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How to Attract Participants in the Ecological Construction of Emerging Technology Applications?

-- Analysis based on Cost Sharing Strategy

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Abstract

Aiming at the problem of participant incentives in the ecological construction of emerging technology applications, this paper takes a single core enterprise and a single participating enterprise as the research objects. By constructing a differential game model, the HJB equation is used to analyze the core enterprise and the participating enterprise in the two cases with or without cost sharing. The respective optimal cooperative R&D effort level, the optimal R&D benefit, the optimal total R&D benefit of both parties, and the Cost-sharing coefficient between the core enterprises and the participating enterprises. The results show that: (1) Cost sharing, as an incentive strategy, can promote the level of cooperative R&D efforts of participating enterprises, the respective cooperative R&D benefits of core enterprises and participating enterprises, and the improvement of the total R&D revenue of both parties; (2) Core enterprises can increase their R&D benefits under the condition of cost sharing. The level of R&D efforts in cooperation with the participating companies, the R&D benefits of their respective cooperation, and the total R&D benefits of both parties are better than the case of no cost sharing. Finally, the results of theoretical derivation are verified by example analysis.

Keywords

Emerging Technology Application Ecology; Participant Incentives; Cost Sharing; Differential Game; Technology Maturity.

1. Introduction

Emerging technology is an emerging or developing technology that is fundamentally innovative and may be commercialized. It will have a significant impact on the future economy or industry, with “high uncertainty,” “creative It has gradually become the focus of competition among major powers.

In recent years, government reports have repeatedly proposed to give better play to the important role of strategic emerging industries, and to cultivate and expand eight strategic emerging industries such as new generation information technology, equipment manufacturing, new materials, and new energy. Implement the industrial cluster innovation capability improvement project, implement the industrial cluster public service capability improvement project, etc. The well-known "Iridium Project" is a global satellite mobile communication system that Motorola of the United States spent nearly 5 billion US dollars and spent 12 years working hard on. It finally ended sadly after 15 months of listing. The fundamental reason is that it did not make accurate market forecasts, was out of market demand, and did not cultivate a stable customer base and establish a complete application ecology. It can be seen that in the

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field of emerging industries, the ecological construction of emerging technologies is particularly important. As one of the strategic emerging industries in my country, the government attaches great importance to the development of the new energy vehicle industry, and has successively issued comprehensive incentive policies, ranging from government subsidies for research and development, double points for production, to financial subsidies for consumption, Tax relief, unlimited licenses and unlimited purchases in the use link, charging discounts on the operation side, etc., cover almost the entire life cycle of new energy vehicles. New energy vehicles have established a raw material (lithium ore, manganese oxide, asphalt, etc.), battery The application ecology of raw materials (ternary, electrolyte, natural graphite, etc.), batteries (lithium batteries) and terminal applications (passenger cars, special vehicles, passenger cars) has accumulated more than 4.5 million new energy vehicles, accounting for more than 50% of the world's total. Therefore, in order to promote the growth of emerging industries and realize the development of emerging technologies, the key is to build an application ecology of emerging technologies. As the main body of the development of emerging technologies, how to promote emerging technologies and build the application ecology of emerging technologies, so that emerging technologies become the core competitiveness of enterprise development, is an important problem that enterprises need to solve urgently.

Regarding the discussion of the application ecology of emerging technologies, Yang Renfei and Tong Yunhuan pointed out that due to changes in the situation, the characteristics of the commercialization process in China are different from those in foreign countries, and further exploration is needed. Li Shiming and others provided a reference for the management of emerging technologies from the aspects of cluster innovation of emerging technologies, edge competition of emerging technologies, and research methods of emerging technologies. By comparing the "Iridium Project" and PHS, the importance of dynamic capabilities of enterprises is expounded from the perspective of dynamic changes of enterprises themselves. Cheng Yue and Yinlu further elaborated that the formation of dynamic capabilities is conducive to the development of emerging technologies through the case analysis of SONY Walkman. evolution. Duan Limin et al. studied the impact of emerging technology applications from the technology market. The above research has explored the influencing factors and paths that affect the characteristics of emerging technologies and the realization of commercialization. However, further research is needed on how emerging technologies can build their own application ecology and attract more participants to overcome their own uncertainties.

In the ecological construction of emerging technology applications, core enterprises attract participating enterprises to enter the ecology, which is actually similar to the principle of manufacturers attracting suppliers. Naini et al. and Ghosh et al. analyzed the incentive problem of profit distribution under symmetric information, and used a game model to solve the Pareto optimality of optimal effort and revenue; Liu Cong et al. believed that innovation cost allocation can effectively motivate suppliers to innovate; Sajadieh et al. used the three-stage production inventory supply chain model to study the production system of multi-supplier, multi-manufacturer and multi-retailer, constructed an incentive coordination model, and gave the optimal incentive strategy; Chen Changbin et al. and Li Juan et al. Aiming at the incentive problem in the process of supply chain cooperation, the information sharing strategy was used to design the information sharing incentive contract mechanism; He Zheng et al. used game theory to analyze the impact of information sharing on information asymmetry, and established a product service integrator-led system. The game model of information sharing incentives for two-level cooperation, and some incentive strategies for information sharing of product service supply chains; Zhao Chenyuan et al. integrated fairness preference into the multiple principal-agent structure, and conducted in-depth research on the incentive mechanism in this structure. analyze. Aiming at the incentive problem of collaborative development of complex products, Chen Hongzhuan et al. believed that the effort level of suppliers is the key to improving the

