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Research Article

Incentive Mechanism of R&D Firms' Collaborative Innovation Based on Organisational Ambidexterity

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From the perspective of organizational ambidexterity, we consider the choice of innovation strategy among R&D firms. By building on contractual arrangements and employing a dynamic game model, we focus on the incentive mechanism of R&D Firms' collaborative innovation and analyze incentive contracts of benefits distribution and cost-sharing when two firms conduct market-driven innovation (exploitative innovation) strategy and technological research-driven innovation (exploratory innovation) strategy respectively, and collaborate for innovation with each other. We also discuss the influence of exploratory and exploitative innovation effects on decision-making of R&D firms regarding whether to choose collaborative innovation under different incentive contracts. The results show that the effects of exploratory innovation acts as the intrinsic motivation of collaborative innovation while exploratory innovation could be improved to some degree by exploitative innovation. In addition, both investment levels of exploratory and exploitative innovation would decrease (increase) when innovation cost (innovative efficiency) increases. Moreover, compared with a benefit-distribution contract, cost-sharing contracts would not only lead exploitative innovation to realize optimal revenue, but also provide incentives for exploratory innovation more effectively.

1. Introduction

Technological innovation plays an important role in regional economics [1]; accordingly, cooperation between R&D institutions is becoming increasingly important in the current innovation-driven era [2], to the extent that even competitors can become partners to achieve technical and market aims [3]. The overall innovation process includes both R&D firms' new technology and its successful commercialisation [4]. However, inefficient cooperation has always critically affected the transformation of technological achievements into marketable products [2]. Collaborative innovation should be considered a way to improve innovational efficiency and enable this transformation of R&D results [5], bearing in mind that collaborative innovation efficiency among R&D firms is influenced by collaborative strategies [6].

For a long time, most scholars in the innovation field have focused on the absorptive capacity of innovation [7], technological interdependence [8–10], government subsidies [11], and industry differences [12]. There is a lack of research on innovation strategies and collaborative innovation among R&D firms from the perspective of complementarity and resource dependence based on the concept of firm competence. Regardless of the form of collaborative innovation, problems involving contractual arrangements will arise among partners [13], and different ways of allocation produce different optimal benefits under different conditions. The setting of contract parameters can also differ under different benefit-distribution conditions [14]. A firm's level of risk aversion will also influence the benefit-distribution contract and the firm's cost investment decision [15]. These issues raise the question of what form of cooperation different companies should choose in a cooperative innovation network in order to improve the efficiency of cooperative innovation. Some scholars proposed an incentive model for cooperative innovation networks based on the perspective of commissioned agency [16]. However, firms and service providers must have highly complementary knowledge to effectively promote service provision [17].

Ambidextrous innovation has become an effective way to improve organisational competitiveness, and how to achieve this type of innovation has emerged as a topic of much interest in organisational theory [18]. Ambidextrous innovation refers to a firm's rational use of trade-off of exploratory and exploitative innovation to enhance its ability to innovate and increase the flexibility of R&D [19], thereby ultimately improving innovation performance [20]. In a technology market environment, information asymmetry between exploratory innovation and exploitative innovation is substantial [21], creating a situation where exploitative innovation firms generally face a moral hazard from technology development companies [4]. In addition, technology firms devoted to exploratory innovation usually bear full product costs while exploitative innovation firms directly enjoy those R&D achievements, which results in insufficient innovation power for technology companies [22]. Therefore, it is important to consider more effective ways to redistribute innovation earnings and share costs to encourage exploratory and exploitative enterprise collaborative innovation, thereby improving collaboration efficiency. However, few studies have currently examined the different innovation strategy choices and interactional incentive mechanisms of multiple R&D companies in the collaborative innovation process. Based on the study above, this paper attempts to analyse the strategic choice of collaborative innovation by R&D firms from the perspective of organisational ambidexterity and to construct an innovation decision-making model of R&D firms based on the incentive contracts of profit distribution and cost sharing. The incentive mechanisms of exploitative innovation and exploratory innovation under different contractual arrangements are compared and discussed to improve the collaborative innovation efficiency of R&D firms.

2. Dynamic Game Model

2.1. Model Description. First, we consider collaborative R&D firms A and B in a collaborative innovation network wherein firm A is an exploratory innovation-oriented firm, and firm B is an exploitative innovation-oriented firm. Assume that under these different innovation orientations, the effect of these R&D firms' investment level on market demand will also be different. Firms A and B will utilise a collaboration contract around technology and markets. Firm A is devoted to inventing new technology, and firm B specialises in exploring new markets. Then, a dynamic sequential game model is built to analyse the innovative decision-making and incentive mechanisms under different contractual arrangements.

