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Research Article

Research on the Benefit-Sharing Model of Collaborative Innovation Mechanism in Power Innovation Park

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Currently, innovation is no longer limited to a single enterprise. The joint realization of collaborative innovation by multiple parties has become the main driving force for innovation and development. The Power Innovation Park is an emerging innovation and entrepreneurship model. It is guided by power grid companies, and the school, government, and enterprise are combined in the park. The Power Innovation Park urgently needs theoretical guidance in terms of the resource allocation mechanism, support incentive mode, and benefit-sharing mode, so this paper takes the park as an example to study the benefit-sharing mode of collaborative innovation. In this paper, the transformation methods of the Power Innovation Park are divided into two types: cooperation between members within the park and dominated by external enterprises in the park. This paper applies cooperative game theory and HJB equation to study the benefit-sharing model of each member in the Power Innovation Park under two different result transformation modes. Research has shown that an appropriate method of transformation of results can maximize the overall and individual interests of the park and that individual interests are affected by many factors. Finally, this paper puts forward policy recommendations to promote the collaborative innovation development of the innovation park through the research results.

1. Introduction

The Power Innovation Park is an emerging industrial park that is driven by a collaborative innovation mechanism. High-quality emerging technology research and development, achievement transformation, and benefit distribution are realized in the park through enterprise alliance. The operation of the collaborative innovation park with the power as the technology carrier is a brand new business model. In the park, power grid companies will not only perform research and development work as the main innovation but also play the role of government in traditional industrial parks for management support. As the leader of collaborative innovation, power grid companies should form an interagency park management team to make overall plans for the resources of entrepreneurs. They should guide the research and development, transformation, and benefit distribution of cutting-edge common technologies. The information asymmetry and uncertainty should be reduced in the process of complex knowledge flow. In the collaborative innovation mechanism, resource allocation mechanism, incentive support mode, and benefit-sharing model are current research hotspots, and they are also important factors affecting the effect of collaborative innovation. However, this collaborative innovation mechanism is still in its infancy, and there are many problems. The park is in urgent need of theoretical guidance.

Many scholars research collaborative innovation. Zhang et al. [1] analyzed the connotation of collaborative innovation from the three levels of micro, middle, and macro and believed that collaborative innovation is an innovation model that breaks the boundaries of departments, industries, and regions, integrates innovation resources and elements, optimizes resource allocation, and realizes the effective docking of knowledge and technology. According to Zheng [2], the economic benefit, resource sharing, and risk sharing are the internal driving force of industry-university-research collaborative innovation. The external driving force of industry-university-research collaborative innovation is policy environmental incentives. By analyzing the development status and existing problems of collaborative innovation in the Beijing-Tianjin-Hebei region, Wang et al. [3] constructed a collaborative innovation mechanism from the aspects of the collaboration of innovation entities, internal driving of collaborative innovation, and collaborative innovation support. Xu et al. [4] thought that the benefits of cooperation entities are the driving mechanism of industry-university-research collaborative innovation. Only when the cooperation can obtain stable benefits, will deep and stable cooperation be carried out. According to Song et al. [5], the driving mechanism of collaborative innovation includes service mode, capital investment, benefit distribution, evaluation, and monitoring. Cheng et al. [6] conducted research on the driving mechanism of online/offline collaborative innovation of Chinese enterprises and found that the relevant elements of resource allocation need to be coordinated by enterprises in order to obtain the synergy benefits of online/offline innovation. Zhou constructed a collaborative innovation simulation model with multiagent participation and simulated the policy support incentives for collaborative innovation [7]. According to the discussion on the innovation incentive effect of collaborative innovation, Qiu found that innovation incentives can improve the quality of innovation, and the level of incentives is related to the type of enterprise, the level of marketization, and the protection of intellectual property rights [8].

In collaborative innovation cooperation, the resource allocation mechanism is one of the main factors affecting the progress of scientific and technological achievements' research and development and transformation, which have been studied by scholars. Yang et al. [9] systematically analyzed the research on resource allocation in recent years with the help of CiteSpace software and found out the weak points of such problems. With a variety of comprehensive evaluation methods, Miao and Yang [10] revealed that the allocation of talent and funding resources is an important factor affecting the transformation of scientific and technological resources and conducted a numerical analysis with the central region as an example. Taking some high-tech industrial parks in Beijing as examples, Cheng et al. analyzed the financial policy support enjoyed by enterprises at different stages of development and gave policy suggestions to help both the strong and the weak [11]. Han analyzed the allocation of incubation resources for scientific and technological achievements and held the view that the cumulative investment in public technology service platforms was an important factor affecting the allocation of resources. A reasonable adjustment of this indicator can promote the improvement of the efficiency of incubation resource allocation [12]. Zhang et al. [13] comprehensively evaluated the allocation efficiency of scientific and technological resources in 30 provinces of China from 2009 to 2018 by using the data envelope Malmquist index and the DEA-Tobit two-step method. Liang et al. [14] found that the efficiency of the allocation of scientific and technological resources in China was basically shown to be developing towards a high stage. Moreover, pure technical efficiency had a more significant impact on comprehensive efficiency than scale efficiency. Li and Liu [15] quantitatively studied the influence mechanism between government subsidies and technology diffusion and the efficiency of resource allocation. They found that government subsidies and technology diffusion promoted each other and improved the efficiency of resource allocation. Some scholars discussed the efficiency of resource allocation of provincial governments and put forward relevant policy suggestions [16–18].

