operation of the social e-commerce platform, this paper incorporated the value co-creation benefit obtained by the social e-commerce platform enterprise's operation team into knowledge transfer, and studied the knowledge transfer behavior of the social e-commerce platform enterprise's operation team, based on the complex network-based evolutionary game in combination with the bounded rationality of strategy imitation preferences. The work of this paper not only enriches knowledge transfer research of social e-commerce platform enterprises, but also puts forward suggestions for the operation of social e-commerce platform enterprises.

3. Game of Knowledge Transfer in Social E-Commerce Platform Enterprise's Operation Team

3.1. Knowledge Transfer in Social E-Commerce Platform Enterprise's Operation Team

In the operation of the social e-commerce platform enterprise, each member of the operation team is connected with several other members, and the team can achieve sustainable development and enhance competitiveness through the stable transfer of knowledge among members. Due to the scale-free nature of the real network [71], the knowledge transfer among members of the operation team can be regarded as a scale-free complex network. At the same time, the layout of sustainable ecological business mode around the social e-commerce platform is a feasible way for the platform to enhance its competitiveness through value co-creation. Under the sustainable ecological business mode, the value network is characterized as having a large scale, strong relationship strength and high heterogeneity of members [16]. Inspired by the value co-creation modes (multilateral collaboration mode and multilateral symbiosis mode) in the rising stage of the social e-commerce platform [16], this paper divided the knowledge transfer of the social e-commerce platform enterprise's operation team into intra-organizational operation knowledge transfer and cross-organizational knowledge sharing for value co-creation. The knowledge transfer topology of the sustainable ecological business mode, cored with the social e-commerce platform enterprise's operation team, is illustrated in Figure 1.

As can be seen from Figure 1, the knowledge transfer of the social e-commerce platform enterprise's operation team contains the intra-organizational operation knowledge transfer and the cross-organizational knowledge sharing for value co-creation, and there is a relationship between the intra-organizational operation knowledge transfer and the cross-organizational knowledge sharing for value co-creation. The relationship can be characterized as follows. On the one hand, intra-organizational operation knowledge transfer serves cross-organizational knowledge sharing for value co-creation. On the other hand, the revenue of the cross-organizational knowledge sharing for value co-creation conversely influences intra-organizational operation knowledge transfer. In view of the above relationship, this paper incorporated the value co-creation benefit obtained from the cross-organizational knowledge sharing into the knowledge transfer for the social e-commerce platform enterprise's operation team.

3.2. Influencing Factors and Benefits Function

Based on the studies on knowledge transfer [14,21–23], and the characteristics of the relationship between intra-organizational operation knowledge transfer and the cross-organizational knowledge sharing for value co-creation, described in Section 3.1, the influencing factors on knowledge transfer of the social e-commerce platform enterprise's operation team can be described as below:

(1) Amount of knowledge transfer (T): T_i represents the amount of knowledge transferred from member i to member j.
(2) Direct absorption coefficient of knowledge (σ): σ_i represents the ability of member i to directly absorb knowledge; $\sigma_i T_j$ is the amount of knowledge that member i absorbs directly from member j.
(3) Knowledge synergy coefficient (η): η_i represents the knowledge synergy coefficient of member i, determined by innovation ability, cooperation level and knowledge complementarity between member i and other members, while $\eta_i T_i^m T_j^n$ represents the new knowledge created by member i and member j in the process of knowledge transfer, where m and n are the elastic coefficients of amount of knowledge transfer for member i and member j, respectively, satisfying $m + n = 1$, $m > 0$, and $n > 0$.
(4) Cost coefficient (ε): $\varepsilon_i T_i$ represents the knowledge transfer cost as member i selects the knowledge transfer strategy.
(5) Reward coefficient (w): wT_i represents the reward benefit as member i selects the knowledge transfer strategy.
(6) Punishment (θ): θ represents the punishment for opportunistic behaviors or knowledge non-transfer behaviors.
(7) Cross-organizational value co-creation benefit (φ): φ_i represents the cross-organizational value co-creation benefit of member i, defined as a function in this paper, i.e., $\varphi_i(\lambda_i, M_i) = \lambda_i M_i$. In the definition, λ_i is the cross-organizational value co-creation benefit rate of member i, affected by factors, such as ability and cost for the cross-organizational knowledge sharing; and M_i is the amount of cross-organizational knowledge sharing of member i, defined as the amount of newly increased knowledge obtained by member i in intra-organizational operation knowledge transfer.

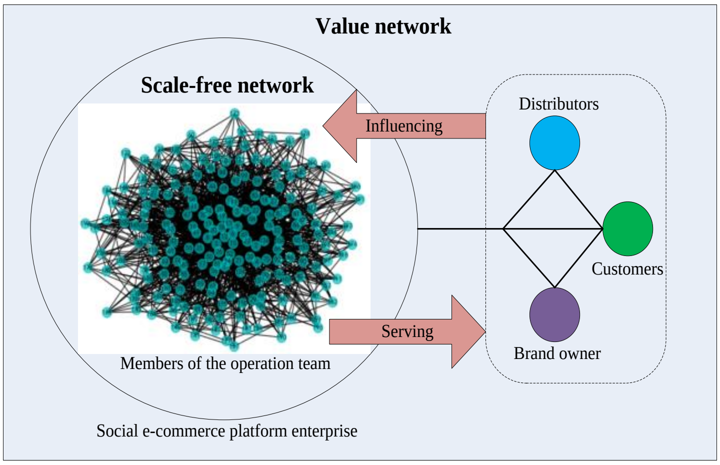

Figure 1. Knowledge transfer topology of the sustainable ecological business mode, cored with the social e-commerce platform enterprise's operation team, where the scale-free network is the carrier for the intra-organizational operation knowledge transfer, and the value network is the carrier for the cross-organizational knowledge sharing for value co-creation.

Based on the above, the benefits function for the knowledge transfer of the social e-commerce platform enterprise's operation team is formulated as Equations (1)–(3), where $\psi_i(\sigma_i, \eta_i, \varepsilon_i, T_i, T_j, w, \theta_i, m, n)$ and $\varphi_i(\lambda_i, M_i)$ represent the intra-organizational operation knowledge benefit and the cross-organizational value co-creation benefit of member i, respectively, and $M_i = \sigma_i T_j + \eta_i T_i^m T_j^n$ represents the amount of newly increased knowledge from intra-organizational operation knowledge transfer, used for cross-organizational knowledge sharing by operation member i:

$$u_i = \psi_i(\sigma_i, \eta_i, \varepsilon_i, T_i, T_j, w, \theta_i, m, n) + \varphi_i(\lambda_i, M_i) \tag{1}$$

$$\begin{cases} \psi_i(\sigma_i, \eta_i, \varepsilon_i, T_i, T_j, w, \theta_i, m, n) = \sigma_i T_j + \eta_i T_i^m T_j^n - \varepsilon_i T_i + w T_i - \theta_i \\ \varphi_i(\lambda_i, M_i) = \lambda_i M_i = \lambda_i(\sigma_i T_j + \eta_i T_i^m T_j^n) \end{cases} \tag{2}$$

$$\theta_i = \begin{cases} 0, & T_i > 0 \\ \theta, & T_i = 0 \end{cases} \tag{3}$$

3.3. Game Payoff Matrix

In the game of knowledge transfer, the members of the social e-commerce platform enterprise's operation team can select between two strategies, i.e., transfer and non-transfer. Suppose that the social e-commerce platform enterprise's operation team is a system, composed of two subgroups, briefly named as Subgroup #1 and Subgroup #2, which differ from one another in knowledge transfer costs. In addition, member i in Subgroup #1 and member j in Subgroup #2 can select four different combinations of knowledge transfer strategies to play the game, i.e., (transfer, transfer), (transfer, non-transfer), (non-transfer, transfer), (non-transfer, non-transfer). Under different strategy combinations, different payoffs can be drawn by member i in Subgroup #1 and member j in Subgroup #2, shown as below:

(1) Member i in Subgroup #1 and member j in Subgroup #2 select (transfer, transfer), so the payoffs of members i and j are shown in Equations (4) and (5), respectively:

$$Y_i = (\lambda_i + 1)(\sigma_i T_j + \eta_i T_i^m T_j^n) - \varepsilon_i T_i + \omega T_i \tag{4}$$

$$Y_j = (\lambda_j + 1)(\sigma_j T_i + \eta_j T_i^m T_j^n) - \varepsilon_j T_j + \omega T_j \tag{5}$$

(2) Member i in Subgroup #1 and member j in Subgroup #2 select (transfer, non-transfer), so the payoffs of members i and j are shown in Equations (6) and (7), respectively:

$$B_i = \omega T_i - \varepsilon_i T_i \tag{6}$$

$$D_j = (\lambda_j + 1)\sigma_j T_i - \theta \tag{7}$$

(3) Member i in Subgroup #1 and member j in Subgroup #2 select (non-transfer, transfer), so the payoffs of the members i and j are shown in Equations (8) and (9), respectively:

$$D_i = (\lambda_i + 1)\sigma_i T_j - \theta \tag{8}$$

$$B_j = \omega T_j - \varepsilon_j T_j \tag{9}$$

(4) Member i in Subgroup #1 and member j in Subgroup #2 select (non-transfer, non-transfer), so the payoffs of members i and j are shown in Equations (10) and (11), respectively:

$$N_i = -\theta \tag{10}$$

$$N_j = -\theta \tag{11}$$

Based on the above, the game payoff matrix of the knowledge transfer for the social e-commerce platform enterprise's operation team established in this paper is shown in Table 1.

Table 1. Game payoff matrix of knowledge transfer for social e-commerce platform enterprise's Operation Team.

		Member *j* in Subgroup #2	
		Transfer	Non-ransfer
Member *i* in Subgroup #1	Transfer	Y_i, Y_j	B_i, D_j
	Non-transfer	D_i, B_j	N_i, N_j

3.4. Local Stability Analyses

In this section, the local stability conditions are drawn by local stability analyses of knowledge transfer, to comprehensively analyze the knowledge transfer under all possible scenarios and to provide the basis for parameter setting of the subsequent complex network-based evolutionary simulations.

Assume that the proportion of the members in Subgroup #1 selecting knowledge transfer strategy is x, and selecting knowledge non-transfer strategy is $1-x$, and that the proportion of the members in Subgroup #2 selecting knowledge transfer strategy is y, and selecting knowledge non-transfer strategy is $1-y$. Based on the game payoff matrix in Table 1, the average payoff of the members in Subgroup #1 selecting knowledge transfer strategy is $V_i = yY_i + (1-y)B_i$, the average payoff of the members in Subgroup #1 selecting knowledge non-transfer strategy is $V_i' = yD_i + (1-y)N_i$, and the average payoff of the members in Subgroup #1 is $\overline{V}_i = xV_i + (1-x)V_i'$. Similarly, the average payoff of the members in Subgroup #2 selecting knowledge transfer strategy is $V_j = xY_j + (1-x)B_j$, the average payoff of the members in Subgroup #2 selecting knowledge non-transfer strategy is $V_j' = xD_j + (1-x)N_j$, and the average payoff of the members in Subgroup #2 is $\overline{V}_j = yV_j + (1-y)V_j'$. According to the replicator dynamics equation, the following Equation (12) can be produced:

$$\begin{cases} \frac{\mathrm{d}x}{\mathrm{d}t} = x(1-x)[y(\lambda_i+1)\eta_i T_i^m T_j^n - \varepsilon_i T_i + wT_i + \theta] \\ \frac{\mathrm{d}y}{\mathrm{d}t} = y(1-y)[x(\lambda_j+1)\eta_j T_i^m T_j^n - \varepsilon_j T_j + wT_j + \theta] \end{cases} \quad (12)$$

Let $\mathrm{d}x/\mathrm{d}t = 0$ and $\mathrm{d}y/\mathrm{d}t = 0$, the following equilibrium points (0,0), (0,1), (1,0), (1,1), and (x_D, y_D) can be drawn, where $x_D = \frac{\varepsilon_j T_j - wT_j - \theta}{(\lambda_j+1)\eta_j T_i^m T_j^n}$, $y_D = \frac{\varepsilon_i T_i - wT_i - \theta}{(\lambda_i+1)\eta_i T_i^m T_j^n}$.