Figure 1 illustrates the decision-making sequence of R&D firms. Firm B implements an exploitative innovation strategy, seeking to supply and transform the technology provided by A, and A invests in exploration innovation under certain contractual arrangements and set technology transfer prices. Based on the firm A' R&D results, B provides exploitative innovation inputs such as product pricing, publicity, and expanding channels to improve the product market demand and sell the products to consumers.

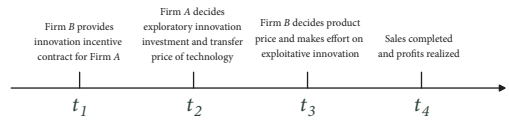

Figure 1: Decision-making sequence.

2.2. Assumptions. (1) Market demand assumption. Assume that different strategy-oriented firms A and B, which are devoted to exploratory innovation and exploitative innovation, respectively, collaborate around intermediate technology products; namely, B sells every product that A requires to provide one unit of technology as an intermediate product. We assume that the internal transfer price of intermediate technology products is ω, and the sales price of the product is p.

(2)Innovation input and cost function. Firms A and B share the cost of innovation according to their collaborative innovation contract. It is assumed that investing in technological innovation will improve product quality and ultimately increase market demand, but it will not increase the marginal production cost. An empirical study has shown that R&D activities are not exactly economics of scale; R&D investment returns decrease gradually as R&D spending increases [23]; accordingly, the cost function of innovation is a strictly convex function. Assume that B's investment level is e, and A's investment level is θ; then firm A's and firm B's innovation costs are

$$IC_A = \eta_A \theta^2 \tag{1}$$

$$IC_B = \eta_B e^2 \tag{2}$$

Where η_A and η_B represent exploratory innovation cost coefficients, θ represents A's exploratory innovation input level, and e represents B's exploitative innovation input level.

(3)Influence of ambidextrous innovation investment. We simplify treatment of R&D costs and effects on product demand function in [24]. Assuming that market demand is not only affected by prices, but also affected by the level of investment from A and B, the market demand function is

$$D = a - bp + \alpha\theta + \beta e \tag{3}$$

where a represents market capacity, b represents the sensitivity of the selling price, θ represents A's exploratory innovation level, which directly determines products' level of technological content, α demonstrates A's exploratory innovation effect, which measures the market's preference regarding product technology level and it can increase demand by $\alpha\theta$, e denotes B's exploitative innovation level, and β denotes B's exploitative innovation effect, namely, the degree of impact on market demand, and it can increase demand by βe.

3. Incentive Contracts

3.1. Benefit-Distribution Contract. An ambidextrous innovation strategy leads to collaborative innovation between

parties engaged in exploration and exploitation. Both parties require joint investment in innovation. B develops products based on A's technological achievements and develops markets for these products, including deciding upon the innovative level and product prices. According to the decision-making sequence, A decides to explore the level of innovation inputs and price of the technical results. The profit-maximisation functions of A and B, respectively, are

$$\max_{\omega,\theta} \pi_A = \omega q - IC_A = \omega (a - bp + \alpha\theta + \beta e) - \eta_A \theta^2 \quad (4)$$

$$\begin{aligned} \max_{p,e} \pi_B &= (p - \omega) q - IC_B \\ &= (p - \omega)(a - bp + \alpha\theta + \beta e) - \eta_B e^2 \end{aligned} \quad (5)$$

Using backward induction to maximise the profit function and solving for the first-order equilibrium conditions of p and e yield

$$\begin{aligned} p^* &= \frac{2(a + \alpha\theta)\eta_B + (2b\eta_B - \beta^2)\omega}{4b\eta_B - \beta^2} \\ e^* &= \frac{\beta(a + \alpha\theta - b\omega)}{4b\eta_B - \beta^2} \end{aligned} \quad (6)$$

By maximising A's profit function and substituting B's first-order equilibrium condition, an equilibrium solution for the exploratory innovation level and internal transfer price for collaborative innovation is obtained as follows:

$$\begin{aligned} \theta^w &= \frac{a\alpha\eta_B}{2\eta_A(4b\eta_B - \beta^2) - \alpha^2\eta_B} \\ \omega^w &= \frac{a\eta_A(4b\eta_B - \beta^2)}{b(2\eta_A(4b\eta_B - \beta^2) - \alpha^2\eta_B)}, \end{aligned} \quad (7)$$

$$\begin{aligned} p^w &= \frac{6ab\eta_A\eta_B - a\eta_A\beta^2}{b(2\eta_A(4b\eta_B - \beta^2) - \alpha^2\eta_B)} \\ e^w &= \frac{a\beta\eta_A}{2\eta_A(4b\eta_B - \beta^2) - \alpha^2\eta_B} \end{aligned} \quad (8)$$