The incentive support mode is an important guarantee for promoting collaborative innovation mechanisms and the sharing of scientific and technological resources [19]. Scholars in various countries have conducted extensive research on this issue. Li et al. [20] established the economic effect model under the TIM model and believed that a reasonable income distribution method could stimulate the efficiency of scientific and technological innovation. Li et al. [21] proposed a game model with dynamic analysis and emphatically analyzed the policy of supporting and stimulating the innovative R&D of small and microenterprises. Wang et al. [22] established a support and incentive method for regional collaborative development based on innovation vouchers and suggested putting the innovation platform into use. Some scholars discussed the current situation of the scientific research incentive policies in Beijing-Tianjin-Hebei and Zhejiang Province, analyzed the shortcomings of the policy, and put forward suggestions for improving the macrocontrol and award system [23, 24]. Based on the perspective of organizational control, Huang and Chen [25] studied how formal collaborative management mechanisms, collaborative rules and regulations, and collaborative innovation atmosphere can improve innovation performance in the process of industry-university-research collaborative innovation. Chen and Li [26] pointed out that improving the status and profitability of scientific research institutions in the process of collaborative innovation within a certain range can improve the level of collaborative innovation efforts of the party with a lower level of effort to a certain extent. He and Xie [27] used quantum games to study the incentive mechanism of collaborative innovation. After considering the entanglement state, the "prisoner's dilemma" problem was solved to a certain extent.

In a collaborative innovation mechanism, the construction of a benefit-sharing mechanism can stimulate the enthusiasm of participating members and improve the efficiency of innovative technology research and development and achievement transformation. The research objects of this problem focus on a single principal and agent, and the research methods are mainly developed from the cooperative game and Shapley value method. By using a differential game and HJB equation, Ma and Zhao, respectively, studied the benefit-sharing between two subjects of industrial generic technology and civil-military integration collaborative innovation technology [28, 29]. Based on the differential game, Wang considered the random uncertainty and constructed the stochastic HJB equation to study the benefit-sharing model under the collaborative innovation mechanism [30]. Yu et al. studied the cooperative game problem under the fuzzy alliance, realized the fairness of the cross-regional supply chain benefit distribution, and reduced the risk of cooperation breakdown [31]. A number of scholars used Shapley value to study the quadratic distribution of benefits in collaborative innovation alliances, encouraging enterprises to improve the efficiency of collaborative innovation [32, 33]. Wang et al. [34] described the dependence relationship between enterprises by means of Choquet, proposed a cooperative game model with Shapley value, and studied the benefit distribution mechanism of collaborative innovation alliance. Zhao [35] improved the benefit-sharing method of the original industry-university-research alliance and established a distribution model more in line with objective reality. Yu et al. [36] studied the complex interest relationships between the government, schools, and enterprises in the process of school-enterprise cooperation and made an evolutionary analysis of the interests, psychology, and decision-making behavior of the three in the process of the cooperative game. The research methods and research objects in the benefit-sharing are mainly considered in the abovementioned literature, and the research objects are limited to a single client and agent in the innovation park.

The establishment of the benefit-sharing model is based on multiagents. The multiagent model has been applied in many fields and has its own advantages and research value. In the collaborative innovation system, multiagents pursue a win-win situation through cooperative games. Some scholars have constructed an evolutionary game model between enterprises, scientific research institutions, and governments in the literature, studied the conditions for choosing cooperative innovation among the three, and put forward countermeasures to improve innovation efficiency through simulation research [37]. In addition, the multiagent model has also been applied in the field of Energy Internet. Chen [38] studied the cyber-attacks detection and mitigation of the Energy Internet and proposed a multiagent-based distributed Kalman filter consensus control method. This method can provide Energy Internet fault tolerance and timely attack mitigation and further recovery. Liu et al. [39] applied the multiagent model to the energy storage technology research of the Energy Internet and proposed a multiagent particle swarm algorithm to solve the energy storage coordination problem. Li et al. [40] established a power generation investment decision-making model based on the interests of multiagent, studied the strategies of different entities, and proposed investment strategies that enable multiple entities to obtain optimal benefits.

Based on the analysis of the above literature, this paper aims to discuss the issue of benefit-sharing among multiagent in the Power Innovation Park led by grid companies. The contributions of this paper are as follows. According to the difference between the transformation method and the subject of the achievement transformation in the Power Innovation Park, the benefit-sharing model of the park is divided into two types: the internal member cooperation model and the external enterprise-led model. In the problem description and basic assumptions' section, the difference between the two models and the selection method is introduced. We discussed the benefit sharing of park members under the two scenarios of multiagent cooperation transformation and technology transfer, constructed corresponding benefit-sharing models, and proved it with calculation examples.

According to the difference between the transformation method and the undertaker of the Power Innovation Park, we divide the benefit-sharing model in the park into two types: the internal member cooperation mode and the external enterprise-led mode. We discuss the issue of benefit sharing in the context of multiagent and technology transfer and construct the benefit-sharing model using cooperative games.

The paper proceeds as follows: Section 2 describes the problem and proposes basic assumptions. Section 3 constructs a benefit-sharing model. In Section 4, we perform a case study. Section 5 concludes the paper and outlines directions for future research.

2. Problem Description and Basic Assumptions

2.1. Problem Description. After the research and development of a certain scientific and technological achievement in the Power Innovation Park, the R&D participating units can carry out differentiated benefit distribution according to different transformation methods of the achievements. Depending on the subject of the transformation, the transformation methods can be divided into two types: the transformation methods of cooperation among members within the park and the transformation methods led by enterprises outside the park, as shown in Figure 1. The selection methods and differences of the benefit-sharing model corresponding to these two transformation methods are introduced as follows.