Jacobian matrix $\boldsymbol{J}$ can be expressed as Equation (13):

$$\boldsymbol{J} = \begin{bmatrix} (1-2x)[y(\lambda_i+1)\eta_i T_i^m T_j^n - \varepsilon_i T_i + wT_i + \theta] & x(1-x)(\lambda_i+1)\eta_i T_i^m T_j^n \\ y(1-y)(\lambda_j+1)\eta_j T_i^m T_j^n & (1-2y)[x(\lambda_j+1)\eta_j T_i^m T_j^n - \varepsilon_j T_j + wT_j + \theta] \end{bmatrix} \quad (13)$$

The determinant Det$\boldsymbol{J}$ of Jacobian matrix $\boldsymbol{J}$ can be expressed as Equation (14):

$$\begin{aligned} \mathrm{Det}\boldsymbol{J} = \; & (1-2x)(1-2y)[y(\lambda_i+1)\eta_i T_i^m T_j^n - \varepsilon_i T_i + wT_i + \theta][x(\lambda_j+1)\eta_j T_i^m T_j^n - \varepsilon_j T_j + wT_j + \theta] - \\ & xy(1-x)(1-y)(\lambda_i+1)(\lambda_j+1)\eta_i\eta_j T_i^{2m} T_j^{2n} \end{aligned} \quad (14)$$

The trace Tr$\boldsymbol{J}$ of Jacobian matrix $\boldsymbol{J}$ can be expressed as Equation (15):

$$\mathrm{Tr}\boldsymbol{J} = (1-2x)[y(\lambda_i+1)\eta_i T_i^m T_j^n - \varepsilon_i T_i + wT_i + \theta] + (1-2y)[x(\lambda_j+1)\eta_j T_i^m T_j^n - \varepsilon_j T_j + wT_j + \theta] \quad (15)$$

The local stability analyses of the system under different scenarios are shown in Tables 2–7.

According to the local stability analyses in Tables 2–7, the local stability of the knowledge transfer system can be summarized as follows:

(1) As $0 < \varepsilon_i T_i < wT_i + \theta$ and $0 < \varepsilon_j T_j < wT_j + \theta$, (1,1) is the evolutionary stable strategy of the knowledge transfer system.

(2) As $\varepsilon_i T_i > (\lambda_i + 1)\eta_i T_i^m T_j^n + wT_i + \theta$ and $\varepsilon_j T_j > (\lambda_j + 1)\eta_j T_i^m T_j^n + wT_j + \theta$, (0,0) is the evolutionary stable strategy of the knowledge transfer system.

(3) As $wT_i + \theta < \varepsilon_i T_i < (\lambda_i + 1)\eta_i T_i{}^m T_j{}^n + wT_i + \theta$ and $0 < \varepsilon_j T_j < wT_j + \theta$, (1,1) is the evolutionary stable strategy of the knowledge transfer system.

(4) As $\varepsilon_i T_i > (\lambda_i + 1)\eta_i T_i{}^m T_j{}^n + wT_i + \theta$ and $wT_j + \theta < \varepsilon_j T_j < (\lambda_j + 1)\eta_j T_i{}^m T_j{}^n + wT_j + \theta$, (0,0) is the evolutionary stable strategy of the knowledge transfer system.

(5) As $\varepsilon_i T_i > (\lambda_i + 1)\eta_i T_i{}^m T_j{}^n + wT_i + \theta$ and $0 < \varepsilon_j T_j < wT_j + \theta$, (0,1) is the evolutionary stable strategy of the knowledge transfer system.

(6) As $wT_i + \theta < \varepsilon_i T_i < (\lambda_i + 1)\eta_i T_i{}^m T_j{}^n + wT_i + \theta$ and $wT_j + \theta < \varepsilon_j T_j < (\lambda_j + 1)\eta_j T_i{}^m T_j{}^n + wT_j + \theta$, (0,0) and (1,1) are the evolutionary stable strategies of the knowledge transfer system.

Table 2. Stability analyses for scenario 1.

Stability Condition	Equilibrium Point	Det *J*	Tr *J*	Stability
$0 < \varepsilon_i T_i < wT_i + \theta$ $0 < \varepsilon_j T_j < wT_j + \theta$	(0,0)	Positive	Positive	Unstable point
	(0,1)	Negative	Uncertain	Saddle point
	(1,0)	Negative	Uncertain	Saddle point
	(1,1)	Positive	Negative	ESS

Table 3. Stability analyses for scenario 2.

Stability Condition	Equilibrium Point	Det *J*	Tr *J*	Stability
$\varepsilon_i T_i > (\lambda_i + 1)\eta_i T_i{}^m T_j{}^n + wT_i + \theta$ $\varepsilon_j T_j > (\lambda_j + 1)\eta_j T_i{}^m T_j{}^n + wT_j + \theta$	(0,0)	Positive	Negative	ESS
	(0,1)	Negative	Uncertain	Saddle point
	(1,0)	Negative	Uncertain	Saddle point
	(1,1)	Positive	Positive	Unstable point

Table 4. Stability analyses for scenario 3.

Stability Condition	Equilibrium Point	Det *J*	Tr *J*	Stability
$wT_i + \theta < \varepsilon_i T_i < (\lambda_i + 1)\eta_i T_i{}^m T_j{}^n + wT_i + \theta$ $0 < \varepsilon_j T_j < wT_j + \theta$	(0,0)	Negative	Uncertain	Saddle point
	(0,1)	Negative	Uncertain	Saddle point
	(1,0)	Positive	Positive	Unstable point
	(1,1)	Positive	Negative	ESS

Table 5. Stability analyses for scenario 4.

Stability Condition	Equilibrium Point	Det *J*	Tr *J*	Stability
$\varepsilon_i T_i > (\lambda_i + 1)\eta_i T_i{}^m T_j{}^n + wT_i + \theta$ $wT_j + \theta < \varepsilon_j T_j < (\lambda_j + 1)\eta_j T_i{}^m T_j{}^n + wT_j + \theta$	(0,0)	Positive	Negative	ESS
	(0,1)	Negative	Uncertain	Saddle point
	(1,0)	Positive	Positive	Unstable point
	(1,1)	Negative	Uncertain	Saddle point

Table 6. Stability analyses for scenario 5.

Stability Condition	Equilibrium Point	Det *J*	Tr *J*	Stability
$\varepsilon_i T_i > (\lambda_i + 1)\eta_i T_i{}^m T_j{}^n + wT_i + \theta$ $0 < \varepsilon_j T_j < wT_j + \theta$	(0,0)	Negative	Uncertain	Saddle point
	(0,1)	Positive	Negative	ESS
	(1,0)	Positive	Positive	Unstable point
	(1,1)	Negative	Uncertain	Saddle point

It can be seen from the results of local stability analyses that the relationships among knowledge transfer cost, reward, punishment, knowledge synergy benefit, and cross-organizational value co-creation benefit rate affect the local stability of the knowledge transfer system. The results of the above local stability analyses, in a certain sense, explain the decision-making mechanism of the knowledge transfer behavior of the social e-commerce platform enterprise's operation team. However, the local stability analyses ignore the characteristics of the scale-free network structure among the members in the social e-commerce platform enterprise's operation team, and cannot study and analyze strategy imitation preferences of the members. The complex network theory holds that many systems in the real world have topological statistical characteristics, and results of games are closely related to the structure of the network [72]. Therefore, this paper establishes the complex network-based evolutionary game model of the knowledge transfer system in the following section, and introduces the strategy imitation preferences of the members into the knowledge transfer system.

Table 7. Stability analyses for scenario 6.

Stability Condition	Equilibrium Point	Det *J*	Tr *J*	Stability
$wT_i + \theta < \varepsilon_i T_i < (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$ $wT_j + \theta < \varepsilon_j T_j < (\lambda_j + 1)\eta_j {T_i}^m {T_j}^n + wT_j + \theta$	(0,0)	Positive	Negative	ESS
	(0,1)	Positive	Positive	Unstable point
	(1,0)	Positive	Positive	Unstable point
	(1,1)	Positive	Negative	ESS
	(x_D, y_D)	Negative	0	Saddle point

4. Complex Network-Based Evolutionary Game Model and Strategy Imitation Preferences

4.1. Complex Network-Based Evolutionary Game Model

In the social e-commerce platform enterprise's operation team, each member is connected with several other members, which means the knowledge transfer network has a scale-free nature. In this paper, the BA scale-free network [73] was taken as the carrier for the knowledge transfer in the social e-commerce platform enterprise's operation team, and a complex network-based evolutionary game model for the knowledge transfer in the social e-commerce platform enterprise's operation team was constructed. The detailed steps, for the complex network-based evolutionary game model, are described as follows.

Step 1. The knowledge transfer network for the social e-commerce platform enterprise's operation team adopts the BA scale-free network model, and the network is composed of G(V, A, E). V is a set of nodes, representing the social e-commerce platform enterprise's operation members in the network, A = {#1, #2} is the set of subgroup attributes of the nodes, that is, a node with subgroup attribute #1 indicates that the node is a member in Subgroup #1, while a node with subgroup attribute #2 indicates that the node is a member in Subgroup #2, E is the set of edges, $E = \{e_{pq}\}$, $p \in V$, $q \in V$, and $e_{pq} = 1$ means there is a direct connection between nodes p and q, while $e_{pq} = 0$ means there is no direct connection between nodes p and q.

Step 2. Network nodes play the knowledge transfer game according to the payoff matrix of knowledge transfer for social e-commerce platform enterprise's operation team (i.e., Table 1). The knowledge transfer game only occurs as nodes p and q and there is a direct connection but with different subgroup attributes, i.e., $e_{pq} = 1$ and $A(p) \neq A(q)$. The game payoff of the node p is expressed as follows:

$$U_p = \sum_{p \in G_p} U_{pq} \quad (16)$$

where U_p is the cumulative game payoff of node p, G_p is the set of nodes that are directly connected to node p but have different subgroup attributes from node p, and U_{pq} is the game payoff of the node p after playing with node q.

Step 3. Any node only imitates the strategy of a randomly selected node to which it has a direct connection. After the completion of each round of the game, each node uses the rule of the strategy imitation and updates, based on strategy imitation preference (see Section 4.2 for details), so as to update its own knowledge transfer strategy for the next round of the game.

Step 4. Before the next round of the game, the BA scale-free network is dynamically adjusted. The adjustment method is as follows. Firstly, a new BA scale-free network is generated and its nodes are arranged in descending order of degree. Secondly, every node p in the original network is converted into a node in the descending order of the new network with probability r_p. The probability r_p is denoted as below:

$$r_p = \frac{f(U_p)}{\sum_{v \in V} f(U_v)} \tag{17}$$

where $f(U_p)$ is shown as follows:

$$f(U_p) = \begin{cases} U_p - U_{\min} + 1, & if\ U_{\min} \le 0 \\ U_p, & otherwise \end{cases} \tag{18}$$

where $U_{\min} = \min_{p \in V} U_p$.