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production quality and efficiency of complex products, and used the Nsah and Stackelberg game model to design effort level parameters and constructed a master manufacturer. The incentive strategy model for allocating the supplier's effort cost gives two different incentive modes; Peng Hongguang et al. used game theory to analyze the optimal Cost-sharing linear incentive contract problem in the supply chain under the situation of information symmetry and asymmetry, and measured the problem. Incentive levels for suppliers under different sharing factors. Therefore, on the basis of the above research, this paper introduces the differential game method to study the ecological construction of emerging technology applications from a dynamic perspective, and uses the Hamilton-Jacobi-Bellman equation (HJB equation for short) to investigate the two R&D game scenarios respectively. The optimal cooperative R&D effort level of core enterprises and participating enterprises, the optimal R&D income and the optimal total R&D income of both parties, discuss the incentive effect of the cost sharing strategy on the participating enterprises, and hope that the conclusions can provide a point for the ecological construction of emerging technology applications suggestion.

2. Problem Description and Basic Assumptions

2.1. Problem Description

After an emerging technology appears, a small number of enterprises will take the lead in mastering the key parts of the technology, which we call core enterprises. In order to expand the scale, realize the productization of technology, and promote the development of the industrialization of the technology, core enterprises will cooperate with other entities in research and development around their core business, including suppliers, manufacturers, sellers, integrators and other enterprises. These enterprises cooperate with core enterprises, share information and resources, and integrate resources to promote the productization of emerging technologies or obtain final results. We collectively refer to them as participating enterprises. When participating companies cooperate with core companies, they will take into account the high uncertainty of emerging technologies, and there may be a problem of investing a lot of costs and not getting benefits. Considering the asymmetry of information, in the process of enterprises cooperating to build an emerging technology application ecosystem, core enterprises and participating enterprises tend to independently decide their own cooperative R&D efforts. In order to improve the willingness of participating companies to cooperate, core companies may provide Cost-sharing strategies to increase the enthusiasm of participating companies for cooperation and attract more companies to enter the application ecosystem.

2.2. Basic Assumptions

The participating companies studied in this paper are independent of each other. The core companies have more information on emerging technologies and lead the R&D activities of emerging technologies. It is necessary to attract more participating companies to construct the application ecology of emerging technologies; each participating company is independent Engaged in a certain aspect of research and development cooperation activities with core enterprises, so this article considers the situation of one core enterprise and one participating enterprise; while in the emerging technology application ecology, technology research and development products are relatively personalized, and the price and quantity are relatively stable, so this article does not consider The impact of factors such as price and quantity on the entire system, the following assumptions are made:

Assumption 1: Assuming that the cooperative R&D effort level of core enterprises is $S0(t)$, and the R&D cooperation effort level of participating enterprises is $S_{1(t)}$, the cost of R&D cooperation efforts of enterprises can be expressed as:

$$C_{i(t)} = \frac{\alpha_i}{2} S_{i(t)}^2 (i{=}1, 2) \tag{1}$$

Among them, α_0 and α_1 are the cost coefficients of cooperative R&D efforts of core enterprises and participating enterprises, respectively; $C_{0(t)}$ and $C_{1(t)}$ are the degree of cooperative R&D efforts $S_{0(t)}$ and $S_{1(t)}$ of core enterprises and participating enterprises, respectively.) costs.

Assumption 2: Assuming that the technology R&D degree of core enterprises and participating enterprises at time t is $K_{(t)}$, technology R&D is a dynamic process, which is not only affected by the R&D cooperation effort and technology update of core enterprises and participating enterprises, but also by technology maturity degree of influence. Technology maturity (Υ, $0<\Upsilon<1$) refers to the degree of industrialization and practicality of scientific and technological achievements in terms of technical level, technological process, supporting resources, technology life cycle, etc. The more difficult it is to innovate in technology. The cooperative R&D process between core enterprises and participating enterprises is expressed as:

$$\dot{K}_{(t)} = \frac{\lambda_0 S_{0(t)} + \lambda_1 S_{1(t)}}{\gamma} - \delta K_{(t)} \tag{2}$$

In the formula, time t and initial time are respectively expressed as $K_{(t)}$ and K_0, where $K_0=K_{(0)}$, $K_0 \geq 0$; λ_0 and λ_1 represent the R&D capability coefficients of core enterprises and participating enterprises, respectively The influence of the degree of cooperation efforts of enterprises on the degree of technology research and development; δ represents the technology elimination rate, $\delta>0$.

Hypothesis 3: Assume that the total revenue of R&D cooperation between the core enterprise and participating enterprises at time t can be expressed as:

$$\pi_{(t)} = \chi_0 S_{0(t)} + \chi_1 S_{1(t)} + \eta K_{(t)} \tag{3}$$

In the formula, χ_0 and χ_1 are the R&D cooperation effort benefit coefficients of core enterprises and participating companies, respectively, and η ($\eta>0$) is the technology benefit influence coefficient.