The profits of A and B are

$$\begin{aligned} {\pi_A}^w &= \omega(a - bp + \alpha\theta + \beta e) - \eta_A\theta^2 \\ &= \frac{\eta_A\eta_B a^2}{2\eta_A(4b\eta_B - \beta^2) - \alpha^2\eta_B} \end{aligned} \quad (9)$$

$$\begin{aligned} {\pi_B}^w &= (p - \omega)(a - bp + \alpha\theta + \beta e) - \eta_B e^2 \\ &= \frac{4a^2 b\eta_A^2\eta_B^2 - a^2\beta^2\eta_A^2\eta_B}{(2\eta_A(4b\eta_B - \beta^2) - \alpha^2\eta_B)^2} \end{aligned} \quad (10)$$

3.2. Cost-Sharing Contract. Due to firm A's own funding and other pressures, the uncertainty risks it faces will limit its exploratory innovation investment. Meanwhile, B carries out exploitative innovation, which will increase market demand, thereby increasing the profits from collaborative innovation, which earns A more profits. Therefore, A hopes that the market can share R&D tasks or costs to reduce the risk of exploratory innovation, while firm B will engage in R&D of original technologies in order to update products and gain higher market demand.

In order to further analyse the synergistic mechanism arising from ambidexterity in collaborative innovation between exploratory innovation and exploitative innovation, the cost-sharing contract and benefit-distribution contract are introduced. Assume that A and B desire to engage in collaborative innovation. They therefore negotiate to contract an R&D cost-sharing agreement wherein B shares the technology R&D cost of λ, and the collaborative innovation process remains a two-stage dynamic sequential game. In the first phase, the two firms agree to R&D cost-sharing contracts wherein exploitative firm B takes cost ratio λ to gain exploitative innovation rights from A. In the second phase, firm B implements cost-sharing contracts and chooses both level of exploitative innovation and product price to maximise its own profit. Assume that firm A has complete information on B's profit function. In the first stage, exploratory firm A sets an optimal cost-sharing ratio to gain maximum profit based on the second stage of B's exploitative innovation and product market prices. The profit-maximising functions of A and B are as follows:

$$\begin{aligned} \max_{\omega,\theta,\lambda} \pi_A &= \omega q - IC_A \\ &= \omega(a - bp + \alpha\theta + \beta e) - (1 - \lambda)\eta_A\theta^2 \end{aligned} \quad (11)$$

$$\begin{aligned} \max_{p,e,\lambda} \pi_B &= (p - \omega) q - IC_B \\ &= (p - \omega)(a - bp + \alpha\theta + \beta e) - \eta_B e^2 - \lambda\eta_A\theta^2 \end{aligned} \quad (12)$$

In the same way, maximising B's profit function and solving the first-order equilibrium conditions yield

$$\begin{aligned} p^* &= \frac{2(a + \alpha\theta)\eta_B + (2b\eta_B - \beta^2)\omega}{4b\eta_B - \beta^2} \\ e^* &= \frac{\beta(a + \alpha\theta - b\omega)}{4b\eta_B - \beta^2}, \end{aligned} \quad (13)$$

$$\begin{aligned} \theta^*(\lambda) &= \frac{a\alpha\eta_B}{2(1 - \lambda)\eta_A(4b\eta_B - \beta^2) - \alpha^2\eta_B} \\ \omega^*(\lambda) &= \frac{(1 - \lambda)a\eta_A(4b\eta_B - \beta^2)}{b(2(1 - \lambda)\eta_A(4b\eta_B - \beta^2) - \alpha^2\eta_B)} \end{aligned} \quad (14)$$

Then, obtain p^* and e^*, represented by λ:

$$\begin{aligned} p^*(\lambda) &= \frac{6(1 - \lambda)ab\eta_A\eta_B - (1 - \lambda)a\eta_A\beta^2}{b(2(1 - \lambda)\eta_A(4b\eta_B - \beta^2) - \alpha^2\eta_B)} \\ e^*(\lambda) &= \frac{(1 - \lambda)a\beta\eta_A}{2(1 - \lambda)\eta_A(4b\eta_B - \beta^2) - \alpha^2\eta_B} \end{aligned} \quad (15)$$