R&D units and park enterprises should jointly assess the risk of achievement transformation and choose the transformation method. This paper focuses on the benefit-sharing mechanism after achievement transformation, so this paper simplifies the measurement of achievement transformation risk into economic profit. Through a series of efforts, the members involved in collaborative innovation achievement transformation in the park will get the total benefit π after the industrialization of achievement. Meanwhile, P represents the opportunity cost of cooperative transformation among members in the park. If $\pi - P > 0$, the transformation method of internal member cooperation should be selected. Otherwise, the transformation method led by external enterprises should be chosen.

When $\pi > P$, the transformation method led by the members of the park should be adopted. The specific transformation method can be valuation and capital contribution. The process of incubation and transformation of scientific and technological achievements in this way is completed with the aid of the internal funds of the park, and the distribution of benefits should be based on the degree of effort and the input resources in the research and

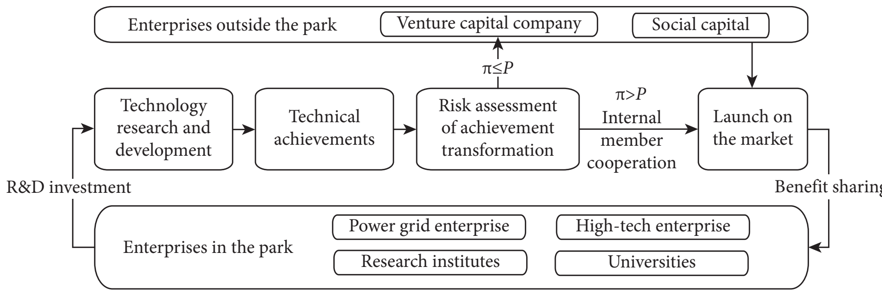


FIGURE 1: Collaborative innovation and benefit-sharing model for Power Innovation Park.

development process. In this way, the game is played with the goal of maximizing common interests.

When $\pi \leq P$, the transformation method led by external enterprises in the park should be adopted, and the specific transformation method can be transfer or implementation of license. In this way, technological achievements are transferred to enterprises outside the park, and the transfer income is the total income of the technology. The distribution process is as follows: first, the R&D unit conducts a cooperative game, discusses and determines the negotiation point, and then conducts a noncooperative game based on the negotiation point to obtain the maximum benefit.

2.2. Basic Assumptions

(1) Assume that the Power Innovation Park is composed of n members including companies, universities, and research institutes. The members' effort changes with time, which can be expressed as $X(t) = [x_i(t)]_n$. The cost of achievement transformation is expressed as $C = [c_i(t)]_n$. And, x_i and c_i should satisfy formula (1), and the transformation cost can be expressed as formula (2), and α_i is the cost coefficient of effort, $\alpha_i > 0$:

$$\frac{\mathrm{d}c_i}{\mathrm{d}x_i} > 0, \frac{\mathrm{d}^2 c_i}{\mathrm{d}x_i^2} > 0, \tag{1}$$

$$c_i(t) = \frac{1}{2} \cdot \alpha_i \cdot x_i^2(t). \tag{2}$$

(2) Under the internal member cooperation mode, the progress of achievement transformation is affected by the degree of effort and technological updates. Referring literature [28], the relationship between the above three is expressed by the following formula:

$$K(t) = \frac{\mathrm{d}K(t)}{\mathrm{d}t} = \sum_{i=1}^{n} \lambda_i x_i(t) - \delta K(t), \tag{3}$$

where $K(0) = K_0 \geq 0$, λ_i represents the impact of the enterprise's effort on the progress of achievement transformation, and δ represents the rate of technology obsolescence and indicates the degree to which technology elimination slows down the transformation of achievements.

(3) Referring to the product quality management and income model in literature [29], the formula of the total income $I(t)$ of collaborative R&D achievement transformation at time t is as follows:

$$I(t) = \eta \cdot K(t) + \sum_{i=1}^{n} \theta_i \cdot x_i(t), \tag{4}$$

where θ_i is the marginal income coefficient of the members participating in the transformation and $\eta > 0$ is the income influence coefficient of the progress of achievement transformation.

(4) In the internal member cooperation mode, the objective function of a single member can be expressed as formula (5). This form is more in line with the structure of the HJB equation and is convenient for model solving:

$$\pi_i(K) = \int_0^{+\infty} e^{-\rho t} \left(w_i \cdot I(t) - c_i(t) \right) \mathrm{d}t, \tag{5}$$

where $e^{-\rho t}$ represents the influence of the positive discount rate.

In formulas (1)–(5), $x_i(t)$ is the control variable, $K(t)$ is the state variable, and other parameters are assumed to be time-independent constants. For convenience, $x_i(t), c_i(t)$, and $K(t)$ are denoted as x_i, c_i, and K below.

(5) In the external enterprise-led model, under any strategy combination, the income p_i of each unit in the park can be quantified, and the total utility corresponding to the income of each member in the park can be expressed through the Cobb–Douglas function.