Assumption 4: At any time, both the core enterprise and the participating enterprises have the same discount factor ρ ($\rho>0$); the total cooperative effort benefits are only distributed between the two parties, the income distribution coefficient of the core enterprise is β, and the income distribution coefficient of the participating enterprises is $1-\beta$, and the distribution ratio is agreed by both parties; the cooperative effort subsidy provided by the core enterprises to the participating enterprises is σ ($0\leq\sigma\leq1$).

In summary, the objective function of the core enterprise can be obtained as:

$$J_0 = \int_0^{\infty} e^{-\rho t} [\beta\pi_{(t)} - \frac{\alpha_0}{2} S_{0(t)}^2 - \sigma \frac{\alpha_1}{2} S_{1(t)}^2] dt \tag{4}$$

The objective function of the participating enterprises is:

$$J_1 = \int_0^{\infty} e^{-\rho t} [(1-\beta)\pi_{(t)} - (1-\sigma)\frac{\alpha_1}{2} S_{1(t)}^2] dt \tag{5}$$

3. Model Building and Solving

3.1. Construction and Solution of Decision-making Model without Cost Sharing

Under the no-cost sharing Decision-making model, the core enterprise and the participating enterprises are equal partnership, which constitutes a Nash game. Under Nash equilibrium, the

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core firm and participating firms aim to maximize their own profits (the superscript n denotes a decentralized Decision-making case without cost allocation).

At this time, the objective functions of core enterprises and participating enterprises are:

$$J_0^n = \int_0^\infty e^{-\rho t}[\beta(\chi_0 S_{0(t)} + \chi_1 S_{1(t)} + \eta K_{(t)}) - \frac{\alpha_0}{2} S_{0(t)}^2]dt \tag{6}$$

$$J_1^n = \int_0^\infty e^{-\rho t}[(1-\beta)(\chi_0 S_{0(t)} + \chi_1 S_{1(t)} + \eta K_{(t)}) - \frac{\alpha_1}{2} S_{1(t)}^2]dt \tag{7}$$

The optimal control problem of the core enterprise satisfies the following HJB equation

$$\rho V_0^n(K) = \max[\beta(\chi_0 S_0^n + \chi_1 S_1^n + \eta K) - \frac{\alpha_0}{2} {S_0^n}^2 + {V_0^n}'(K)(\frac{\lambda_0 S_0^n + \lambda_1 S_1^n}{\gamma} - \delta K)] \tag{8}$$

Find the first-order partial derivative with respect to S_0^n on the right side of Equation (8) and set it to zero, we can get

$$S_0^n = \frac{\gamma\beta\chi_0 + \lambda_0 {V_0^n}'(K)}{\gamma\alpha_0} \tag{9}$$

In the same way, the optimal problem of participating enterprises can satisfy the following HJB equation

$$\rho V_1^n(K) = \max\left[(1-\beta)(\chi_0 S_0^n + \chi_1 S_1^n + \eta K) - \frac{\alpha_1}{2} {S_1^s}^2 + {V_1^s}'(K)\left(\frac{\lambda_0 S_0^n + \lambda_1 S_1^n}{\gamma} - \delta K\right)\right] \tag{10}$$

Find the first-order partial derivative with respect to S_0^n on the right side of Equation (10) and set it to zero, we can get

$$S_1^n = \frac{(1-\beta)\gamma\chi_1 + \lambda_1 {V_1^n}'(K)}{\gamma\alpha_1} \tag{11}$$

Bring (9), (11) into (8), (10) and simplify to get:

$$\rho V_0^n(K) = \left(\beta\eta - \delta {V_0^n}'\right)K + \frac{(\gamma\beta\chi_0 + \lambda_0 {V_0^n}')^2}{2\gamma^2\alpha_0\alpha_0} + \frac{((1-\beta)\gamma\chi_1 + \lambda_1 {V_1^n}')(\gamma\beta\chi_1 + \lambda_1 {V_0^n}')}{\gamma^2\alpha_1\alpha_1} \tag{12}$$

$$\rho V_1^n(K) = [(1-\beta)\eta - \delta {V_1^n}']K + \frac{(\gamma\beta\chi_0 + \lambda_0 {V_0^n}')(\gamma(1-\beta)\chi_0 + \lambda_0 {V_1^n}')}{\gamma^2\alpha_0} + \frac{((1-\beta)\gamma\chi_1 + \lambda_1 {V_1^n}')^2}{2\gamma^2\alpha_1} \tag{13}$$

According to equations (12) and (13), it can be inferred that the linear optimal value function of K is the solution of the HJB equation. Therefore, let:

$$V_0^n(K) = a_0^n K + a_1^n \tag{14}$$

$$V_1^n(K) = b_0^n K + b_1^n \tag{15}$$

Among them, $a_0^n, a_1^n, b_0^n, b_1^n$ are unknown constants with solution, and ${V_0^n}'(K) = a_0^n$, ${V_1^n}'(K) = b_0^n$; Bring equations (14) and (15) into equations (12) and (13), sort out and compare similar items, and get the constraint equations about $a_0^n, a_1^n, b_0^n, b_1^n$ group, the solution can be obtained:

$$a_0^n = \frac{\beta\eta}{\rho + \delta}$$

$$a_1^n = \frac{\beta^2[\gamma\chi_0(\rho+\delta)+\lambda_0\eta]^2}{2\rho\alpha_0\gamma^2(\rho+\delta)^2} + \frac{\beta(1-\beta)[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]^2}{\rho\alpha_1\gamma^2(\rho+\delta)^2}$$

$$b_0^n = \frac{(1-\beta)\eta}{\rho+\delta}$$

$$b_1^n = \frac{(1-\beta)^2[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]^2}{2\rho\alpha_1\gamma^2(\rho+\delta)^2} + \frac{\beta(1-\beta)[\gamma\chi_0(\rho+\delta)+\lambda_0\eta]^2}{\rho\alpha_0\gamma^2(\rho+\delta)^2}$$