4.2. Strategy Imitation Preferences

This paper applied the paired comparison learning rule [70] for modeling of the bounded rationality of strategy imitation preference in the knowledge transfer of the social e-commerce platform enterprise's operation team.

For convenience, we made the following notations in this subsection. Let i represent a node with subgroup attribute #1, that is, the node i is a member in Subgroup #1. Let $SG_{i\#1}$ represent the set of neighbor nodes with subgroup attribute #1 of the node i, which indicates that the nodes in $SG_{i\#1}$ are both neighbors of node i and members in Subgroup #1. Let $SG_{i\#2}$ represent the set of neighbor nodes with subgroup attribute #2 of the node i, which indicates that the nodes in $SG_{i\#2}$ are both neighbors of node i and members in Subgroup #2. Let j represent a node with subgroup attribute #2, that is, the node j is a member in Subgroup #2. Let $SG_{j\#1}$ represent the set of neighbor nodes with subgroup attribute #1 of the node j, which indicates that the nodes in $SG_{j\#1}$ are both neighbors of node j and members in Subgroup #1. Let $SG_{j\#2}$ represent the set of neighbor nodes with subgroup attribute #2 of the node j, which indicates that the nodes in $SG_{j\#2}$ are both neighbors of node j and members in Subgroup #2.

In this paper, we present the following four different kinds of strategy imitation preferences.

Strategy imitation preference P1: In the social e-commerce platform enterprise's operation team, members in Subgroup #1 prefer to imitate the knowledge transfer strategy of members in Subgroup #1, while members in Subgroup #2 prefer to imitate the knowledge transfer strategy of members in Subgroup #2.

In the strategy imitation preference P1, the corresponding rule of strategy imitation and update can be described as follows: Any member i in Subgroup #1 prefers to randomly select a member, i#1, from the set $SG_{i\#1}$ for comparisons of their cumulative game payoffs. If the cumulative game payoff of member i#1 is higher than that of member i, then member i imitates the knowledge transfer strategy of member i#1 with probability $P(s_i,s_{i\#1})$ and uses it for the next round of the game. Any member j in Subgroup #2 prefers to randomly select a member, j#2, from the set $SG_{j\#2}$ for comparisons of their cumulative game payoffs. If the cumulative game payoff of the member j#2 is higher than that of member j, then member j imitates the knowledge transfer strategy of member j#2 with the probability $P(s_j,s_{j\#2})$ and uses it for the next round of the game. The values $P(s_i,s_{i\#1})$ and $P(s_j,s_{j\#2})$ are expressed as follows:

$$\begin{cases} P(s_i, s_{i\#1}) = \frac{1}{1+\exp[-(U_{i\#1}-U_i)/K]} & (i\#1 \in SG_{i\#1}) \\ P(s_j, s_{j\#2}) = \frac{1}{1+\exp[-(U_{j\#2}-U_j)/K]} & (j\#2 \in SG_{j\#2}) \end{cases} \tag{19}$$

where s_i, $s_{i\#1}$, s_j, and $s_{j\#2}$ represent the knowledge transfer strategies of *i*, *i*#1, *j*, and *j*#2, respectively, U_i, $U_{i\#1}$, U_j, and $U_{j\#2}$ represent the cumulative game payoffs of *i*, *i*#1, *j*, and *j*#2, respectively and *K* represents the system noise.

Strategy imitation preference P2: In the social e-commerce platform enterprise's operation team, members in Subgroup #1 prefer to imitate the knowledge transfer strategy of members in Subgroup #2, while members in Subgroup #2 prefer to imitate the knowledge transfer strategy of members in Subgroup #1.

In the strategy imitation preference P2, the corresponding rule of strategy imitation and update can be described as follows. Any member *i* in Subgroup #1 prefers to randomly select a member, *i*#2, from the set $SG_{i\#2}$ for comparisons of their cumulative game payoffs. If the cumulative game payoff of the member *i*#2 is higher than that of member *i*, then member *i* imitates the knowledge transfer strategy of member *i*#2 with the probability $P(s_i,s_{i\#2})$ and uses it for the next round of the game. Any member *j* in Subgroup #2 prefers to randomly select a member, *j*#1, from the set $SG_{j\#1}$ for comparisons of their cumulative game payoffs. If the cumulative game payoff of the member *j*#1 is higher than that of member *j*, then member *j* imitates the knowledge transfer strategy of the member *j*#1 with the probability $P(s_j,s_{j\#1})$ and uses it for the next round of the game. The values $P(s_i,s_{i\#2})$ and $P(s_j,s_{j\#1})$ are expressed as follows:

$$\begin{cases} P(s_i, s_{i\#2}) = \frac{1}{1+\exp[-(U_{i\#2}-U_i)/K]} & (i\#2 \in SG_{i\#2}) \\ P(s_j, s_{j\#1}) = \frac{1}{1+\exp\left[-\left(U_{j\#1}-U_j\right)/K\right]} & (j\#1 \in SG_{j\#1}) \end{cases} \tag{20}$$

where s_i, $s_{i\#2}$, s_j, and $s_{j\#1}$ represent the knowledge transfer strategies of *i*, *i*#2, *j*, and *j*#1, respectively, U_i, $U_{i\#2}$, U_j, and $U_{j\#1}$ represent the cumulative game payoffs of *i*, *i*#2, *j*, and *j*#1, respectively and *K* represents the system noise.

Strategy imitation preference P3: In the social e-commerce platform enterprise's operation team, members in Subgroup #1 and Subgroup #2 all prefer to imitate the knowledge transfer strategy of members in Subgroup #2.

In the strategy imitation preference P3, the corresponding rule of strategy imitation and update can be described as follows. Any member *i* in Subgroup #1 prefers to randomly select a member, *i*#2, from the set $SG_{i\#2}$ for comparisons of their cumulative game payoffs. If the cumulative game payoff of the member *i*#2 is higher than that of the member *i*, then member *i* imitates the knowledge transfer strategy of member *i*#2 with the probability $P(s_i,s_{i\#2})$ and uses it for the next round of the game. Any member *j* in Subgroup #2 prefers to randomly select a member, *j*#2, from the set $SG_{j\#2}$ for comparisons of their cumulative game payoffs. If the cumulative game payoff of member *j*#2 is higher than that of member *j*, then member *j* imitates the knowledge transfer strategy of the member *j*#2 with the probability $P(s_j,s_{j\#2})$ and uses it for the next round of the game. The values $P(s_i,s_{i\#2})$ and $P(s_j,s_{j\#2})$ are expressed as follows:

$$\begin{cases} P(s_i, s_{i\#2}) = \frac{1}{1+\exp[-(U_{i\#2}-U_i)/K]} & (i\#2 \in SG_{i\#2}) \\ P(s_j, s_{j\#2}) = \frac{1}{1+\exp\left[-\left(U_{j\#2}-U_j\right)/K\right]} & (j\#2 \in SG_{j\#2}) \end{cases} \tag{21}$$

where s_i, $s_{i\#2}$, s_j, and $s_{j\#2}$ represent the knowledge transfer strategies of *i*, *i*#2, *j*, and *j*#2, respectively, U_i, $U_{i\#2}$, U_j, and $U_{j\#2}$ represent the cumulative game payoffs of *i*, *i*#2, *j*, and *j*#2, respectively and *K* represents the system noise.

Strategy imitation preference P4: In the social e-commerce platform enterprise's operation team, members in Subgroup #1 and Subgroup #2 all prefer to imitate the knowledge transfer strategy of members in Subgroup #1.

In the strategy imitation preference P4, the corresponding rule of strategy imitation and update can be described as follows. Any member *i* in Subgroup #1 prefers to randomly select a member, *i*#1, from the set $SG_{i\#1}$ for comparisons of their cumulative game payoffs. If the cumulative game payoff of member *i*#1 is higher than that of member *i*, then the member i imitates the knowledge transfer strategy of the member $i\#1$ with the probability $P(s_i, s_{i\#1})$ and uses it for the next round of the game. Any member j in Subgroup #2 prefers to randomly select a member, $j\#1$, from the set $SG_{j\#1}$ for comparisons of their cumulative game payoffs. If the cumulative game payoff of member $j\#1$ is higher than that of member j, then member j imitates the knowledge transfer strategy of the member $j\#1$ with the probability $P(s_j, s_{j\#1})$ and uses it for the next round of the game. The values $P(s_i, s_{i\#1})$ and $P(s_j, s_{j\#1})$ are expressed as follows:

$$\begin{cases} P(s_i, s_{i\#1}) = \frac{1}{1+\exp[-(U_{i\#1}-U_i)/K]} & (i\#1 \in SG_{i\#1}) \\ P(s_j, s_{j\#1}) = \frac{1}{1+\exp[-(U_{j\#1}-U_j)/K]} & (j\#1 \in SG_{j\#1}) \end{cases} \quad (22)$$

where s_i, $s_{i\#1}$, s_j, and $s_{j\#1}$ represent the knowledge transfer strategies of i, $i\#1$, j, and $j\#1$, respectively, U_i, $U_{i\#1}$, U_j, and $U_{j\#1}$ represent the cumulative game payoffs of i, $i\#1$, j, and $j\#1$, respectively and K represents the system noise.

From the above rules of strategy imitation and update in strategy imitation preferences P1, P2, P3 and P4, it can be seen that the strategy imitation preference is fundamentally different from both reciprocity [22] and reputation [23]. Strategy imitation itself is an important internal mechanism of the complex network-based evolutionary game [70], which is the basis for decision makers to select game strategies [14,21–23]. Both reciprocity and reputation introduce external incentive signals into the complex network-based evolutionary game, while the strategy imitation preference changes the benchmark regarding decision maker selecting game strategies without introducing external incentive signals; thereby, affecting the knowledge transfer behavior of decision makers.

5. Methodology

Based on the established complex network-based evolutionary game model and four kinds of strategy imitation preferences, this paper used the python programming software to simulate the influences of key factors and strategy imitation preferences on knowledge transfer behavior in the social e-commerce platform enterprise's operation team.

5.1. Simulation Steps

A brief diagram illustrating the simulation steps of the established complex network-based evolutionary game model under strategy imitation preferences is presented in Figure 2.

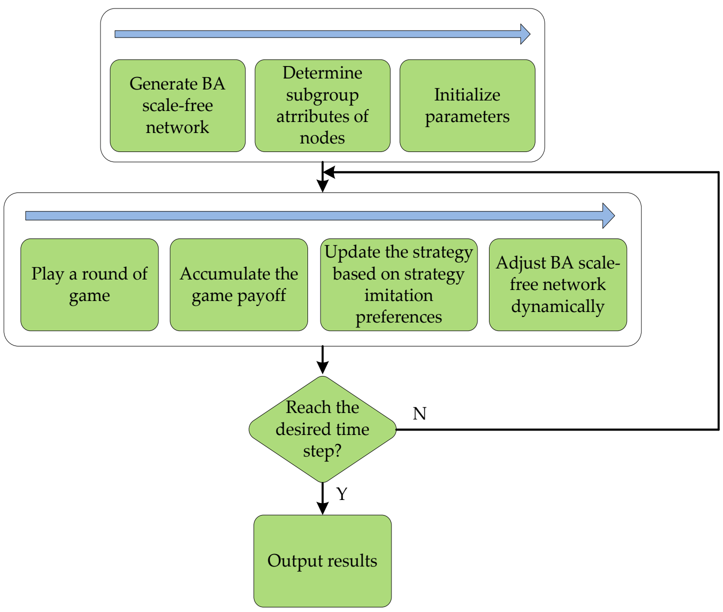

Figure 2. Brief diagram for simulation steps.