(6) In the transformation mode that is led by external enterprises, there are m strategies adopted by member i in the park under the benefit distribution of this mode, and the strategy j of member i can be expressed as $s_{ij} \in S$. The enterprise income in the strategy portfolio is a set of vectors $(p_1, p_2, \ldots, p_n)$. If p_i satisfies formula (6), the strategy combination corresponding to this income is a feasible strategy combination $s^{\#}$, where P is the total income of the

benefit distribution game, that is, the opportunity cost of the internal member cooperative transformation method. All members participating in the benefit distribution will form a benefit negotiation point p_i', and the negotiation point and benefit vector should satisfy the constraints of the following formulas:

$$\sum_{i=1}^{n} p_i = P, \quad \forall p_i \geq p_i', \tag{6}$$

$$P \geq \sum_{i=1}^{n} p_i'. \tag{7}$$

(7) The equilibrium coefficient $w_i \in (0, 1)$ represents the inherent proportion of each member in the park in the distribution of collaborative innovation, and the coefficient should satisfy the following formula:

$$\sum_{i=1}^{n} w_i = 1. \tag{8}$$

3. Construction of the Benefit-Sharing Model

3.1. Benefit-Sharing Model of Internal Member Cooperation. Driven by collaborative innovation, the goal of the game among park members is to maximize the overall benefits. Therefore, the objective function $\pi(K)$ can be obtained by adding up the benefits $\pi_i(K)$ of each member, as shown in equation (9). $\pi(K)$ is continuously bounded and differentiable and satisfies the HJB equation in all cases where $K > 0$:

$$\begin{aligned}\pi(K) &= \sum_{i=1}^{n} \pi_i(K)dt \\ &= \int_0^{+\infty} e^{-\rho t}\left(\eta \cdot K + \sum_{i=1}^{n}\left(\theta_i \cdot x_i - \frac{1}{2}\alpha_i \cdot x_i^2\right)\right)dt.\end{aligned} \tag{9}$$

According to the relationship between the objective function structure of equation (9) and the variables of equation (3), the model can be solved by the conclusion of the HJB equation. Therefore, with the help of the conclusion of the HJB equation, equation (9) is changed to the form of equation (10), which can facilitate the solution of the model:

$$\begin{aligned}\rho \cdot \pi(K) = \max_{x_i \geq 0}\Bigg\{&\eta \cdot K + \sum_{i=1}^{n}\left(\theta_i \cdot x_i - \frac{1}{2}\alpha_i \cdot x_i^2\right) \\ &+ \pi'(K) \cdot \left(\sum_{i=1}^{n} \lambda_i \cdot x_i - \delta \cdot K\right)\Bigg\}.\end{aligned} \tag{10}$$

Take the first partial derivative of x_i in the right part of equation (10), make it equal to zero, and get the following equation:

$$x_i = \frac{\left[\theta_i + \lambda_i \cdot \pi'(K)\right]}{\alpha_i}, \quad i = 1, 2, \ldots, n. \tag{11}$$

Formula (12) can be obtained by substituting formula (11) into formula (10):

$$\rho \cdot \pi(K) = \left[\eta - \delta \cdot \pi'(K)\right] \cdot K + \sum_{i=1}^{n} \frac{\left[\theta_i + \lambda_i \cdot \pi'(K)\right]^2}{2\alpha_i}. \tag{12}$$

According to formula (12), the solution of the HJB equation is a linear function of one variable with K as the independent variable, so

$$\begin{aligned}\pi(K) &= a_1 K + a_0, \\ \pi'(K) &= \frac{d\pi(K)}{dK} = a_1.\end{aligned} \tag{13}$$

Formula (14) can be obtained by substituting formula (13) into formula (12). Comparing formula (14) with formula (13), a_1 and a_0 can be obtained, as shown in the following formula:

$$\rho \cdot \left(a_1 K + a_0\right) = \left[\eta - \delta \cdot \pi'(K)\right] \cdot K + \sum_{i=1}^{n} \frac{\left[\theta_i + \lambda_i \cdot a_1\right]^2}{2\alpha_i}, \tag{14}$$

$$\begin{aligned}a_1 &= \frac{\eta}{\rho + \delta}, \\ a_0 &= \sum_{i=1}^{n} \frac{\left[\theta_i \cdot (\rho + \delta) + \lambda_i \cdot \eta\right]^2}{2\rho \cdot \alpha_i \cdot (\rho + \delta)^2}.\end{aligned} \tag{15}$$

Substituting a_1 into formula (11) can calculate the effort level of each member to obtain the best benefit in any situation. The formula is as follows:

$$x_i = \frac{\theta_i \cdot (\rho + \delta) + \lambda_i \cdot \eta}{\alpha_i \cdot (\rho + \delta)}, \quad i = 1, 2, \ldots, n. \tag{16}$$

Put a_1 and a_0 into formula (13) to obtain the optimal value function of the overall income of the members, as shown in formula (17). At the same time, the optimal value function of individual income can be obtained, as shown in formula (18):

$$\pi(K) = \frac{\eta}{\rho + \delta} K + \sum_{i=1}^{n} \frac{\left[\theta_i \cdot (\rho + \delta) + \lambda_i \cdot \eta\right]^2}{2\rho \cdot \alpha_i \cdot (\rho + \delta)^2}, \tag{17}$$

$$\pi_i(K) = \frac{w_i \cdot \eta}{\rho + \delta} K + w_i \cdot \sum_{i=1}^{n} \frac{\left[\theta_i \cdot (\rho + \delta) + \lambda_i \cdot \eta\right]^2}{2\rho \cdot \alpha_i \cdot (\rho + \delta)^2}. \tag{18}$$

The expression of achievement transformation progress can be obtained by solving equation (3). The formula is as follows:

$$K(t) = \frac{\sum_{i=1}^{n} \lambda_i \cdot x_i}{\delta} + \left(K_0 - \frac{\sum_{i=1}^{n} \lambda_i \cdot x_i}{\delta}\right) e^{-\rho t}. \tag{19}$$