Bring a_0^n, b_0^n into equations (9) and (11) to get the optimal level of cooperation effort between the core enterprise and the participating enterprises as follows:

$$S_0^{n*} = \frac{\gamma\beta\chi_0(\rho+\delta)+\lambda_0\beta\eta}{\gamma\alpha_0(\rho+\delta)} \tag{16}$$

$$S_1^{n^*} = \frac{(1-\beta)[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]}{\gamma\alpha_1(\rho+\delta)} \tag{17}$$

Putting equations (16) and (17) into the state equation, according to the boundary conditions of the state equation, the optimal trajectory of the degree of technology research and development can be obtained as:

$$K^{n*}(\mathrm{t}) = a^n - (a^n - K_0)e^{-\delta t} \tag{18}$$

$$\mathrm{a^n} = \lambda_0 S_0^{n^*}/\gamma\delta + \lambda_1 S_1^{n^*}/\gamma\delta$$

Substituting $a_0^n, a_1^n, b_0^n, b_1^n$ into equations (14) and (15), the optimal R&D benefit function of the core enterprises and participating enterprises can be obtained as follows:

$$V_0^{n^*}(\mathrm{K}) = \frac{\beta\eta}{\rho+\delta}K + \frac{\beta^2[\gamma\chi_0(\rho+\delta)+\lambda_0\eta]^2}{2\rho\alpha_0\gamma^2(\rho+\delta)^2} + \frac{\beta(1-\beta)[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]^2}{\rho\alpha_1\gamma^2(\rho+\delta)^2} \tag{19}$$

$$V_1^{n^*}(\mathrm{K}) = \frac{(1-\beta)\eta}{\rho+\delta}K + \frac{(1-\beta)^2[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]^2}{2\rho\alpha_1\gamma^2(\rho+\delta)^2} + \frac{\beta(1-\beta)[\gamma\chi_0(\rho+\delta)+\lambda_0\eta]^2}{\rho\alpha_0\gamma^2(\rho+\delta)^2} \tag{20}$$

At this time, the optimal R&D total revenue function of core enterprises and participating enterprises is:

$$V^{n^*}(\mathrm{K}) = \frac{\eta}{\rho+\delta}K + \frac{(2\beta-\beta^2)[\gamma\chi_0(\rho+\delta)+\lambda_0\eta]^2}{2\rho\alpha_0\gamma^2(\rho+\delta)^2} + \frac{(1-\beta^2)[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]^2}{2\rho\alpha_1\gamma^2(\rho+\delta)^2} \tag{21}$$

3.2. Construction and Solution of Cost-sharing Decision-making Model

Compared with the Decision-making model without cost sharing, in the Decision-making model with cost sharing, the core enterprises and participating enterprises constitute the Stackelberg game. The specific game sequence is as follows: the core enterprise first determines the degree of cooperation effort and the cost sharing ratio of the cooperative effort to the participating enterprises, and then the participating enterprises make the optimal strategy through the decision information of the core enterprise (the superscript s represents the decentralized Decision-making of cost allocation. situation). In the Decision-making model with cost sharing, the objective functions of core enterprises and participating enterprises are:

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$$\mathrm{J}_0^s=\int_0^{\infty} e^{-\rho t}[\beta(\chi_0 S_0+\chi_1 S_1+\eta K_{(t)})-\frac{\alpha_0}{2}S_0^2-\frac{\sigma\alpha_1}{2}S_1^2]dt \tag{22}$$

$$\mathrm{J}_1^s=\int_0^{\infty} e^{-\rho t}[(1-\beta)(\chi_0 S_0+\chi_1 S_{11}+\eta K_{(t)})-(1-\sigma)\frac{\alpha_1}{2}S_1^2]dt \tag{23}$$

According to the reverse induction method, the optimal control problem of participating enterprises satisfies the following HJB equation:

$$\rho V_1^s(\mathrm{K})=\max[(1-\beta)(\chi_0 S_0+\chi_1 S_1+\eta\mathrm{K})-(1-\sigma)\frac{\alpha_1}{2}{S_1^s}^2+{V_1^s}'(\frac{\lambda_0 S_0^s+\lambda_1 S_1^s}{\gamma}-\delta\mathrm{K})] \tag{24}$$

Find the first-order partial derivative with respect to S_{11}^s on the right side of Equation (24) and set it to zero, we can get:

$$S_1^s=\frac{(1-\beta)\chi_1\gamma+\lambda_1 {V_1^s}'}{(1-\sigma)\gamma\alpha_1} \tag{25}$$