The detailed simulation steps are described as follows:

Step 1. Generate a BA scale-free network for the knowledge transfer of the social e-commerce platform enterprise's operation team with 200 members. Assign each node in the network to two different subgroups randomly so that the number of the nodes in Subgroup #1 equals that in Subgroup #2, and initialize the parameters of the complex network-based evolutionary game.

Step 2. Each node in the network plays a round of the game with its directly connected neighbor nodes with different subgroup attributes, and each node accumulates its game payoff, according to the game payoff matrix in Table 1.

Step 3. Each node in the network updates its knowledge transfer strategy, according to the rules of the strategy imitation, and updates the imitation preferences shown in Equations (19)–(22).

Step 4. Adjust the BA scale-free network dynamically, according to the method mentioned in Step 4 of Section 4.1 before the next round of the game.

Step 5. Repeat Step 2, Step 3, and Step 4 until the desired time step is reached. Set the time steps as 50 to achieve a stable state of knowledge transfer, and calculate the proportion of the knowledge transfer strategies.

Step 6. Run each set of the same parameters 50 times, and take the average of the results of the 50 runs as the final result.

5.2. Settings of Parameters for Different Scenarios

Corresponding to the local stability conditions in Section 3.4, we provided six scenarios with different settings of parameters in the simulations to analyze knowledge transfer behaviors under strategy imitation preferences. Correspondences among the scenarios and the local stability conditions are shown as follows:

(1) Scenario 1: $0 < \varepsilon_i T_i < wT_i + \theta$ and $0 < \varepsilon_j T_j < wT_j + \theta$. Scenario 1 indicated that knowledge transfer costs of members in both Subgroup #1 and Subgroup #2 were smaller than the sum of reward and punishment.

(2) Scenario 2: $\varepsilon_i T_i > (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$ and $\varepsilon_j T_j > (\lambda_j + 1)\eta_j {T_i}^m {T_j}^n + wT_j + \theta$. Scenario 2 indicated that knowledge transfer costs of members in both Subgroup #1 and Subgroup #2 were larger than the sum of (λ + 1) times of knowledge synergy benefit, reward and punishment.

(3) Scenario 3: $wT_i + \theta < \varepsilon_i T_i < (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$ and $0 < \varepsilon_j T_j < wT_j + \theta$. Scenario 3 indicated that knowledge transfer cost of members in Subgroup #1 was larger than the sum of reward and punishment but smaller than the sum of (λ + 1) times of knowledge synergy benefit, reward and punishment, while knowledge transfer cost of members in Subgroup #2 was smaller than the sum of reward and punishment.

(4) Scenario 4: $\varepsilon_i T_i > (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$ and $wT_j + \theta < \varepsilon_j T_j < (\lambda_j + 1)\eta_j {T_i}^m {T_j}^n + wT_j + \theta$. Scenario 4 indicated that knowledge transfer cost of members in Subgroup #1 was larger than the sum of (λ + 1) times of knowledge synergy benefit, reward and punishment, while knowledge transfer cost of members in Subgroup #2 was larger than the sum of reward and punishment, but smaller than the sum of (λ + 1) times of knowledge synergy benefit, reward and punishment.

(5) Scenario 5: $\varepsilon_i T_i > (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$ and $0 < \varepsilon_j T_j < wT_j + \theta$. Scenario 5 indicated that knowledge transfer cost of members in Subgroup #1 was larger than the sum of (λ + 1) times of knowledge synergy benefit, reward and punishment, while knowledge transfer cost of members in Subgroup #2 was smaller than the sum of reward and punishment.

(6) Scenario 6: $wT_i + \theta < \varepsilon_i T_i < (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$ and $wT_j + \theta < \varepsilon_j T_j < (\lambda_j + 1)\eta_j {T_i}^m {T_j}^n + wT_j + \theta$. Scenario 6 indicated that knowledge transfer costs of members in both Subgroup #1 and Subgroup #2 were larger than the sum of reward and punishment but smaller than the sum of (λ + 1) times of knowledge synergy benefit, reward and punishment.

The above six scenarios covered all possible knowledge transfer scenarios in the framework of the local stability analyses, which ensured the subsequent simulations on knowledge transfer were more comprehensive and convincing.

In all the scenarios, the parameters, including amount of knowledge transfer (T), direct absorption coefficient of knowledge (σ), knowledge synergy coefficient (η), cost coefficient (ε), and reward coefficient (w) were made similar to settings in [14,21–23]. In order to show differences between Subgroup #1 and Subgroup #2, parameters, such as amount of knowledge transfer (T), direct absorption coefficient of knowledge (σ), and knowledge synergy coefficient (η), and cost coefficient (ε), were set different values for Subgroup #1 and Subgroup #2 in all the scenarios. Note that, as described in Section 3.3, Subgroup #1 and Subgroup #2 were different from each other in knowledge transfer costs. In the following settings of parameters, knowledge transfer cost $\varepsilon_j T_j$ of members in Subgroup #2 was assumed to be smaller than knowledge transfer cost $\varepsilon_i T_i$ of members in Subgroup #1, i.e., $\varepsilon_j T_j < \varepsilon_i T_i$. Detailed settings of parameters for different scenarios are shown in Table 8.

Table 8. Settings of Parameters for Different Scenarios.

Scenarios	Parameters for Members in Subgroup #1					Parameters for Members in Subgroup #2					w	θ
	T_i	σ_i	η_i	ε_i	λ_i	T_j	σ_j	η_j	ε_j	λ_j		
1	10.0	0.50	0.10	0.30	0.10	12.0	0.60	0.30	0.10	0.10	0.2	3.0
2	10.0	0.50	0.10	0.75	0.10	12.0	0.60	0.20	0.55	0.10	0.1	1.0
3	10.0	0.50	0.30	0.45	0.10	12.0	0.60	0.50	0.10	0.10	0.2	1.0
4	10.0	0.50	0.10	0.65	0.10	12.0	0.60	0.30	0.45	0.10	0.1	2.0
5	10.0	0.50	0.10	0.80	0.10	12.0	0.60	0.30	0.30	0.10	0.2	3.0
6	10.0	0.50	0.40	0.40	0.10	12.0	0.60	0.60	0.30	0.10	0.1	1.0

6. Simulation Results and Analyses

Based on the established complex network-based evolutionary game model and four kinds of strategy imitation preferences, this paper analyzed the influences of key factors and strategy imitation preferences on knowledge transfer behavior in the social e-commerce platform enterprise's operation team through simulations.

6.1. Influence of Strategy Imitation Preferences on Knowledge Transfer

In simulations, different strategy imitation preferences were adopted in each scenario for comparisons. For convenience, we denoted F as the initial proportion in which members took transfer strategies, $F \in [0, 1]$ and $F = 0$ meant that no members took the transfer strategy (i.e., all the members took the non-transfer strategy), while $F = 1$ meant that all the members took the transfer strategy. In addition, the initial proportion in which members took transfer strategies varied from 0.1 to 0.9.

(1) Influence of strategy imitation preferences on knowledge transfer in scenario 1

The evolution results of the different proportions in which members took transfer strategies under the four different kinds of strategy imitation preferences, i.e., P1, P2, P3, and P4, for scenario 1 are plotted in Figure 3. Results in Figure 3 suggest that the proportion in which members took transfer strategies (i.e., F) became increasingly large with increase in the time step under all the strategy imitation preferences. When both the knowledge transfer costs of members in Subgroup #1 and Subgroup #2 were smaller than the sum of reward and punishment, i.e., $0 < \varepsilon_i T_i < wT_i + \theta$ and $0 < \varepsilon_j T_j < wT_j + \theta$, all the members in the social e-commerce platform enterprise's operation team would carry out stable knowledge transfer under all the different strategy imitation preferences, which meant the four kinds of strategy imitation preference. The main reason might be as follows. As the knowledge transfer cost was smaller than the sum of reward and punishment under all the strategy imitation preferences, the operation members were willing to take the transfer strategy to obtain the intra-organizational operation knowledge. Further, the newly increased intra-organizational operation knowledge motivated the operation members to take much more value co-creation benefits by cross-organizational knowledge sharing. As a result, all the members took the transfer strategy quickly.

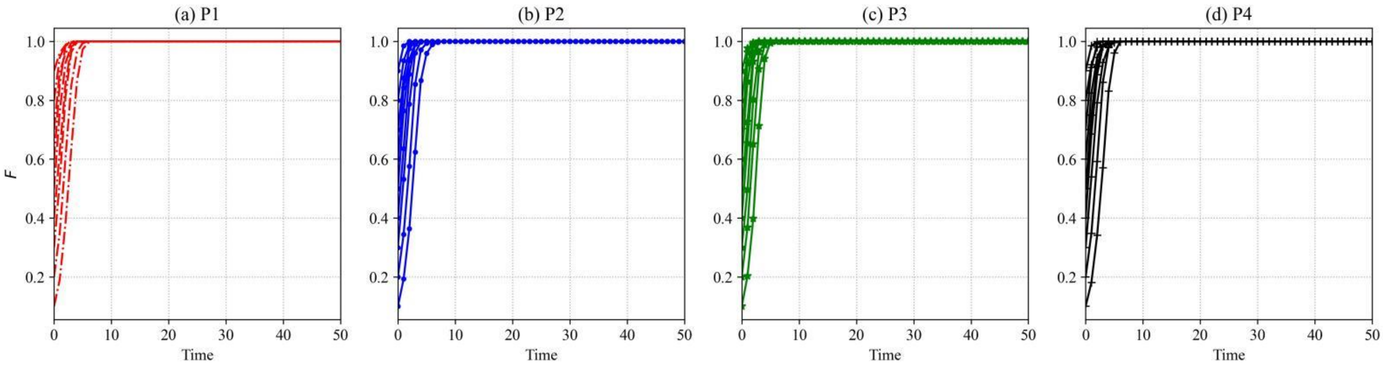

Figure 3. Evolution results of knowledge transfer for scenario 1 under four kinds of different strategy imitation preferences, i.e., (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

(2) Influence of strategy imitation preferences on knowledge transfer in scenario 2

The evolution results of the different proportions in which members took transfer strategies under the four different kinds of strategy imitation preferences, i.e., P1, P2, P3, and P4, for scenario 2 are plotted in Figure 4. The results in Figure 4 suggest that the proportion in which members took transfer strategies (i.e., F) became increasingly small with increase in the time step under all the strategy imitation preferences. When both the knowledge transfer costs of members in Subgroup #1 and Subgroup #2 were larger than the sum of reward, punishment, and $(\lambda + 1)$ times the synergistic knowledge, i.e., $\varepsilon_i T_i > (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$ and $\varepsilon_j T_j > (\lambda_j + 1)\eta_j {T_i}^m {T_j}^n + wT_j + \theta$, all the members in the social e-commerce platform enterprise's operation team would stop knowledge transfer under all the different strategy imitation preferences. The main reason might be as follows. As the knowledge transfer cost was larger than the sum of reward, punishment, and $(\lambda + 1)$ times the synergistic knowledge under all the strategy imitation preferences, all the operation members were not willing to take the transfer strategy because this would lead to the loss of benefit. In this scenario, all the strategy imitation preferences did not work to improve the proportion in which members took the transfer strategy. Consequently, all the members took the non-transfer strategy quickly.