3.2. Benefit-Sharing Model Led by External Companies. The game goal of each unit is to maximize its own interests, but due to their own differences, each member needs to use the equilibrium coefficient w_i of formula (8) to ensure the fairness and justice of the benefit distribution. In this model, the effort and time factors in the transformation of achievements need not be considered, but the bargaining power of members should be considered. At the same time, considering basic hypothesis (5) and the goals of each member, the model can use the Cobb–Douglas function to express the total utility of benefit-sharing among members in the park. After taking the logarithm of it, we construct the benefit-sharing model. Formula (20) is the objective function, and formulas (21) and (22) are constraints:

$$\max \sum_{i=1}^{n} w_i \cdot \ln\left(p_i - p_i'\right), \tag{20}$$

$$\forall p_i > p_i', \tag{21}$$

$$\sum_{i=1}^{n} p_i = P. \tag{22}$$

The decision variable of this model is the income p_i, and the equilibrium coefficient w_i is a constant, which will be described in the next section. To solve the above model, the Lagrangian function needs to be constructed first, as in the following equation:

$$L = \sum_{i=1}^{n} w_i \cdot \ln\left(p_i - p_i'\right) + \mu \cdot \left(P - \sum_{i=1}^{n} p_i\right). \tag{23}$$

Formulas (24) and (25) can be derived from the optimality conditions of convex optimization:

$$\nabla_{p_i} = \frac{w_i}{\left(p_i - p_i'\right)} - \mu = 0, \tag{24}$$

$$\nabla_{\mu} = P - \sum_{i=1}^{n} p_i = 0. \tag{25}$$

Simplify equation (24) to obtain the equation of p_i and μ. Put it into equation (25) to obtain the equation of μ and p_i'. Substitute it into equation (24) to obtain the equation of p_i and P, p_i'. The equation is shown in the following formula:

$$p_i = p_i' + w_i \cdot \left(P - \sum_{i=1}^{n} p_i'\right). \tag{26}$$

According to formula (8), it can be verified that the result of benefit distribution is greater than its own interest negotiation point, that is, formula (26) satisfies the constraint of formula (21). Therefore, formula (26) is the result of the distribution of benefits of each member in the park at the level of w_i.

Besides, according to $w_i \in (0,1)$ and formula (26), the relationship between member income and negotiation points can be further derived, as shown in formula (27). The income distributed by each member in the park is positively correlated with their own negotiation points and negatively correlated with the negotiation points of other members. At the same time, the income distributed by each member in the park is also positively correlated with its own equilibrium coefficient and negatively correlated with the equilibrium coefficients of other members:

$$\begin{aligned} \frac{\partial p_i}{\partial p_i'} &= 1 - w_i > 0, \\ \frac{\partial p_i}{\partial p_j'} &= -w_i < 0. \end{aligned} \tag{27}$$

3.3. Parameter Determination

3.3.1. Equilibrium Coefficient w_i. According to the analysis of important influencing factors in collaborative innovation, w_i is mainly related to the degree of knowledge sharing b_1, investment quota b_2, and risk-taking share b_3. The proportions of the three factors in the equilibrium coefficient (w_{b1}, w_{b2}, w_{b3}) can be determined by the Delphi method, and the equilibrium coefficient of the members is weighted according to the following formula:

$$w = \left(w_{b1}, w_{b2}, w_{b3}\right) \cdot \left(b_1, b_2, b_3\right)^T. \tag{28}$$

The degree of knowledge sharing b_1 reflects the complexity, difficulty, and quantity of the technology provided by members. This index can be determined by the Delphi method or fuzzy evaluation method and should satisfy $b_{1i} \in (0,1), \sum_{i=1}^{n} b_{1i} = 1$.

The investment quota b_2 can measure the contribution of collaborative innovation members. This indicator can be determined by formula (29) according to the actual situation, and q_i is the capital contribution of member i:

$$b_{2i} = \frac{q_i}{\sum_{i=1}^{n} q_i}. \tag{29}$$

Risk-taking share b_3 can measure the R&D uncertainty undertaken by members and reflects the degree of responsibility for collaborative innovation projects. Members with greater risk-bearing should get a higher distribution ratio. This index can be determined by the Delphi or fuzzy evaluation method and should satisfy $b_{3i} \in (0,1), \sum_{i=1}^{n} b_{3i} = 1$.

3.3.2. Benefit Negotiation Point p_i'. According to the analysis of cost factors in collaborative innovation, p_i' is mainly related to invested capital and effort cost. At the same time, because p_i' represents the lowest benefit of the external

Table 1: The parameters of the case.

Parameter	Value
ρ	0.2
δ	0.2
η	0.3
$K(0) = K_0$	2
α	$(0.3, 0.4, 0.5)$
λ	$(0.2, 0.3, 0.4)$
θ	$(0.5, 0.6, 0.7)$
w	$(0.25, 0.35, 0.4)$

enterprise-led benefit-sharing game, p_i' must be greater than or equal to the effort cost in the benefit-sharing model of internal member cooperation. So, p_i' satisfies the following formula:

$$p_i' \geq 0.5 \cdot \alpha_i \cdot x_i^2. \tag{30}$$

4. Case Study

In this paper, the total number of members of collaborative innovation is set as $n = 3$, $i = 1$ refers to a university, $i = 2$ refers to a scientific research institute, and $i = 3$ refers to a power grid enterprise. The time spent by each member on the industrialization of achievements is set as $t = 30$. According to the parameter selection in [29], parameters satisfying the basic assumptions are set, as shown in Table 1. This paper constructs two scenarios of benefit sharing. Scenario 1 is $\pi > P$. At this point, benefit distribution should be carried out according to the benefit-sharing model of internal member cooperation. To clarify the advantages of this model in scenario 1, the benefit-sharing results of the external enterprise-led model in this scenario are also calculated. Scenario 2 is $\pi < P$, and the benefit-sharing model led by the external enterprise should be selected. At the same time, the benefit-sharing results of internal member cooperation are set as a contrast.