Similarly, it can be seen that the optimal control problem of core enterprises satisfies the following HJB equation:

$$\rho V_{00}^s(\mathrm{K})=\max[\beta(\chi_0 S_0^s+\chi_1 S_1^s+\eta\mathrm{K})-\frac{\alpha_0}{2}{S_0^s}^2-\frac{\sigma\alpha_1}{2}{S_1^s}^2+{V_0^s}'(\mathrm{K})(\frac{\lambda_0 S_0^s+\lambda_1 S_1^s}{\gamma}-\delta\mathrm{K})] \tag{26}$$

Substitute equation (25) into equation (26) to find the first-order partial derivatives with respect to S_0^s and σ and set them to zero, we can get:

$$S_0^s=\frac{\beta\chi_0\gamma+\lambda_0 {V_0^s}'}{\gamma\alpha_0} \tag{27}$$

$$\sigma_1=\frac{[\gamma\chi_1(1-3\beta)+\lambda_1(-2{V_0^s}'(\mathrm{K})+{V_1^s}'(\mathrm{K}))](-1)}{\gamma\chi_1(\beta+1)+\lambda_1(2{V_0^s}'(\mathrm{K})+{V_1^s}'(\mathrm{K}))} \tag{28}$$

Substitute equations (25), (27), and (28) into equations (24) and (26) to simplify:

$$\rho V_0^s(\mathrm{K})=\left(\beta\eta-\delta {V_0^s}'\right)\mathrm{K}+\frac{(\gamma\beta\chi_0+\lambda_0 {V_0^s}')^2}{2\alpha_0\gamma^2}+\frac{[\gamma\chi_1(\beta+1)+\lambda_1(2{V_0^s}'+{V_1^s}')]^2}{8\alpha_1\gamma^2} \tag{29}$$

$$\rho V_1^s(\mathrm{K})=\left((1-\beta)\eta-\delta {V_1^s}'\right)\mathrm{K}+\frac{[\gamma(1-\beta)\chi_0+\lambda_0 {V_1^s}'](\gamma\beta\chi_0+\lambda_0 {V_0^s}')}{\alpha_0\gamma^2}+\frac{\left[\gamma\chi_1(\beta+1)+\lambda_1\left(2{V_0^s}'+{V_1^s}'\right)\right][\gamma(1-\beta)\chi_1+\lambda_1 {V_1^s}']}{4\alpha_1\Upsilon^2} \tag{30}$$

According to equations (29) and (30), it can be inferred that the linear optimal value function of K is the solution of the HJB equation. Therefore, set:

$$V_0^s(\mathrm{K})=\mathrm{a}_0^s K+a_1^s \tag{31}$$

$$V_1^s(\mathrm{K})=\mathrm{b}_0^s K+b_1^s \tag{32}$$

Among them, $a_0^s, a_1^s, b_0^s, b_{11}^s$ are unknown constants with solution, and $V_0^{s\prime}(K) = a_0^s, V_1^{s\prime}(K) = b_0^s$; Bring equations (31) and (32) into equations (29) and (30), sort out and compare similar items, and get the constraint equations about $a_0^s, a_1^s, b_0^s, b_1^s$ group, the solution can be obtained:

$$a_0^s = \frac{\beta\eta}{\rho+\delta}$$

$$a_1^s = \frac{\beta^2[\gamma\chi_0(\rho+\delta)\lambda_0\eta]^2}{2\rho\alpha_0\gamma^2(\rho+\delta)^2} + \frac{(1+\beta)^2[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]^2}{8\rho\alpha_1\gamma^2(\rho+\delta)^2}$$

$$b_0^s = \frac{(1-\beta)\eta}{\rho+\delta}$$

$$b_1^s = \frac{(1-\beta)(1+\beta)[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]^2}{4\rho\alpha_1\gamma^2(\rho+\delta)^2} + \frac{\beta(1-\beta)[\gamma\chi_0(\rho+\delta)+\lambda_0\eta]^2}{\rho\alpha_0\gamma^2(\rho+\delta)^2}$$

Substitute a_0^s, b_0^s into equations (25), (27), and (28) to obtain the optimal level of cooperation effort and the subsidy coefficient of optimal cooperation effort input for the core enterprises and participating enterprises:

$$S_0^{s^*} = \frac{\gamma\beta\chi_0(\rho+\delta)+\lambda_0\beta\eta}{\gamma\alpha_0(\rho+\delta)} \tag{33}$$

$$S_1^{s^*} = \frac{(1+\beta)[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]}{2\gamma\alpha_1(\rho+\delta)} \tag{34}$$

$$\sigma_1^* = \begin{cases} \frac{(3\beta-1)}{(\beta+1)}, & \frac{1}{3} < \beta \le 1 \\ 0, & 0 < \beta \le \frac{1}{3} \end{cases} \tag{35}$$

Among them, since 0<σ≤1, 0<β≤1 can be obtained as 1/3<β≤1.

Substitute equations (33) and (34) into the state equation, and according to the boundary conditions of the state equation, the optimal trajectory function for the degree of technology research and development can be obtained as follows:

$$K^{s*} = a^s - (a^s - K_0)e^{-\delta t} \tag{36}$$

Among them, $a^s = \lambda_0 S_0^{s^*}/\gamma\delta + \lambda_1 S_1^{s^*}/\gamma\delta$.