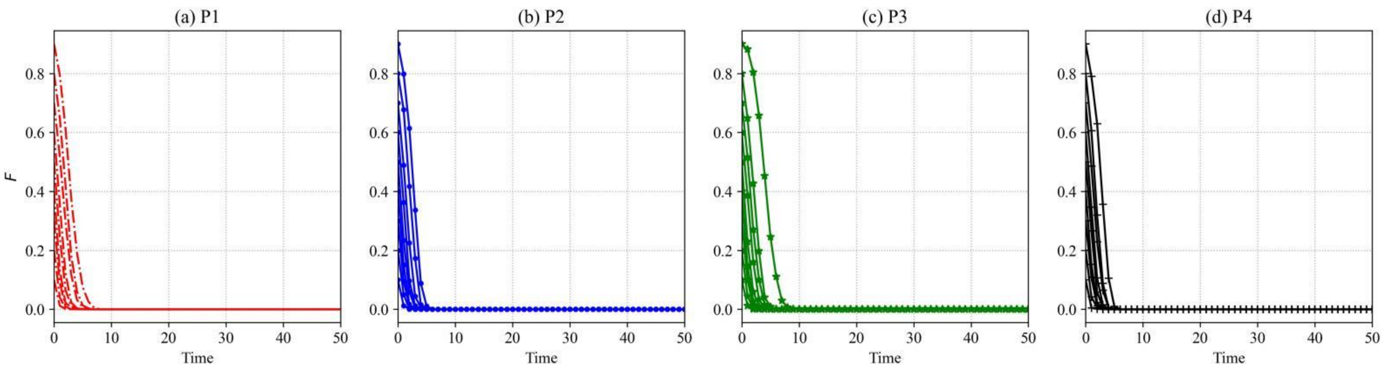

Figure 4. Evolution results of knowledge transfer for scenario 2 under four kinds of different strategy imitation preferences, i.e., (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

(3) Influence of strategy imitation preferences on knowledge transfer in scenario 3

The evolution results of the different proportions in which members took transfer strategies under the four different kinds of strategy imitation preferences, i.e., P1, P2, P3, and P4, for scenario 3 are plotted in Figure 5. It can be seen from Figure 5 that, under strategy imitation preferences P1, P2, and P3, the social e-commerce platform enterprise's operation team with initial proportions varying from 0.1 to 0.9 of members taking the transfer strategy could carry out the transfer strategy. However, under strategy imitation preference P4, the social e-commerce platform enterprise's operation team with initial proportions of 0.1 and 0.2 of members taking transfer strategy could not carry out the effective knowledge transfer. In order to distinguish the influences of the four kinds of strategy imitation preferences on the knowledge transfer, we took the average on the above evolution results for each strategy imitation preference, shown in Figure 6. It can be seen from Figure 6 that the social e-commerce platform enterprise's operation team under strategy imitation preference P3 had the best efficiency and effectiveness in the knowledge transfer, while the operation team under the strategy imitation preference P4 had the worst efficiency and effectiveness in the knowledge transfer.

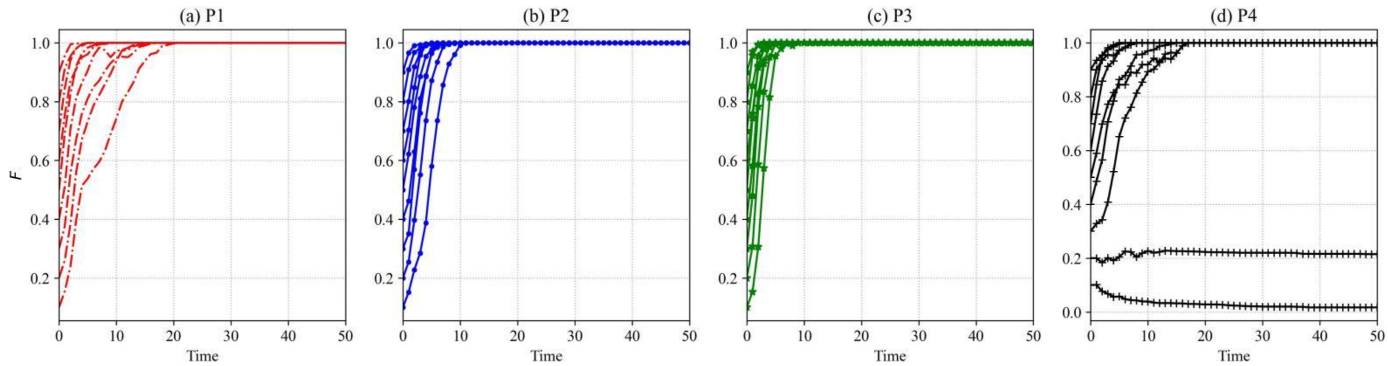

Figure 5. Evolution results of knowledge transfer for scenario 3 under four kinds of different strategy imitation preferences, i.e., (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

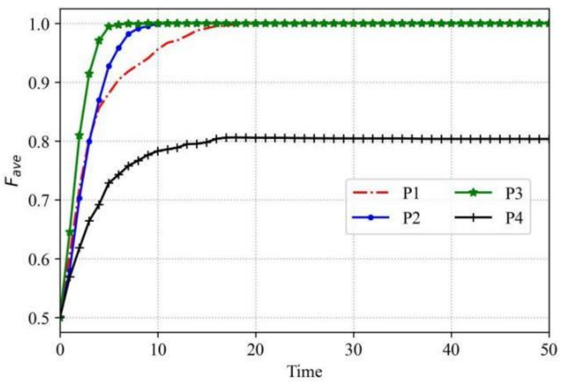

Figure 6. Average evolution results of knowledge transfer for scenario 3 under four kinds of different strategy imitation preferences.

Note that the knowledge transfer cost of members in Subgroup #1 satisfied the condition $wT_i + \theta < \varepsilon_i T_i < (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$, while the knowledge transfer cost of members in Subgroup #2 satisfied the condition $0 < \varepsilon_j T_j < wT_j + \theta$. This meant the operation members in Subgroup #2 had stronger willingness to carry out the knowledge transfer than those in Subgroup #1, because the knowledge transfer cost of members in Subgroup #2 was smaller than the sum of reward and punishment. The strategies of members in Subgroup #2 were imitated by all the operation members under strategy imitation preference P3, while the strategies of members in Subgroup #1 were imitated by all the operation members under strategy imitation preference P4. Therefore, the operation team under the strategy imitation preference P3 had the best efficiency and effectiveness in the knowledge transfer, while the operation team under the strategy imitation preference P4 had the worst efficiency and effectiveness in the knowledge transfer.

However, although the knowledge transfer cost of members in Subgroup #1 was larger than the sum of reward and punishment, it was smaller than the sum of reward, punishment, and $(\lambda + 1)$ times the synergistic knowledge. This meant that there still existed a part of the operation members in Subgroup #1 who were willing to carry out the knowledge transfer with the incentive of intra-organizational synergistic knowledge and cross-organizational value co-creation. This explained why all the operation members finally carried out the transfer strategy under strategy imitation preferences P1 and P2. Note that the strategies of members in Subgroup #1 were imitated by the members in Subgroup #1 and the strategies of members in Subgroup #2 were imitated by the members in Subgroup #2 under strategy imitation preference P1, while the strategies of members in Subgroup #1 were imitated by the members in Subgroup #2 and the strategies of members in Subgroup #2 were imitated by the members in Subgroup #1 under strategy imitation preference P2. The operation members in Subgroup #2 had stronger willingness to carry out the knowledge transfer than those in Subgroup #1. This explained why the efficiency and effectiveness of the knowledge transfer under strategy imitation preference P2 were superior to strategy imitation preference P1 in Figure 6.

(4) Influence of strategy imitation preferences on knowledge transfer in scenario 4

The evolution results of the different proportions in which members took transfer strategies under the four different kinds of strategy imitation preferences, i.e., P1, P2, P3, and P4, for the scenario 4 are plotted in Figure 7. From Figure 7, the following phenomena can be observed. Firstly, under strategy imitation preferences P2 and P4, the social e-commerce platform enterprise's operation team with all the initial proportions in which members took the transfer strategy stopped the knowledge transfer. However, the operation team under strategy imitation preference P4 stopped the knowledge transfer faster than strategy imitation preference P2. Secondly, under strategy imitation preference P1, the operation team with the initial proportions of 0.8 and 0.9 of members taking transfer strategy could only hold a certain level of knowledge transfer. Thirdly, under strategy imitation preference P3, the operation team with the initial proportions of 0.8 and 0.9 of members taking transfer strategy could carry out the effective knowledge transfer. Averages on the above evolution results for each strategy imitation preference are plotted in Figure 8. Similarly, results in Figure 8 show that the operation team under strategy imitation preference P3 had the best efficiency and effectiveness in the knowledge transfer, while the operation team under strategy imitation preference P4 had the worst efficiency and effectiveness in the knowledge transfer.

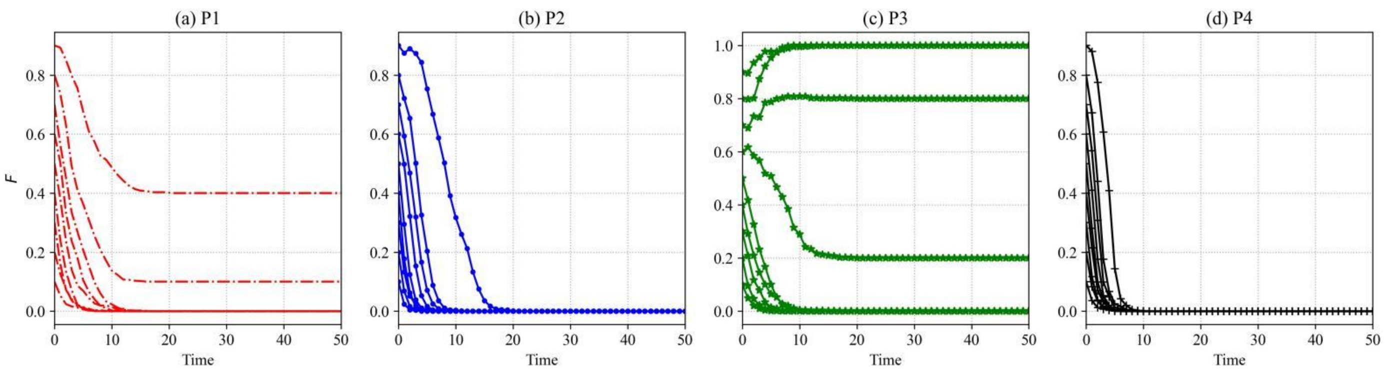

Figure 7. Evolution results of knowledge transfer for scenario 4 under four kinds of different strategy imitation preferences, i.e., (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

Note that the knowledge transfer cost of members in Subgroup #1 satisfied the condition $\varepsilon_i T_i > (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$, while the knowledge transfer cost of members in Subgroup #2 satisfied the condition $wT_j + \theta < \varepsilon_j T_j < (\lambda_j + 1)\eta_j {T_i}^m {T_j}^n + wT_j + \theta$. This meant that there still existed a part of the members in Subgroup #2 who were willing to carry out the transfer strategy with the incentive of intra-organizational synergistic knowledge and cross-organizational value co-creation, while all the members in Subgroup #1 were willing to take the non-transfer strategy to avoid the loss of benefits. Hence, according to strategy imitation preferences P3 and P4, the operation team under strategy imitation preference P3 had the best efficiency and effectiveness in the knowledge transfer, while the operation team under strategy imitation preference P4 had the worst efficiency and effectiveness in the knowledge transfer.

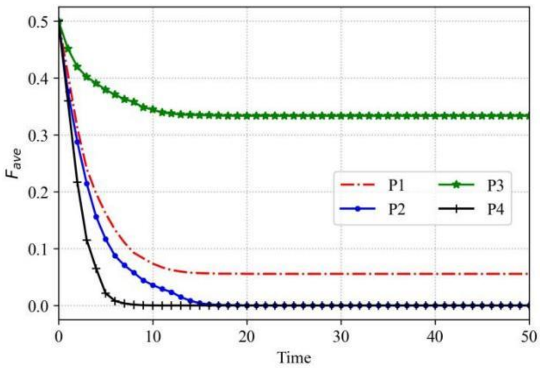

Figure 8. Average evolution results of knowledge transfer for scenario 4 under four kinds of different strategy imitation preferences.