In scenario 1, according to the parameters in Table 1, the total income of the internal member cooperation model can be calculated as $\pi = 196$ thousand yuan. According to the conditions listed in III (B), set $P = 170$ thousand yuan. Since $\pi > P$, the internal member cooperation model should be selected. Effort level x_i, technology transformation progress $K(t)$, and benefit distribution π_i can be calculated according to the formulas (16), (19), and (18), where $K(30) = 92.4$. The benefit distribution p_i for choosing the external enterprise-led model in this situation can be calculated by formula (26). The calculation results of the above two methods are shown in Table 2, and the benefit distribution results at each moment are shown in Figure 2.

It can be seen from Table 2 that, in this scenario, the benefits of participating members by choosing the internal member cooperation mode are generally better than the external enterprise-led mode. By choosing the cooperation mode, the interests of universities have increased by 61.31%, research institutes by 21.05%, and power grid enterprises by 1.02%. In Figure 2, the blue line is a curve that changes with time, so this curve is the result of the "internal member cooperation" model that takes time into account. The yellow line does not change over time, so this line is the result of an "external enterprise-led" model that takes time into account. The benefits obtained by the cooperation mode have the trend of diminishing marginal returns. In the initial stage, the profit of the cooperation model is less than that of the external enterprise-led model, but it can be exceeded in the later stage. This phenomenon is more consistent with the actual situation.

In addition, it can be seen from Table 2 that universities have the highest effort level, followed by scientific research institutes, and power grid enterprises have the lowest. However, the benefits of the cooperation model are not sorted according to the effort level, but the power grid enterprises get the most benefits, followed by scientific research institutes, and universities the least. The main reason for this phenomenon is that λ_i, θ_i, and w_i are different among members. The efforts of members with smaller λ_i and θ_i cannot be converted into actual benefits. Members with smaller w_i also account for a smaller share of the income distribution.

In scenario 2, according to the conditions listed in basic assumptions, set $P = 220$ thousand yuan. In this scenario, $\pi < P$, so the members of the park should choose the external enterprise-led model. Similarly, the effort level x_i, technology transformation progress $K(t)$, benefit distribution π_i of each member, and the enterprise-led benefit distribution p_i are shown in Table 3, and the result of the benefit distribution at each moment is shown in Figure 3.

It can be intuitively learned from Table 3 that, in this scenario, the benefits of the enterprise-led model are greater than the cooperative model. Choosing the enterprise-led model has increased the interests of universities by 11.79%, scientific research institutes by 11.59%, and power grid enterprises by 11.68%. In addition, it can be seen from Figure 3 that although the benefits obtained by the cooperation model will be positively correlated over time, it can never exceed the benefits of the enterprise-led model.

In Figure 4, the changes in the benefits of itself and other members are reflected, when a member's negotiation point changes. In this scenario, it is assumed that the negotiation point of the power grid enterprise changes within the interval satisfying assumption (9) in III (B), that is, $p_3' \in [8, 10)$. The result of "external enterprise-led" benefit-sharing (yellow line) will change with the change of the

Table 2: Results of each member in scenario 1 at $t = 30$.

	Effort level x_i (thousand yuan)	Benefits of internal cooperation π_i (thousand yuan)	Benefit negotiation point p_i' (thousand yuan)	Benefit led by external enterprise p_i (thousand yuan)
University	21.6	49.2	30.0	35.0
Scientific research institute	20.6	69.0	50.0	57.0
Power grid enterprise	20.0	78.8	70.0	78.0