Substitute $a_0^s, a_1^s, b_0^s, b_1^s$ into equations (31) and (32) to obtain the optimal cooperative effort return function of the core enterprise and participating enterprises as follows:

$$V_0^{s^*}(K) = \frac{\beta\eta}{\rho+\delta}K + \frac{\beta^2[\gamma\chi_0(\rho+\delta)+\lambda_0\eta]^2}{2\rho\alpha_0\gamma^2(\rho+\delta)^2} + \frac{(1+\beta)^2[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]^2}{8\rho\alpha_1\gamma^2(\rho+\delta)^2} \tag{37}$$

$$V_1^{s^*}(K) = \frac{(1-\beta)\eta}{\rho+\delta}K + \frac{\beta(1-\beta)[\gamma\chi_0(\rho+\delta)+\lambda_0\eta]^2}{\rho\alpha_0\gamma^2(\rho+\delta)^2} + \frac{(1-\beta)(1+\beta)[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]^2}{4\rho\alpha_1\gamma^2(\rho+\delta)^2} \tag{38}$$

At this time, the optimal R&D total revenue function of core enterprises and participating enterprises is:

$$V^{s^*}(\mathrm{K}) = \frac{\eta}{\rho+\delta}K + \frac{(2\beta-\beta^2)[\gamma\chi_0(\rho+\delta)+\lambda_0\eta]^2}{2\rho\alpha_0\gamma^2(\rho+\delta)^2} + \frac{(3+2\beta-\beta^2)[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]^2}{8\rho\alpha_1\gamma^2(\rho+\delta)^2} \tag{39}$$

3.3. Problem Description

In the above Decision-making model, comparing the optimal cooperative R&D effort level, technology R&D degree and optimal R&D benefits of core enterprises and participating enterprises, we can obtain:

Proposition 1 In the decision model with or without cost sharing, the level of cooperative R&D efforts of core enterprises remains unchanged, and is positively correlated with their own R&D capabilities and revenue impact coefficients. High; it is negatively correlated with technology maturity and technology elimination rate. The higher the technology maturity and the higher technology elimination rate, the more difficult it is for core enterprises to innovate, and the lower the marginal benefit obtained, and the level of their cooperative R&D efforts. lower.

Proof: Comparing the level of cooperative R&D efforts of core enterprises with or without cost allocation, $\mathrm{S}_0^{s^*} - \mathrm{S}_0^{n^*} = 0$, so $\mathrm{S}_0^{s^*} = \mathrm{S}_0^{n^*}$.

According to the optimal cooperative R&D effort level of core enterprises (16) and (33), it can be seen that the cooperative R&D effort level of core enterprises has a positive correlation with their own R&D capabilities and income impact coefficient, and a negative correlation with technology maturity and technology elimination rate, the certificate is completed.

Proposition 2. The cost sharing coefficient of the core enterprises to the participating enterprises is positively correlated with the income distribution coefficient in the interval (1/3, 1), while in the interval (0, 1/3), the core enterprises will not provide cooperative effort cost sharing. When the income distribution coefficient is greater than 1/3, the level of cooperative R&D efforts of participating companies will be higher than that without cost sharing, and the level of technology research and development will also be higher than that without cost sharing, and vice versa.

Proof: Comparing the cooperative R&D efforts of participating companies before and after the introduction of cost allocation, we can obtain$\mathrm{S}_1^{s^*} - \mathrm{S}_1^{n^*} = \frac{\gamma\chi_1(\rho+\delta)+\lambda_1\eta}{\gamma\alpha_1(\rho+\delta)(1-\Phi_1)}\frac{3-\beta}{2}$. When $\beta>1/3$, $\mathrm{S}_1^{s^*} > \mathrm{S}_1^{n^*}$; when $\beta\le1/3$, $\mathrm{S}_1^{n^*} \ge \mathrm{S}_1^{s^*}$. Similarly, when $\beta>1/3$, $K^{s*} > K^{n*}$; when $\beta\le1/3$, $\mathrm{S}_1^{n^*} \ge \mathrm{S}_1^{s^*}$, $\mathrm{K}^{n*} \ge \mathrm{K}^{s*}$, the certificate is completed.

Proposition 3 Only when the income distribution coefficient is greater than 1/3, the optimal R&D income of the core enterprises, the optimal R&D income of participating enterprises and their total optimal R&D income will be greater than the case of no cost sharing, realizing the realization of the participation of enterprises and the core enterprises. Corporate Pareto Improvements.

Proof: Comparing the optimal R&D profits of participating companies before and after the introduction of cost allocation, we can see that $V_1^{s^*} - V_1^{n^*} = \frac{[\gamma\chi_1(\rho+\delta)+\lambda_1\eta]^2}{2\rho\alpha_1\gamma^2(\rho+\delta)^2}\frac{-3\beta^2+4\beta-1}{4}$, when $\beta>1/3$, $V_1^{s^*} - V_1^{n^*} > 0$ Therefore, when $\beta>1/3$, $V_1^{s^*} > V_1^{n^*}$. Similarly, when $\beta>1/3$, $V_0^{s^*} > V_0^{n^*}$, $V^{s^*} > V^{n^*}$, the proof is completed.