The first-order equilibrium of λ^* is

$$\lambda^* = \frac{\eta_B\alpha^2}{4\eta_A(4b\eta_B - \beta^2)} \quad (16)$$

Finally, the game equilibrium is

$$\begin{aligned} p^c &= \frac{a\left(6\eta_B b-\beta^2\right)\left(\eta_B\alpha^2+4\eta_A\beta^2-16\eta_A\eta_B b\right)}{2b\left(4\eta_B b-\beta^2\right)\left(3\eta_B\alpha^2+4\eta_A\beta^2-16\eta_A\eta_B b\right)} \\ e^c &= \frac{a\beta\left(\eta_B\alpha^2+4\eta_A\beta^2-16\eta_A\eta_B b\right)}{2\left(4\eta_B b-\beta^2\right)\left(3\eta_B\alpha^2+4\eta_A\beta^2-16\eta_A\eta_B b\right)} \\ \theta^c &= \frac{-2\eta_B a\alpha}{\left(3\eta_B\alpha^2+4\eta_A\beta^2-16\eta_A\eta_B b\right)} \\ \omega^c &= \frac{a\left(\eta_B\alpha^2+4\eta_A\beta^2-16\eta_A\eta_B b\right)}{2b\left(3\eta_B\alpha^2+4\eta_A\beta^2-16\eta_A\eta_B b\right)} \end{aligned} \tag{17}$$

Under the R&D cost-sharing contract arrangement, the profits of firms A and B can be determined as follows:

$$\pi_A{}^* = \frac{\eta_B a^2\left(\eta_B\alpha^2+4\eta_A\beta^2-16\eta_A\eta_B b\right)}{2\left(4\eta_B b-\beta^2\right)\left(3\eta_B\alpha^2+4\eta_A\beta^2-16\eta_A\eta_B b\right)} \tag{18}$$

$$\pi_B{}^* = \frac{-\eta_B a^2\left(\eta_B\alpha^2-4\eta_A\beta^2+16\eta_A\eta_B b\right)}{4\left(4\eta_B b-\beta^2\right)\left(3\eta_B\alpha^2+4\eta_A\beta^2-16\eta_A\eta_B b\right)} \tag{19}$$

4. Model Analysis

This section compares and analyses A's and B's innovation input decisions regarding collaborative innovation under different incentive contracts, that is, the cost-sharing contract and the benefit-distribution contract, and thus gains insight into the interactive mechanisms of exploratory and exploitative innovation based on the ambidextrous strategies of collaborative innovation.

Proposition 1. *The internal transfer prices of intermediate technology products, sales prices of final products, and levels of investment in exploratory innovation and exploitative innovation decrease as the cost of exploration and exploitative innovation increases.*

Under the two incentive contracts, the level of exploratory innovation and exploitative innovation input is negatively correlated with exploration-based innovation and development-type innovation input costs. The benefit-distribution contractual arrangement is used as an example for verification. For θ^w and e^w, the first derivative of η_A and η_B is

$$\begin{aligned} \frac{\partial\theta^w}{\partial\eta_A} &= \frac{-2a\alpha\eta_B\left(4b\eta_B-\beta^2\right)}{\left(2\eta_A\left(4b\eta_B-\beta^2\right)-\alpha^2\eta_B\right)^2} < 0 \\ \frac{\partial e^w}{\partial\eta_A} &= \frac{-2a\alpha\eta_A\beta^2}{\left(2\eta_A\left(4b\eta_B-\beta^2\right)-\alpha^2\eta_B\right)^2} < 0 \end{aligned} \tag{20}$$

It can be seen that first derivative is negative, so the level of investment in both exploratory and exploitative innovation decreased as explorative investment increases:

$$\begin{aligned} \frac{\partial\theta^w}{\partial\eta_B} &= \frac{-a\beta\alpha^2\eta_B}{\left(2\eta_A\left(4b\eta_B-\beta^2\right)-\alpha^2\eta_B\right)^2} < 0 \\ \frac{\partial e^w}{\partial\eta_B} &= \frac{-a\beta\eta_A\left(8b\eta_A-\alpha^2\right)}{\left(2\eta_A\left(4b\eta_B-\beta^2\right)-\alpha^2\eta_B\right)^2} < 0 \end{aligned} \tag{21}$$

The level of investment in exploratory and exploitative innovation decreased with increases in exploitative investment; the same method can be used to validate contractual arrangements under cost sharing.