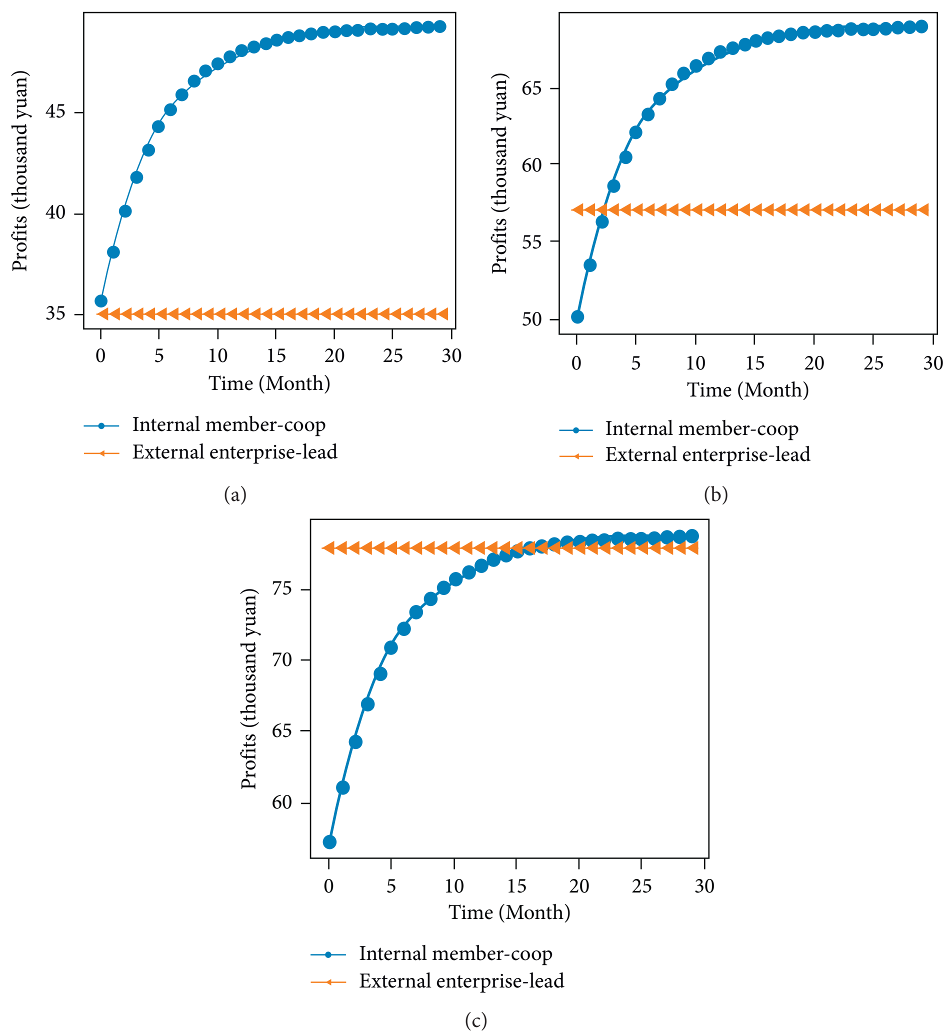


Figure 2: Distribution of profits at each moment in scenario 1. (a) Profits of universities. (b) Profits of research institutes. (c) Profits of grid enterprise.

Table 3: Results of each member in scenario 2 at $t = 30$.

	Effort level x_i (thousand yuan)	Benefits of internal cooperation π_i (thousand yuan)	Benefit negotiation point p_i' (thousand yuan)	Benefit led by external enterprise p_i (thousand yuan)
University	21.6	49.2	50.0	55.0
Scientific research institute	20.6	69.0	70.0	77.0
Power grid enterprise	20.0	78.8	80.0	88.0

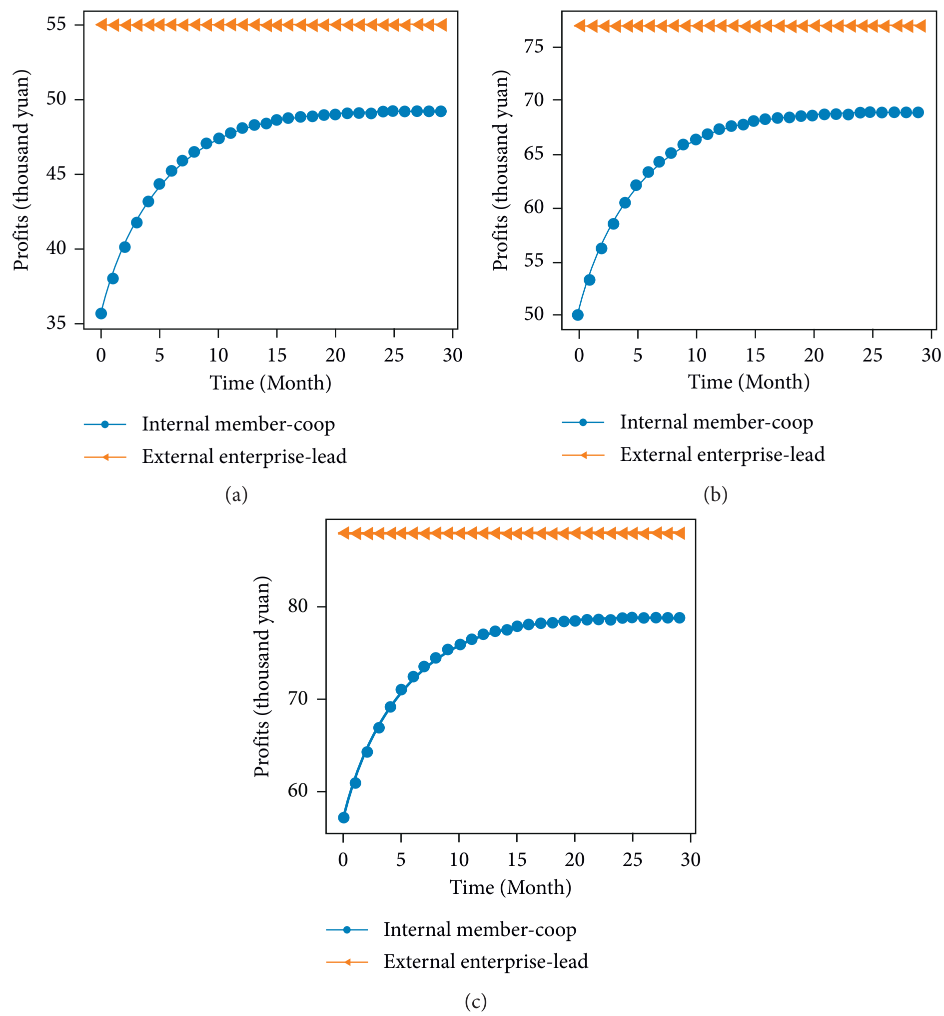


Figure 3: Distribution of profits at each moment in scenario 2. (a) Profits of universities. (b) Profits of research institutes. (c) Profits of grid enterprise.