According to strategy imitation preferences P1 and P2, the proportion in which operation members took the transfer strategy under strategy imitation preference P1 was more likely to be larger than for strategy imitation preference P2, because the members in Subgroup #2 were not negatively affected by the members in Subgroup #1 under strategy imitation preference P1, while they were negatively affected under strategy imitation preference P2. This explained why the efficiency and effectiveness of the knowledge transfer under strategy imitation preference P1 were superior to strategy imitation preference P2 in Figure 8.

(5) Influence of strategy imitation preferences on knowledge transfer in scenario 5

The evolution results of the different proportions in which members took transfer strategies under the four different kinds of strategy imitation preferences, i.e., P1, P2, P3, and P4, for scenario 5 are plotted in Figure 9. From Figure 9, we can observe the following results. Firstly, under strategy imitation preference P3, the social e-commerce platform enterprise's operation team with all the initial proportions in which members took the transfer strategy could carry out the effective knowledge transfer quickly, within the fifty time steps. Secondly, under strategy imitation preference P2, the social e-commerce platform enterprise's operation team with lower initial proportions in which members took the transfer strategy, such as 0.1 and 0.2, needed much more than fifty time steps to carry out the effective knowledge transfer. Thirdly, under strategy imitation preference P1, the social e-commerce platform enterprise's operation team with all the initial proportions in which members took the transfer strategy could only ensure 50% of the members carried out the knowledge transfer, while the other 50% of members carried out the non-transfer strategy. Fourthly, under strategy imitation preference P4, the social e-commerce platform enterprise's operation team with all the initial proportions in which members took transfer strategy stopped the knowledge transfer. In the same way, averages on the above evolution results for each strategy imitation preference are plotted in Figure 10. Results in Figure 10 suggest that the operation team under strategy imitation preference P3 had the best efficiency and effectiveness in the knowledge transfer, while the operation team under strategy imitation preference P4 had the worst efficiency and effectiveness in the knowledge transfer.

Note that the knowledge transfer cost of members in Subgroup #1 satisfied the condition $\varepsilon_i T_i > (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$, while the knowledge transfer cost of members in Subgroup #2 satisfied the condition $0 < \varepsilon_j T_j < wT_j + \theta$. This meant that all the operation members in Subgroup #2 were willing to take the transfer strategy to obtain intra-organizational operation knowledge and cross-organizational value co-creation benefits, while all the members in Subgroup #1 were willing to take the non-transfer strategy to avoid the loss of benefits. Hence, according to strategy imitation preferences of P3 and P4, the operation team under strategy imitation preference P3 had the best efficiency and effectiveness in the knowledge transfer, while the operation team under strategy imitation preference P4 had the worst efficiency and effectiveness in the knowledge transfer.

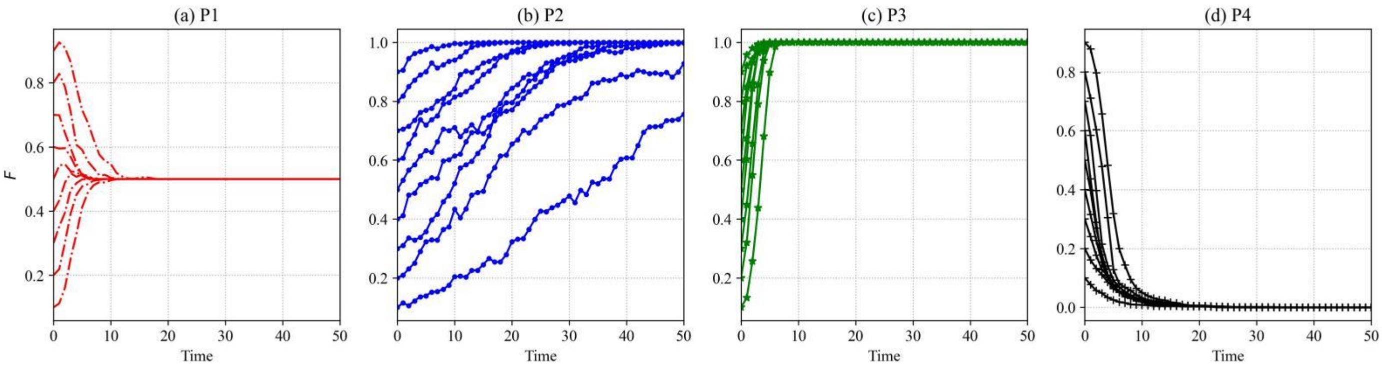

Figure 9. Evolution results of knowledge transfer for scenario 5 under four kinds of different strategy imitation preferences, i.e., (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

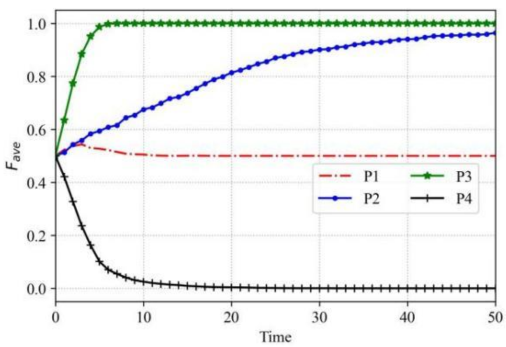

Figure 10. Average evolution results of knowledge transfer for scenario 5 under four kinds of different strategy imitation preferences.

According to strategy imitation preferences P1 and P2, the proportion in which operation members took the transfer strategy under strategy imitation preference P2 was more likely to be larger than for strategy imitation preference P1, because the members in Subgroup #1 were not positively affected by the members in Subgroup #2 under strategy imitation preference P1, while they were positively affected under strategy imitation preference P2. This explained why the efficiency and effectiveness of the knowledge transfer under strategy imitation preference P2 were superior to strategy imitation preference P1 in Figure 10.

(6) Influence of strategy imitation preferences on knowledge transfer in scenario 6

The evolution results of the different proportions in which members took transfer strategies under the four different kinds of strategy imitation preferences, i.e., P1, P2, P3, and P4, for scenario 6 are plotted in Figure 11. It can be seen from Figure 11 that, under the four kinds of strategy imitation preferences, only the social e-commerce platform enterprise's operation team with some initial proportions of members who took the transfer strategy could carry out effective knowledge transfer. Firstly, under strategy imitation preferences P1 and P3, the social e-commerce platform enterprise's operation team could carry out effective knowledge transfer with the initial proportions of members that took the transfer strategy, such as 0.4, 0.5, 0.6, 0.7, and 0.8, while knowledge transfer was stopped when the initial proportions were 0.1 and 0.2 of members taking transfer the strategy.

However, when the initial proportion in which members took the transfer strategy was 0.3, the final evolution proportion in which members took the transfer strategy under strategy imitation preference P3 was much higher than strategy imitation preference P1. Secondly, when the initial proportion in which members took the transfer strategy was 0.3, the operation team under strategy imitation preference P2 held a higher level of knowledge transfer than P4. Similarly, we took the average of the above evolution results for each strategy imitation preference, and plotted the average results in Figure 12. It can be seen from Figure 12 that the social e-commerce platform enterprise's operation team under strategy imitation preference P3 had the best efficiency and effectiveness in the knowledge transfer, while the operation team under strategy imitation preference P4 had the worst efficiency and effectiveness in the knowledge transfer.

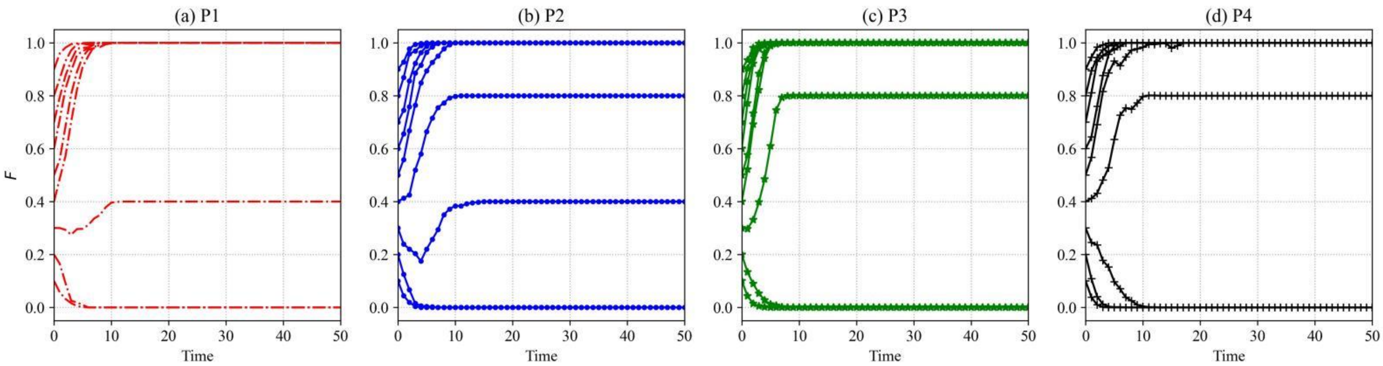

Figure 11. Evolution results of knowledge transfer for scenario 6 under four kinds of different strategy imitation preferences, i.e., (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

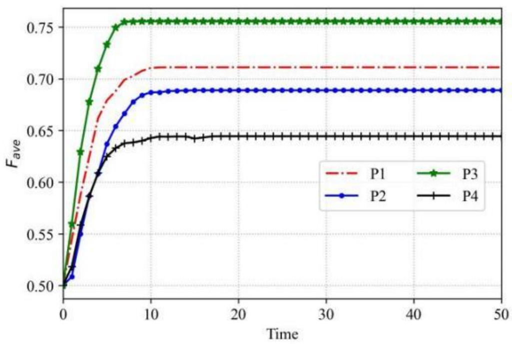

Figure 12. Average evolution results of knowledge transfer for scenario 6 under four kinds of different strategy imitation preferences.

Note that the knowledge transfer cost of members in Subgroup #1 satisfied the condition $wT_i + \theta < \varepsilon_i T_i < (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$, while the knowledge transfer cost of members in Subgroup #2 satisfied the condition $wT_j + \theta < \varepsilon_j T_j < (\lambda_j + 1)\eta_j {T_i}^m {T_j}^n + wT_j + \theta$. This meant that there still existed a part of the members in both Subgroup #1 and Subgroup #2 who were willing to carry out the transfer strategy with the incentive of intra-organizational synergistic knowledge and cross-organizational value co-creation. However, the knowledge transfer cost of members in Subgroup #1 was larger than in Subgroup #2, which meant there was superiority of members taking the transfer strategy in Subgroup #2 over Subgroup #1. Hence, according to strategy imitation preferences of P3 and P4, the operation team under strategy imitation preference P3 had the best efficiency and effectiveness in the knowledge transfer, while the operation team under strategy imitation preference P4 had the worst efficiency and effectiveness in the knowledge transfer.

According to strategy imitation preferences of P1 and P2, the proportion in which operation members took the transfer strategy under strategy imitation preference P1 was more likely to be larger than for strategy imitation preference P2, because the members in

Subgroup #2 were not negatively affected by the members in Subgroup #1 under strategy imitation preference P1, while they were negatively affecte under strategy imitation preference P2. This explained why the efficiency and effectiveness of knowledge transfer under strategy imitation preference P1 were superior to those under strategy imitation preference P2 in Figure 12.