On one hand, Conclusion 1 shows that the lower the cost coefficient of exploratory innovation, the higher the exploratory firm's innovation efficiency. Accordingly, exploitative innovation firms are willing to expand channels in the market after they obtain the innovation information from exploratory firms, so as to obtain higher profit income. On the other hand, if the input cost coefficient of the exploitative innovation rises, the market investment level of the exploitative firm will have weaker influence on demand. This situation, in turn, will lead the exploitative firm to reduce market investment, while, for the exploratory firm, the risk of market uncertainty in product innovation increases, so the exploratory firm will be reluctant to increase investment in innovation costs. Thus, the level of exploratory innovation input decreases.

In addition, with a reduction in the innovation cost coefficient, the exploratory firm's innovation efficiency will increase, which will boost the internal transfer price of the intermediate technology to obtain the product premium. This, in turn, will lead the exploitative firm to increase the product's final selling price. To some extent, this situation is due to an incomplete contract caused by asymmetric information and invalid corporate commitments.

Proposition 2. *Under the two incentive contracts, the internal transfer price of intermediate technology and final product sales price are positively related to the exploratory innovation effect and exploitative innovation effect.*

For p^w, ω^w, p^c, and ω^c, the first derivatives of α and β are

$$\begin{aligned} \frac{\partial p^w}{\partial\alpha} &= \frac{2a\alpha\eta_A\eta_B\left(6b\eta_B-\beta^2\right)}{b\left(\alpha^2\eta_B+2\beta^2\eta_A-8b\eta_A\eta_B\right)^2} > 0 \\ \frac{\partial p^w}{\partial\beta} &= \frac{2a\beta\eta_A\eta_B\left(4b\eta_A+\alpha^2\right)}{b\left(\alpha^2\eta_B+2\beta^2\eta_A-8b\eta_A\eta_B\right)^2} > 0 \\ \frac{\partial w^w}{\partial\alpha} &= \frac{2a\alpha\eta_A\eta_B\left(4b\eta_B-\beta^2\right)}{b\left(\alpha^2\eta_B+2\beta^2\eta_A-8b\eta_A\eta_B\right)^2} > 0 \\ \frac{\partial w^w}{\partial\beta} &= \frac{2a\alpha^2\beta\eta_A\eta_B}{b\left(\alpha^2\eta_B+2\beta^2\eta_A-8b\eta_A\eta_B\right)^2} > 0 \end{aligned}$$

$$\frac{\partial p^c}{\partial \alpha} = \frac{8a\alpha\eta_A\eta_B\left(6b\eta_B - \beta^2\right)}{b\left(3\alpha^2\eta_B + 4\beta^2\eta_A - 16b\eta_A\eta_B\right)^2} > 0$$
$$\frac{\partial p^c}{\partial \beta} = \frac{8a\beta\eta_A\eta_B\left(4b\eta_A + \alpha^2\right)}{b\left(3\alpha^2\eta_B + 4\beta^2\eta_A - 16b\eta_A\eta_B\right)^2} > 0$$
$$\frac{\partial w^c}{\partial \alpha} = \frac{8a\alpha\eta_A\eta_B\left(4b\eta_B - \beta^2\right)}{b\left(3\alpha^2\eta_B + 4\beta^2\eta_A - 16b\eta_A\eta_B\right)^2} > 0$$
$$\frac{\partial w^c}{\partial \beta} = \frac{8a\alpha^2\beta\eta_A\eta_B}{b\left(3\alpha^2\eta_B + 4\beta^2\eta_A - 16b\eta_A\eta_B\right)^2} > 0 \tag{22}$$

Proposition 2 shows that both exploratory and exploitative firms benefit from an increase in exploratory and exploitative innovation effects. The greater the exploratory innovation effect, the higher the degree of consumer satisfaction with product quality and performance, which in turn promotes exploratory firms to invest in product technology and improve product quality levels. Accordingly, exploitative firms will invest more to advertise or expand product channels to meet market demand, and product sales will increase, which in turn inspires the exploratory firms to innovate further product. Similarly, the greater the effect of exploitative innovation, the greater the exploitative firms' ability to advertise or expand product channels, leading them to obtain a greater market share. Thus, exploratory firms will also use this effect to improve product quality and strengthen their corporate brand.