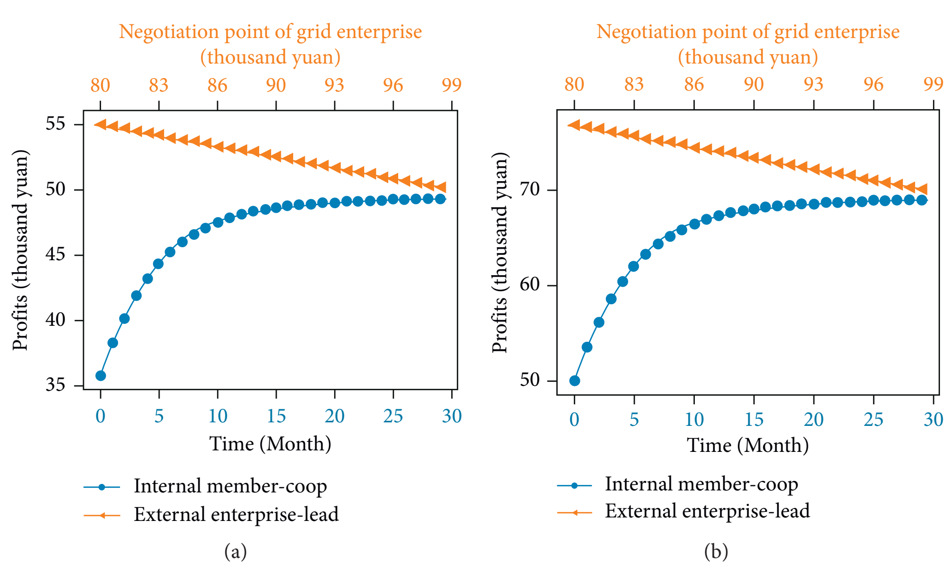
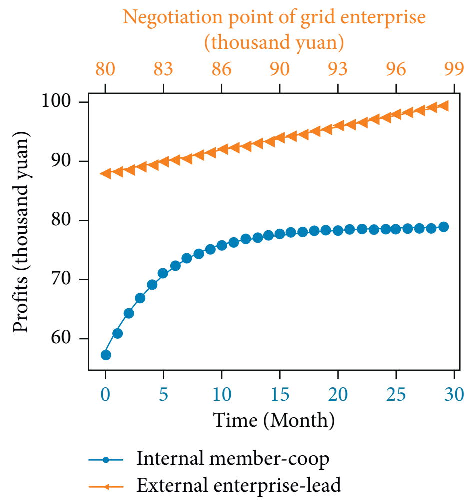


Figure 4: Continued.



(c)

Figure 4: Changes in the profits of other members when the negotiation point of the power grid enterprise changes in scenario 2. (a) Profits of universities. (b) Profits of research institutes. (c) Profits of grid enterprise.

upper abscissa (the benefit negotiation point p_3' of the power grid enterprise). According to Figures 4(a) and 4(b), the income of universities and research institutes decreases with the increase of p_3'. According to Figure 4(c), the income of power grid enterprises increases with the increase of p_3'. Therefore, it can be concluded that the benefits of members are positively related to their own negotiation points and negatively related to other members' negotiation points. This phenomenon confirms the correctness of formula (27). Although the benefits will change with the negotiation points of the members, the benefits of the enterprise-led model will never be lower than the benefits of the internal cooperation model when $\pi < P$. Therefore, the superiority of the enterprise-led model in this scenario is proved.

5. Conclusions

In this paper, the benefit-sharing model is established for different transformation modes. This paper briefly describes the conditions for selecting the transformation mode of achievement, proves that the appropriate transformation mode can maximize the benefits, and probes into the main factors affecting the benefit-sharing of members under different transformation modes. Finally, the following conclusions are formed: (1) this paper synthesizes relevant research and proposes that the benefit-sharing model is determined by the transformation method of results and is affected by its own effort, negotiation, and bargaining power. Taking the multiagent internal member cooperation model and external enterprise-led model as an example, the benefit-sharing model based on cooperative games is constructed. (2) This paper uses a case study to prove that when $\pi > P$, the income of the members of the cooperation model is higher than that of the enterprise-led model; when $\pi < P$, the income of the members of the enterprise-led model is higher than that of the cooperation model. (3) This paper proves that, in the cooperation model, the benefits of members are less affected by the effort level x_i, but more affected by the degree of technological innovation λ_i, the marginal income coefficient θ_i, and the equilibrium coefficient w_i; in the enterprise-led model, the benefits of members are affected by the equilibrium coefficient w_i and the negotiation point p_i'.

The benefit-sharing model based on the cooperative game in this paper can be used to solve practical problems, and its policy and management significance lying in (1) this paper proves that a cooperative game can optimize the overall benefits and individual benefits. Therefore, from the perspective of park operations, the Power Innovation Park should implement collaborative innovation research and development mechanism, promote win-win cooperation between power grids, enterprises, and universities, and accelerate the integrated development of production, education, and research. (2) If the internal cooperation method is chosen, the members participating in R&D should improve their technological innovation capabilities, share the marginal benefits of technology, expand the equilibrium coefficient of benefit distribution, reduce useless efforts, and obtain more benefits from productization of achievements. (3) If the external enterprise-led mode is chosen, members participating in R&D should increase the degree of technology sharing so that they can gain an advantage in determining the negotiation point and obtain more benefits.

There are still some improvements to be made in this paper. In the following research, we will study in-depth the benefit-sharing cooperative game model under time-varying parameters or the benefit-sharing model considering other risk and uncertain factors.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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