To clearly demonstrate the influences of the complex network-based evolutionary game under different strategy imitation preferences and the local stability analyses on the knowledge transfer behaviors of the social e-commerce platform enterprise's operation team, their average evolution results are summarized in Table 9. The initial proportion in which members took transfer strategies varied from 0.1 to 0.9. The results in Table 9 indicate the final average proportions in which members took the transfer strategy in the complex network-based evolutionary game under different strategy imitation preferences (i.e., P1, P2, P3, and P4) and the local stability analyses.

Table 9. Average evolution results obtained by the complex network-based evolutionary game under different strategy imitation preferences and the local stability analyses as the initial proportion in which members took transfer strategies varying from 0.1 to 0.9.

Scenarios	Complex Network-Based Evolutionary Game				Local Stability
	P1	P2	P3	P4	
1	1.00	1.00	1.00	1.00	1.00
2	0.00	0.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.81	1.00
4	0.05	0.00	0.33	0.00	0.00
5	0.50	0.96	1.00	0.00	0.50
6	0.71	0.69	0.76	0.64	0.78

As for scenarios 1 and 2, it can be seen from the results in Table 9 and Figures 3 and 4 that the final evolution results of the knowledge transfer obtained from the complex network-based evolutionary game were same with those from the local stability analyses. When both the knowledge transfer costs of members in Subgroup #1 and Subgroup #2 were smaller than the sum of reward and punishment, or larger than the sum of reward, punishment, and $(\lambda + 1)$ times the synergistic knowledge, the four kinds of strategy imitation preferences presented in this paper had few effects on the knowledge transfer results, The social e-commerce platform enterprise's operation team would carry out stable knowledge transfer if $0 < \varepsilon_i T_i < wT_i + \theta$ and $0 < \varepsilon_j T_j < wT_j + \theta$ (scenario 1), while the social e-commerce platform enterprise's operation team would stop knowledge transfer if $\varepsilon_i T_i > (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$ and $\varepsilon_j T_j > (\lambda_j + 1)\eta_j {T_i}^m {T_j}^n + wT_j + \theta$ (scenario 2).

However, as for scenarios 3, 4, 5 and 6, all the simulation results in Table 9 and Figure 6, Figure 8, Figure 10, and Figure 12 indicate that the social e-commerce platform enterprise's operation team under strategy imitation preference P3 had the best efficiency and effectiveness in knowledge transfer, while the operation team under strategy imitation preference P4 had the worst efficiency and effectiveness in knowledge transfer. This was caused by the following facts in scenarios 3, 4, 5 and 6. For one thing, the knowledge transfer cost $\varepsilon_j T_j$ of members in Subgroup #2 was assumed to be smaller than the knowledge transfer cost $\varepsilon_i T_i$ of members in Subgroup #1. For another, compared with the members with the larger knowledge transfer costs $[wT_i + \theta < \varepsilon_i T_i < (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta$ or $\varepsilon_i T_i > (\lambda_i + 1)\eta_i {T_i}^m {T_j}^n + wT_i + \theta]$, the members with the lower knowledge transfer costs $[0 < \varepsilon_j T_j < wT_j + \theta$ or $wT_j + \theta < \varepsilon_j T_j < (\lambda_j + 1)\eta_j {T_i}^m {T_j}^n + wT_j + \theta]$ tended to have stronger willingness to carry out the knowledge transfer to get more revenues. In strategy imitation preference P3, members in both Subgroup #1 and Subgroup #2 preferred to imitate the knowledge transfer strategies of members in Subgroup #2, namely, all the members in the operation team preferred to imitate the knowledge transfer strategies of the members with the lower knowledge transfer costs. Hence, the operation team under P3 had the best efficiency and effectiveness in knowledge transfer. Conversely, in strategy imitation preference P4, members in both Subgroup #1 and Subgroup #2 preferred to imitate the knowledge transfer strategies of members in Subgroup #1, namely, all the members in the operation team preferred to imitate the knowledge transfer strategies of the members with the larger knowledge transfer costs. As a result, the operation team under P4 had the worst efficiency and effectiveness in knowledge transfer.

6.2. Analyses of Influencing Factors for Knowledge Transfer under Strategy Imitation Preferences

In the following, influencing factors, including direct absorption coefficient of knowledge (σ), cost coefficient (ε), knowledge synergy coefficient (η), reward coefficient (w), punishment (θ), and cross-organizational value co-creation benefit rate (λ) are analyzed for the knowledge transfer of the social e-commerce platform enterprise's operation team under different strategy imitation preferences. To this end, under different strategy imitation preferences, we carried out simulations on the knowledge transfer behaviors with changes of the influencing factors, while the other parameters were set to those in scenario 4 and the initial proportion in which members took the transfer strategy (F) was fixed as 0.5. Under different strategy imitation preferences, the simulation results on the knowledge transfer behaviors with changes in the influencing factors are shown in Figures 13–18.

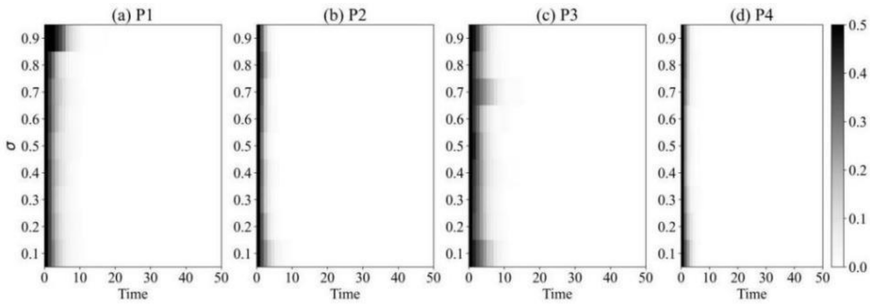

Figure 13. Results of the knowledge transfer as the direct absorption coefficient of knowledge (σ) varies from 0.1 to 0.9 under different strategy imitation preferences: (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

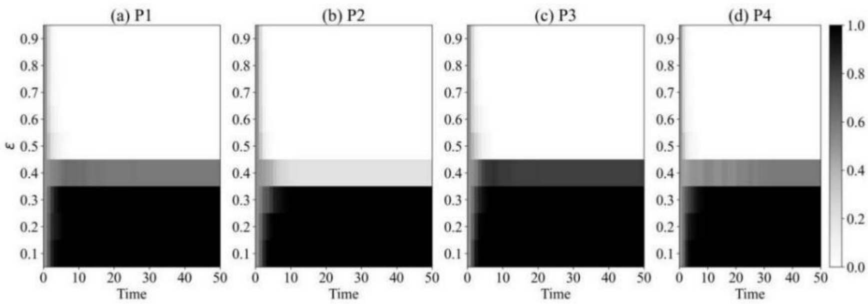

Figure 14. Results of the knowledge transfer as the cost coefficient (ε) varies from 0.1 to 0.9 under different strategy imitation preferences: (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

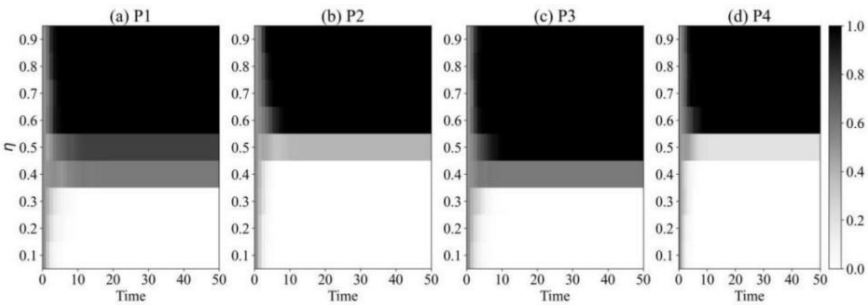

Figure 15. Results of the knowledge transfer as the knowledge synergy coefficient (η) varies from 0.1 to 0.9 under different strategy imitation preferences: (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

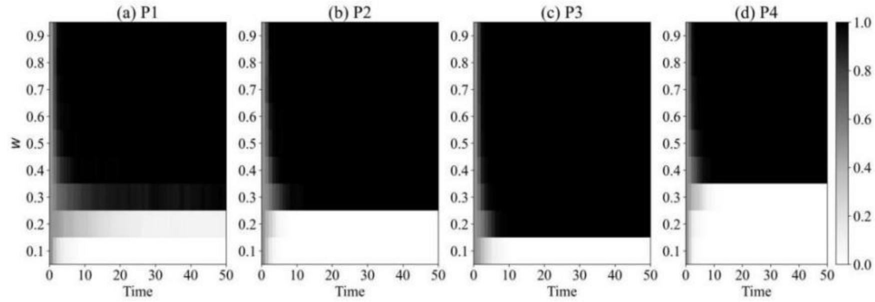

Figure 16. Results of the knowledge transfer as the reward coefficient (w) varies from 0.1 to 0.9 under different strategy imitation preferences: (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

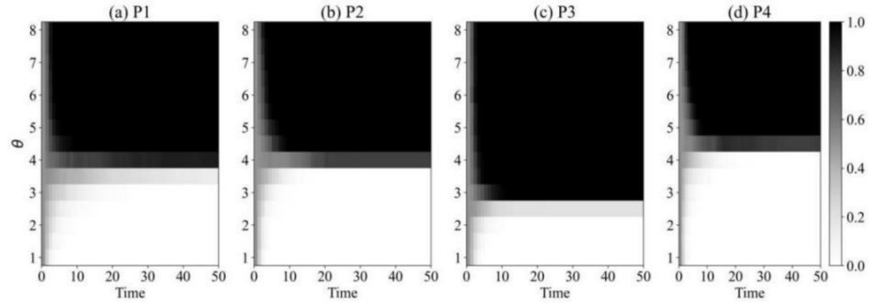

Figure 17. Results of the knowledge transfer as the punishment (θ) varies from 1 to 8 under different strategy imitation preferences: (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

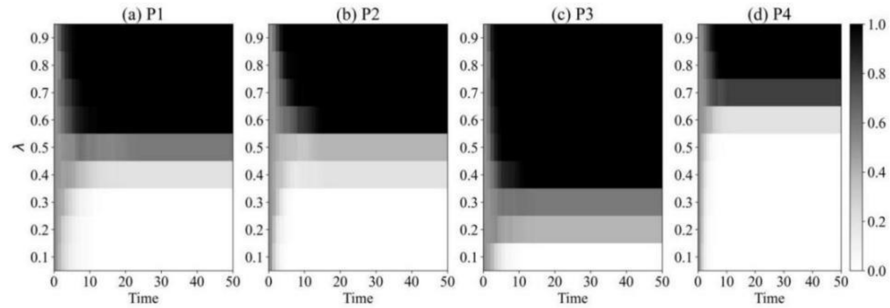

Figure 18. Results of the knowledge transfer as the cross-organizational value co-creation benefit rate (λ) varies from 0.1 to 0.9 under different strategy imitation preferences: (**a**) P1, (**b**) P2, (**c**) P3, and (**d**) P4.

It can be seen from Figure 13 that the social e-commerce platform enterprise's operation team under all the strategy imitation preferences stopped knowledge transfer as the direct absorption coefficient of knowledge varied from 0.1 to 0.9. The results in Figures 14–18 show that the social e-commerce platform enterprise's operation team under all the strategy imitation preferences could reach a stable and sustainable knowledge transfer state with changes of the cost coefficient, the knowledge synergy coefficient, the reward coefficient, the punishment, and the cross-organizational value co-creation benefit rate. This meant that the knowledge transfer of the social e-commerce platform enterprise's operation team under all the four kinds of strategy imitation preferences was not sensitive to change in the direct absorption coefficient of knowledge (σ), but was sensitive to changes in the cost coefficient (ε), the knowledge synergy coefficient (η), the reward coefficient (w), the punishment (θ), and the cross-organizational value co-creation benefit rate (λ).