Proposition 3. *Under the benefit-distribution and cost-sharing contracts, both exploratory and exploitative innovation level will increase with an increase in exploratory innovation effect, an outcome that motivates exploratory and exploitative firms to share costs. The cost-sharing coefficient increases with increases in the exploratory and exploitative innovation effect.*

For e^w and e^c, the first derivative of α is

$$\frac{\partial e^w}{\partial \alpha} = \frac{2a\alpha\beta\eta_A\eta_B}{\left(\alpha^2\eta_B + 2\beta^2\eta_A - 8b\eta_A\eta_B\right)^2} > 0$$
$$\frac{\partial e^c}{\partial \alpha} = \frac{8a\alpha\beta\eta_A\eta_B}{\left(3\alpha^2\eta_B + 4\beta^2\eta_A - 16b\eta_A\eta_B\right)^2} > 0 \tag{23}$$

The first derivatives are positive, indicating that, under the benefit-distribution and cost-sharing contracts, exploitative investment levels are positively correlated with the exploratory innovation effect. Because the level of exploratory investment and internal transfer price of intermediate technology are determined by exploitative firms under the two kinds of contracts, R&D investment decisions can be made based on market feedback for the products.

For α and β, the first derivative of λ is

$$\frac{\partial \lambda}{\partial \alpha} = \frac{\eta_B\alpha}{2\eta_A\left(4b\eta_B - \beta^2\right)} > 0$$
$$\frac{\partial \lambda}{\partial \beta} = \frac{\eta_B\alpha^2\beta}{2\eta_A\left(4b\eta_B - \beta^2\right)^2} > 0 \tag{24}$$

The first derivatives are positive, indicating that cost-sharing coefficient increases with rises in the exploratory and exploitative innovation effect. When $\beta \longrightarrow 0$, cost-sharing factors of exploratory and exploitative firms $\lambda = \eta_B\alpha^2/4\eta_A(4b\eta_B - \beta^2) > 0$; when $\alpha \longrightarrow 0$, the cost-sharing factor $\lambda \longrightarrow 0$.

Proposition 3 illustrates the interactive mechanism between exploratory and exploitative innovation effects. Specifically, exploratory innovation serves as the intrinsic motivating force of technological innovation, and it can inspire technological research and exploitative innovation. The exploitative firm merely increases the cost-sharing ratio between the exploitative and exploratory collaborative innovation. On one hand, exploratory innovation can be pulled by the market to meet consumer demand. In turn, meeting this demand will increase profits of exploitative firms, who will share profits and costs with exploratory firms in order to access the R&D knowledge that will enable them to meet that market demand. Thus, exploitative firms are also willing to share costs with exploratory firms. However, if consumers' interest in an exploratory innovation effect falls to zero, the cost-sharing factor will also drop to zero; that is, exploratory and exploitative firms will no longer have motivation to share costs.

On the other hand, a decline in the effect of exploitative innovation will cause the cost-sharing ratio of exploitative firm to decrease. When the recognition is reduced to zero, however, the cost-sharing ratio will not drop to zero. This is due to the existence of exploratory innovative effects, whereby exploitative firms will also share the cost of innovation with exploratory firms.

Proposition 4. *Cost-sharing contracts are more effective to incentivise innovation. Level of exploratory innovation investment and exploitative innovation investment, as well as the profitability of exploitative innovation companies, all reach higher levels under the cost-sharing contract.*

Let θ^c minus θ^w be defined as follows:

$$\begin{aligned}\theta^c - \theta^w &= \frac{a\alpha\eta_B}{\alpha^2\eta_B + 2\beta^2\eta_A - 8b\eta_A\eta_B} - \frac{2a\alpha\eta_B}{3\alpha^2\eta_B + 4\beta^2\eta_A - 16b\eta_A\eta_B} \\ &= \frac{2a\alpha\eta_B}{2\alpha^2\eta_B + 4\beta^2\eta_A - 16b\eta_A\eta_B} - \frac{2a\alpha\eta_B}{3\alpha^2\eta_B + 4\beta^2\eta_A - 16b\eta_A\eta_B}\end{aligned} \tag{25}$$

Proposition 4 illustrates that exploratory firms would retain higher levels of innovation inputs under the cost-share contract. When the exploratory innovation effect or exploitative innovation effect is low, the exploitative firm's cost-sharing factor would be smaller, while, at the same time, it could collaborate with exploratory firm to improve product technology content and thus get higher returns. However, as long as exploratory and exploitative innovation effects increase, the cost-sharing factor of exploitative firms will also increase, which will have a negative impact on their profit.

5. Conclusions and Implications

5.1. Conclusions. Based on the perspective of organisational ambidexterity, we considered collaborative innovation between exploratory and exploitative firms. According to the process of collaborative innovation, we built a dynamic game model to analyse the innovation decisions under a benefit-distribution contract and cost-sharing contract. Then, the impact of the effects of exploratory and exploitative innovation on the innovation decision making of exploratory and exploitative firms was compared. This paper aimed to shed light on higher-efficiency incentive contractual arrangements for collaborative innovation to promote both new technology and the market. The results show the following.