From the above propositions, it can be seen that the feedback equilibrium strategy of the decision model with or without cost sharing is independent of time, that is, the optimal strategy does not change with the change of time, which brings feasibility to the practical operation of the enterprise, indicating that the decision is in the enterprise. The construction of emerging technology application ecology is highly maneuverable and has certain management practical significance. In the case of decentralized Decision-making with cost sharing, only when $\beta>1/3$, the core enterprise will share the cost of its cooperative R&D efforts for the participating enterprises, and when $\beta\le1/3$, the core enterprise will not provide for the participating

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enterprises. Share the cost of collaborative R&D efforts. Therefore, in order to motivate participating enterprises to join the emerging technology application ecology, when considering the distribution of income among enterprises, it is only valuable when $\beta>1/3$. After cost allocation is provided, when $\beta>1/3$, except that the optimal cooperative R&D effort level of the core enterprise is the same as that of the decentralized Decision-making without cost allocation, the optimal cooperative effort level, technology research and development degree of participating enterprises and the profit of the company has been improved. Although it has not reached the level of centralized Decision-making, Pareto improvement of participating companies and core companies has been achieved. Therefore, under certain conditions, cost sharing has good management practice significance. In order to attract and motivate more companies to jointly build an emerging technology application ecosystem, under certain conditions, core companies can provide cost sharing to maximize value.

4. Case Analysis

This paper uses MATLAB to analyze the decision model with or without cost sharing. The relevant parameter settings are: $\alpha_0=0.3$, $\alpha_1=0.4$, $\lambda_0=0.3$, $\lambda_1=0.2$, $\chi_0=0.6$, $\chi_1=0.5$, $\beta=0.4$, $\eta=0.3$, $\delta=0.2$, $\gamma=0.5$, $K_0=2$, $\rho=0.9$, $t=1$. Table 1 shows the equilibrium results of the game with and without cost sharing.

Table 1. Equilibrium results of the game with or without cost sharing

Equilibrium result	S0	S1	K	σ	V0	V1	V
Decision without cost sharing	1.018	0.914	2.522	—	0.695	1.118	1.813
Decisions with cost sharing	1.018	1.066	2.578	0.143	0.706	1.158	1.864

It can be seen from Table 1 that the magnitude relationship between the equilibrium outcomes under the decision with or without cost sharing is consistent with Proposition 1, Proposition 2, and Proposition 3. The equilibrium results under Decision-making with Cost-sharing are higher than those under Decision-making without Cost-sharing. Specifically, compared with the decision without cost sharing, under the decision with cost sharing, the cooperative R&D efforts of participating companies increased by 16.6%, and the level of technology R&D, the R&D benefits of core companies, the R&D benefits of participating companies, and the total benefits were all increased by 16.6%. has been improved. It shows that the core enterprises have a positive impact on the cost sharing strategy of the participating enterprises, which can effectively improve the cooperative R&D efforts of the participating enterprises.

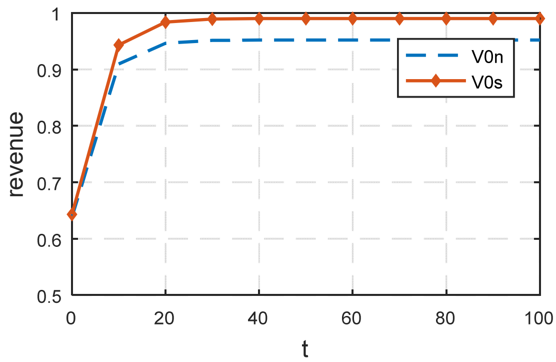

Fig 1. Comparison of R&D benefits of core enterprises with and without cost sharing

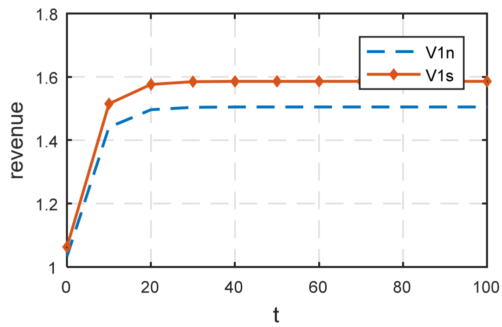

Fig 2. Comparison of R&D benefits of participating companies with and without cost sharing

According to Figures 1 and 2, it can be seen that the R&D benefits of core companies and participating companies are positively correlated with time, and the change in the early stage is greater than that in the later stage.

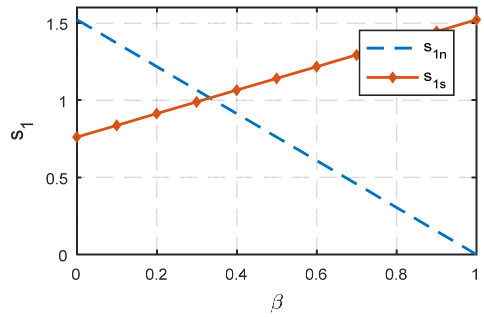

Fig 3. Influence of parameter β on S_1

From Figure 3, we can see that the income distribution coefficient β is negatively correlated with the cooperative R&D effort level of participating companies under the Decision-making model without cost sharing, while it is positively correlated under the Decision-making model with cost sharing. I want to pay at /3. At this time, with the increase of the income distribution coefficient, the greater the proportion of the cost of R&D efforts shared by the core enterprises, the higher the level of cooperative R&D efforts of the participating enterprises. In the absence of a cost sharing strategy, the participating enterprises the level of cooperative R&D efforts will decrease with the increase of the income distribution coefficient.