However, there were some differences in the knowledge transfer behaviors for the changes in the cost coefficient (ε), the knowledge synergy coefficient (η), the reward coefficient (w), the punishment (θ), and the cross-organizational value co-creation benefit rate (λ) under the four kinds of strategy imitation preferences. Firstly, the influences of the change trends of the factors on the knowledge transfer were different. As for the cost coefficient, the smaller it was, the faster the operation team reached a stable knowledge transfer state. On the contrary, as for factors such as the knowledge synergy coefficient, the reward coefficient, the punishment, and the cross-organizational value co-creation benefit rate, the larger they were, the faster the operation team reached a the stable knowledge transfer state. Secondly, the influences of the strategy imitation preferences on the knowledge transfer were different. The social e-commerce platform enterprise's operation team under strategy imitation preference P3 could reach a stable and sustainable knowledge transfer state earlier than the other strategy imitation preferences P1, P2, and P3 at $\eta = 0.5$, $w = 0.2$, $\theta = 3.0$, $\lambda = 0.4$. This suggested that the social e-commerce platform enterprise's operation team under strategy imitation preference P3 was more sensitive than the other strategy imitation preferences P1, P2, and P3 to increase of factors such as the knowledge synergy coefficient, the reward coefficient, the punishment, and the cross-organizational value co-creation benefit rate.

To clearly demonstrate the differences among the strategy imitation preferences, the critical values of the factors under which the operation team reached a stable and sustainable knowledge transfer state are summarized in Table 10. In Table 10, the sign '≤' means that the operation team entered a stable knowledge transfer state when the influencing factor was less than, or equal to, a value. The sign '≥' meant that the operation team entered a stable knowledge transfer state when the influencing factor was greater than, or equal to, a value. The sign '—' meant that the operation team could not enter a stable knowledge transfer state with changes in the influencing factor. As can be seen from Figures 14–18 and Table 10, the proportion in which members took the transfer strategy under the four kinds of strategy imitation preferences was positively correlated with the knowledge synergy coefficient, the reward, the punishment, and the cross-organizational value co-creation benefit rate, while negatively correlated with the cost coefficient. In addition, strategy imitation preference P3 could significantly reduce the critical values of the knowledge synergy coefficient, the reward, the punishment and the cross-organizational value co-creation benefit rate for stable and sustainable knowledge transfer. On the contrary, strategy imitation preference P4 could significantly increase the critical values of the reward, the punishment and the cross-organizational value co-creation benefit rate for stable and sustainable knowledge transfer.

Table 10. Critical values of the influencing factors for stable and sustainable knowledge transfer.

Strategy Imitation Preferences	σ	ε	η	w	θ	λ
P1	—	≤0.3	≥0.6	≥0.3	≥4.5	≥0.6
P2	—	≤0.3	≥0.6	≥0.3	≥4.5	≥0.6
P3	—	≤0.3	≥0.5	≥0.2	≥3.0	≥0.4
P4	—	≤0.3	≥0.6	≥0.4	≥5.0	≥0.8

The joint mechanism of the diffusion of the complex networks and the strategy imitation preferences was the main reason for the above results. From the comparison and analyses in Section 6.1, it can be observed that strategy imitation preference P3 was superior to strategy imitation preference P4 in the efficiency and effectiveness of knowledge transfer. To be specific, strategy imitation preference P3 played a positive role in inducing the operation members to carry out the knowledge transfer, while strategy imitation preference P4 played a negative role in inducing the operation members to carry out the knowledge transfer. These roles of the strategy imitation preferences could be played fully and comprehensively with the help of diffusion of the complex networks so that the operation team was more likely to need low knowledge synergy coefficient, reward, punishment, and cross-organizational value co-creation benefit rate to achieve a stable and sustainable knowledge transfer under strategy imitation preference P3, while needing high knowledge synergy coefficient, reward, punishment, and cross-organizational value co-creation benefit rate to achieve stable and sustainable knowledge transfer under strategy imitation preference P4.

7. Conclusions and Discussions

7.1. Conclusions

This study focused on the knowledge transfer of the social e-commerce platform enterprise's operation team in the self-centered sustainable ecological business mode. In order to improve competitiveness, the social e-commerce platform enterprise's operation team should carry out both intra-organizational operation knowledge transfer and cross-organizational knowledge sharing for value co-creation. Hence, both intra-organizational knowledge transfer, and cross-organizational knowledge sharing, were considered in the framework of knowledge transfer of the social e-commerce platform enterprise's operation team. Specifically, the amount of knowledge transfer, direct absorption coefficient of knowledge, knowledge synergy coefficient, cost coefficient, reward coefficient, and punishment were included in intra-organizational knowledge transfer of the social e-commerce platform enterprise's operation team, while cross-organizational value co-creation benefit was included in cross-organizational knowledge sharing of the social e-commerce platform enterprise's operation team in this study. What is more, the knowledge transfer behaviors were studied by using the complex network-based evolutionary game, combined with strategy imitation preferences. The following conclusions are drawn:

(1) Relationships among the knowledge transfer cost, the knowledge synergy benefit, the cross-organizational value co-creation benefit rate, the reward and the punishment have significant impacts on the knowledge transfer behaviors of the social e-commerce platform enterprise's operation team under the four kinds of strategy imitation preferences. The proportion in which members take transfer strategy under the four kinds of strategy imitation preferences is positively correlated with the knowledge synergy coefficient, the cross-organizational value co-creation benefit rate, the reward, and the punishment, while negatively correlated with the cost coefficient. This finding suggests that both the intra-organizational factors and the cross-organizational factors have important effects on the knowledge transfer of the social e-commerce platform enterprise's operation team. This finding on the intra-organizational factors is consistent with prior studies in [14].

(2) When the knowledge transfer costs of the members in the social e-commerce platform enterprise's operation team are smaller than the sum of the reward and the punishment, the operation team can carry out stable and sustainable knowledge transfer under all the strategy imitation preferences. When the knowledge transfer costs of the members in the social e-commerce platform enterprise's operation team are greater than the sum of the reward, the punishment and (λ + 1) times of the knowledge synergy benefit, the operation team stops knowledge transfer under all the strategy imitation preferences. This finding indicates the significance of the knowledge transfer cost. This finding is similar to that of prior studies in [14,21]. However, when the knowledge transfer costs of the members in the social e-commerce platform enterprise's operation team are greater than the sum of the reward and the punishment, but smaller than the sum of the reward, the punishment and (λ + 1) times of the knowledge synergy benefit, there still exists a part of the operation members who are willing to take the transfer strategy. It is worth noting that the cross-organizational value co-creation benefit rate λ increases the possibility that operational members take the transfer strategy, which is different from [14,21]. Simultaneously, (λ + 1) times of the knowledge synergy benefit also indicates that both the intra-organizational knowledge synergy benefit and the cross-organizational value co-creation benefit rate λ have important significance on the cross-organizational value co-creation for the social e-commerce platform enterprise's operation team.

(3) When all the members of the social e-commerce platform enterprise's operation team prefer to imitate the knowledge transfer strategies of the operation members with smaller knowledge transfer costs, the operation team is much more likely to show a high proportion taking the transfer strategy, and often needs low knowledge synergy coefficient, reward, punishment, and cross-organizational value co-creation benefit

rate to achieve stable and sustainable knowledge transfer. When all the members of the social e-commerce platform enterprise's operation team prefer to imitate the knowledge transfer strategy of the operation members with larger knowledge transfer costs, the operation team is much more prone to show a low proportion taking the transfer strategy, and often needs high reward, punishment, and cross-organizational value co-creation benefit rate to achieve stable and sustainable knowledge transfer. This finding is a novel and important contribution of this paper.

7.2. Implications

In order to facilitate the stability and sustainability of knowledge transfer and improve the competitiveness of the social e-commerce platform enterprise's operation team, we present the following managerial implications.

(1) Social e-commerce platform enterprises should build relevant platforms to meet both intra-organizational operation knowledge transfer and cross-organizational knowledge sharing for value co-creation. Social e-commerce platform enterprises especially need to build convenient mobile APP platforms and provide corresponding technical support to improve the real-time capability of both intra-organization operation knowledge transfer and cross-organization knowledge sharing for value co-creation. Social e-commerce platform enterprises should also facilitate knowledge transfer and sharing of multiple participants and reduce barriers by simplifying the participation process and reducing the difficulty of participation. The above measures can effectively reduce the costs of both intra-organizational operation knowledge transfer and cross-organizational knowledge sharing for value co-creation, which is conducive to the stability and sustainability of knowledge transfer in social e-commerce platform enterprises.

(2) Social e-commerce platform enterprises should pay more attention to cross-organizational value co-creation ability of intra-organizational operation knowledge. For intra-organizational operation knowledge with larger cross-organizational value co-creation benefit rate, especially from synergistic innovation within organizations, social e-commerce platform enterprises should actively create favourable conditions to realize knowledge transfer within the operation team, and encourage the team to make full use of the absorbed knowledge for cross-organizational value co-creation. Social e-commerce platform enterprises should actively transform intra-organizational operation knowledge into cross-organizational value co-creation benefit, which can positively amplify the incentive role of the transfer and sharing of intra-organizational operation knowledge on the operation team and is conducive to the stability and sustainability of knowledge transfer, thereby increasing value co-creation benefit, enhancing the strength of relations in the value network, and improving competitiveness.

(3) Social e-commerce platform enterprises should actively advocate improvement in the ability of knowledge transfer and sharing. At the same time, social e-commerce platform enterprises should establish vanguard groups or individual employees with strong ability in knowledge transfer and sharing, and enhance them as role models. Social e-commerce platform enterprises should also support and encourage the vanguard groups or individual employees to share their means, skills and methods of knowledge transfer within the enterprises, and actively guide and influence the strategy imitation preferences of other groups or employees, thereby improving the efficiency, the effectiveness, the stability, and the sustainability of knowledge transfer.

(4) With the implementation of green and low-carbon policies, green and low-carbon performance is involved, to some extent, in the competition. In the sustainable ecological business mode, cored with social e-commerce platform enterprises, the social e-commerce platform enterprises should deepen collaboration and cooperation with relevant stakeholders in green and low-carbon aspects. First, social e-commerce platform enterprises should carry out synergistic innovation with relevant stakeholders having green and low-carbon knowledge, such as building green data centers,

researching and developing green packaging, reducing packaging quantity and reducing transportation carbon emissions. Then, social e-commerce platform enterprises should carry out the relevant knowledge transfer within organizations by means of strategy imitation preferences in order to effectively transform green and low-carbon knowledge of synergistic innovation to organizational knowledge. Finally, social e-commerce platform enterprises should improve identification of consumers of low-carbon products through knowledge sharing and interactions, thereby increasing the enthusiasm of manufacturers for energy conservation and emission reduction and improving the economic and environmental benefits of a sustainable ecosystem.

7.3. Limitations

In this work, we modeled the cross-organizational value co-creation benefit in general, by using cross-organizational knowledge sharing M and its value co-creation benefit rate λ. To some extent, this can reflect the important effects of cross-organizational value co-creation on knowledge transfer of the social e-commerce platform enterprise's operation team. However, in practice, there exist more cross-organizational knowledge sharing items, along with their corresponding value co-creation benefit rates. With this in mind, we plan to use a case study or empirical research for in-depth and detailed analyses in future research.

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