(1)Exploratory and exploitative innovations were demonstrated to have an interactive effect on the exploratory firm's level of innovation input because technological innovation and its process are intrinsically dependent on exploratory innovation. In addition, exploitative innovation promotes exploratory innovation activities to some extent. In both benefit-distribution and cost-sharing contracts, exploratory and exploitative innovation increase with an increase in the effect of exploratory innovation. As long as the exploratory innovation effect exists, the firms engaged in exploitative innovation will share the innovation cost. Exploratory innovation, as the "original driving force" for improving product quality, is the key to developing core competitiveness. R&D firms need to create their sustainable core competence through exploratory innovation, as well as developing market and business to make more opportunities for sustainable growth.

(2)The level of investment in exploration and exploitative innovation decreases as the cost of innovation increases and increases as innovation efficiency increases. With the increase of innovation cost, both exploration and exploitative innovation will be affected negatively, resulting in the decrease of innovation investment. However, the increase of innovation efficiency can offset the negative effect caused by the increase of innovation cost to some extent and improve the exploratory and exploitative innovation investment. It is found that the lower cost and higher efficiency of explorative innovation would bring more investment of exploitative innovation, and the higher cost of exploitative innovation which is likely to come from poor market demand and response would result in the reduction of exploitative innovation investment, as well as the explorative innovation investment. Meanwhile, it is also found that the choice of ambidextrous innovation strategy depends on the innovation cost; the ambidextrous innovation balance will be inclined to exploratory innovation as the innovative cost is low; in another way, the ambidextrous innovation balance will be inclined to exploitative innovation.

(3)The exploratory and exploitative innovation effects of R&D firms can make a good business and the cooperative innovation of R&D firms is linked by internal transfer payment mechanism. Compared with a benefit-distribution contract, the cost-sharing contract makes the exploitative firms bear a certain proportion of the cost and ensures the income distribution of the cooperative firms through transfer payment, so as to drive the exploration innovation of R&D firms. It is shown that a cost-sharing contract is more effective to improve the investment level of exploratory innovation. The cost sharing of exploitative firms can not only reduce the innovation cost of exploratory firms, but also encourage themselves to strengthen market expansion and accelerate the transformation of technological achievements, so as to solve the inefficiency of R&D costs and insufficient motivation of market exploitation. However, with the decrease of innovation effect and the increase of cost-sharing coefficient, the profits of exploitative firms will be reduced, which leads to the reduction of innovation input and cost sharing.

5.2. Contributions. Our study contributes to the literature on exploration and exploitation in two ways.

(1) Our work could provide a better understanding of the relationship between exploration and exploitation. In current research, the interplay between exploration and exploitation has been analysed from two competing perspectives: continuity versus orthogonality [25, 26]. On the one hand, stemmed from March's pioneering work, the traditional literature on organizational learning argues that exploration and exploitation are two ends of a continuum. In other words, the interplay between those two innovative activities occurs in the form of a zero-sum game. Hence, firms are unable to pursue both exploration and exploitation at the same time. On the other hand, many scholars' empirical studies also suggest that exploration and exploitation are two different and orthogonal aspects of organizational behavior [27, 28]. That is to say, exploration and exploitation can simultaneously achieve in multiple domains. Our work supports the latter view. To put it differently, exploration and exploitation activities are not as mutually exclusive but as interwoven polarities [29]. In particular, this study suggests that exploratory innovation activities could be improved to some degree by exploitative innovation, which is partly consistent with the empirical finding by Piao and Zajac [30]. In addition, our study also implicates that exploratory innovation becomes a key driving force for accelerating performances by delivering significantly new innovation, improving current product quality, and developing the core competence for sustainable competitive advantage.

(2) Prior research on organizational ambidexterity has been discussed in various literature streams such as organizational learning, technological innovation, organizational adaptation, strategic management, and organizational design

[31] and mainly identifies structural, process, and operational mechanisms for achieving ambidexterity [32]. In contrast, this paper draws on the literature from contract theory and focuses on the impact of *incentive mechanism* on firms' exploitative and exploratory innovation activities. By building on contractual arrangements and employing a dynamic game model, our work also sheds light on theoretical diversity and cross-disciplinary approach in exploration and exploitation and consequently contributes to foster innovation ambidexterity at the firm level and provide novelty mechanism for managing ambidexterity through the theoretical lenses of contract design.