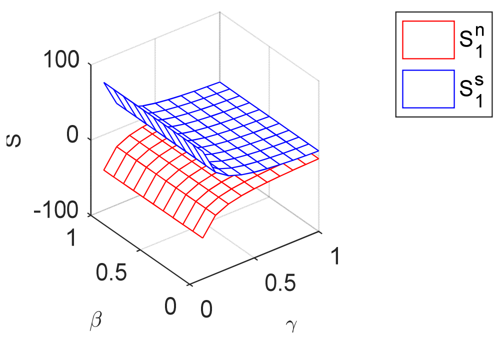

Fig 4. Changes of S_1 with β and γ

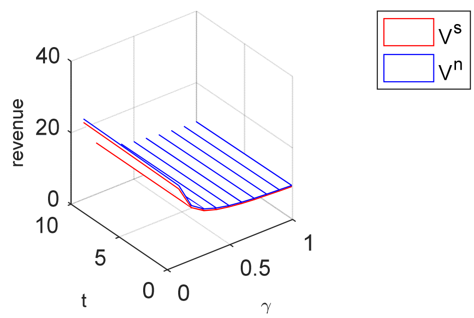

Fig 5. V as a function of t and γ

It can be seen from Figure 4 that when the core enterprises share the cost of cooperative R&D with the participating enterprises, the level of cooperative R&D effort of the participating enterprises is much higher than that without cost sharing. With the increase of technology maturity (Figure 5), the smaller the benefit is, because it is more difficult for enterprises to carry out R&D innovation on this basis, and the relative R&D benefit will be smaller.

5. Summary

In this paper, the method of differential game is introduced to study the cost sharing strategy in the ecological construction of emerging technology applications from a dynamic perspective, and the HJB equation is used to investigate the optimal cooperative R&D effort level and optimal R&D of core enterprises and participating enterprises with or without cost sharing strategy. Revenue, the optimal total R&D revenue of both parties, and the cost sharing coefficient of core enterprises. By comparing the results of the game with and without cost sharing strategy, the following conclusions are drawn: (1) The cost sharing provided by core enterprises, as an incentive strategy, can promote the level of cooperative R&D efforts of participating enterprises, the respective R&D benefits of both parties, and the total R&D benefits of both parties. (2) When the core enterprises share the cost with the participating enterprises, there is a threshold value of the income distribution coefficient, which can realize the Pareto improvement of the individual income of both parties. Finally, the results of the theoretical derivation are verified by numerical example analysis.

The follow-up research in this paper can be expanded in the following aspects. On the one hand, we can consider the influence mechanism of the government on the ecological construction of emerging technology applications, and on the other hand, we can consider the use of utility theory to divide the income increment under the cooperative game.

References

[1] NESTLE V, TAUBE F, HEIDENREICH S, et al. Establishing open innovation culture in cluster initiatives: the role of trust and information asymmetry [J]. Technological forecasting and social change, 2018, 146 (6): 563-572.

[2] Justin Tan, Liang Wang, Hongjuan Zhang, Wan Li, Disruptive innovation and technology ecosystem: The evolution of the intercohesive public–private collaboration network in Chinese telecommunication industry, Journal of Engineering and Technology Management, 2020,101573.

[3] Adner R. Ecosystem as structure: An actionable construct for strategy[J]. Journal of Management, 2017. 43(1):39-58.

[4] Kapoor R, Agarwal S. Sustaining superior performance in business ecosystems: Evidence from application software developers in the iOS and Android smartphone ecosystems[J]. Organization Science, 2017. 28(3):531-551.

[5] Song Yan. Dynamic Evaluation of Emerging Technologies and Success of PHS[J]. Journal of Management, 2005(03):337-339.

[6] Yin Lu, Wang Min, Xiao Yangao, Shi Zhongguo. Some New Ideas of Emerging Technology Management [J]. Journal of Management, 2005(03):277-280+300.

[7] Cheng Yue, Yin Lu. Emerging Technology Evolution Model and Case Study Based on Enterprise Dynamic Capability[J]. Journal of Management, 2010,7(01):43-49.

[8] Yang Li, Wang Yanni, Song Chenchen. Research on the Incentive Mechanism of Logistics Service Supply Chain Based on Ability Cooperation [J]. Keyuan Today, 2019(7):76-80.

[9] Tang Wen, Wang Weibin. Current Situation of Innovation Ecosystem Construction of Tech-based Small and Medium-sized Enterprises--Based on the Investigation and Analysis of 200 Enterprises [J]. Research on Technology Economy and Management, 2021(02):34-39.

[10] Yang Chunbaixue, Cao Xing, Gao Yuan. Evolution and characteristics analysis of emerging technology cooperation innovation network[J]. Research Management,2020,41(7):20-32.