5.3. Managerial Implications. Finally, the models developed in this paper demonstrate that strengthening supervision and improving the contract system, encouraging exploratory innovation, and guiding exploitative innovation to share the cost in collaborative innovation are important measures to promote innovation efficiency. The model used two simplified firms in the collaborative innovation network to analyse the effect of explorative and exploitative innovation on market demand. Although this simplification allowed for the development of a succinct model, the scope of further research on more firms could be expanded. Meanwhile, under the market competition environment, contract design and the uncertain market demand for exploratory and exploitative innovation are all worthy of further research. This study also has important practical implications; we put forward the following suggestions.

(1)With markets becoming increasingly competitive, the traditional invention model faces the risk of diminishing returns. Exploratory innovation develops new technologies and products by acquiring external knowledge, which requires researching new knowledge, mastering new technologies, and developing new products, from which long-term benefits can be reaped through radical change. While exploitative innovation develops the market by consolidating, integrating, and improving existing knowledge, it is relatively robust and can benefit from knowledge improvement without costing too much for R&D. Therefore, firms can strengthen exploration innovation through outsourcing strategy. Such strategy not only reduces innovation cost and improves innovation efficiency (e.g., CRO mode widely used in biological pharmaceutical industry), but also promotes interfirms learning by adopting component outsourcing and modular design [32],which significantly enhances the extent of technological knowledge exploration [33]. For instance, China Delixi Group has built a three-level hierarchical R&D system in Germany, Shanghai, and Wenzhou and extended its product R&D center to Germany by acquiring a German electrical manufacturer. By exploring local technological resources, Delixi strengthens its global leading position, develops exploratory technology of the electrical industry, and applies those exploratory innovations into the exploitation of product and business. The conclusion of this paper also means that firms need to carry out effective outsourcing arrangements management.

(2)Nowadays, exploratory innovations have grown rapidly in China, even surpassing in some fields the advanced level found in other countries. However, given the ongoing persistence of shortcomings such as inefficient, low transformation, China's industries have never been able to move to a high position in the global value chain. China's investment in scientific research ranks second in the world, but the conversion rate of this scientific research results is only about 10%, whereas the rate in developed countries is as high as 40%. How to promote explorative and exploitative innovation from the perspective of improving innovation efficiency? Firstly, firms could take advantage of ecosystem strategy to improve their innovation efficiency, especially in emerging market such as China and India. Ecosystem strategy implies that firms could create value creation value by coordinating their multilateral dependence, which eliminates the need to enter into customized contractual agreements with each partner [34]. Hence, firms should develop and expand ecosystem by identifying different types of complementarities (e.g., super modular or unique, unidirectional or bidirectional). Under the current developed information technology environment, a lot of firms, such as the clothing firms Semir Co. and Meters Bonwe Co. in China, set up advanced MIS to construct virtual cooperative networks to reduce costs and get access to innovative resources conveniently, accelerating the firms' response in the market and R&D field, and covering the shortage of exploration and exploitative innovation resources. On the other hand, internationalization strategy helps firms access foreign knowledge base and market. Therefore, firms could improve their innovation efficiency through acquisitions and strategic alliances in the process of internationalization. Moreover, according to the research [35], the lower innovation efficiency of multinational firms is mainly caused by information asymmetry and cost of capital. Our work complements this study by indicating that during internationalization firms could reduce such information asymmetry by designing suitable benefits distribution and cost-sharing contract.

(3)The conclusion of this paper also implies that firms can design specific benefit-distribution and cost-sharing contracts based on open innovation or crowdsourcing strategy. According to the benefit-distribution and cost-sharing contract arrangements, it can be seen that cost-sharing contract is more effective for incentivise exploratory firms to pursue innovation when we consider the influence of both exploratory and exploitative innovation. Based on China's imperfect-market mechanism and incomplete contract system status, a cost-sharing incentive contract with exploitative firms can help exploratory firms deeply reduce the cost of R&D innovation as well as increase their marketing efforts, thereby promoting transformation of scientific technologies. Take Apple Inc. as an example. By collaborating with upstream suppliers such as Intel, Samsung, and Foxconn, Apple invests only 3.5% of revenue into R&D for exploring the new generation of mobile phones and laptops. Conversely, the main innovations in its product are related to customer or market-oriented exploitative innovation. In other words, Apple mainly uses exploratory innovations for improving

exploitative innovation in existing product-market domains. For instance, Apple is good at developing complementary products and services, such as social media apps and accessories, which bring about a good user experience, and integrating and commercializing the exploratory technology, which are invented by other firms even competitors, into its ecosystem with the greatest degree of success.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All three authors contributed equally to this work. They all read and approved the final version of the manuscript.

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