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RESEARCH ARTICLE

Strategic Interactions in Franchising Systems When Anticipating Innovation: How to Develop Operational Strategies and Cooperative Alliance Models?

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ABSTRACT Correctly responding to the arrival of unexpected innovative events can help members of the franchise system rationally formulate their operational strategies and cooperative alliance modes to improve performance, while the exact time of product innovation realization is often unknown. Based on this, the strategic interactions in the business innovation system when foreseeing innovations are considered: the choice of operation strategies and cooperation modes. Using Bellman's continuum dynamic programming theory to find the optimal strategies and system profits under the three modes of horizontal, non-cooperative and vertical cooperation within the system, the strategic interactions in the franchise system under different cooperation modes are analyzed. It is found that the prediction of innovation events will make the decision makers more active in increasing the input of current strategies, thus maximizing the initiative before the realization of innovations, and the R&D and innovation efforts of franchisors and the local service level of franchisors will increase with the increase of the innovation realization rate and the improvement rate, and the goodwill of franchisors will be improved as a result. Both horizontal and vertical cooperation models can effectively realize the Pareto improvement of the total profit of the franchise system. And the innovation realization rate and upliftment rate positively affect this improvement effect. It is worth noting that the vertical cooperation model is more effective in improving the total system profit and is better in the case of high realization rate-high uplift rate.

INDEX TERMS Cooperative alliance model, foresight innovation, franchise system, product innovation.

I. INTRODUCTION

In recent decades, franchising has flourished [1], [2], [3], [4], [5], [6]. Franchising has become a mainstream business model in many countries, with almost every Canadian city having franchises in areas such as catering, clothing and audiovisual. In the United States, more than 40% of retail turnover is earned by franchising [7], [8], [9], [10], [11]. Brazil [12], France [13] and other countries can also be seen everywhere. In the 2023 China Franchise Conference held by the China Chain Operation Association, it was mentioned that as of April, the total number of commercial franchise registration enterprises in the country has reached 9549, an increase of nearly 2 times compared with 2017. According to the statistics of the China Chain Operation Association, the sales scale of the top 100 franchise chains increased by 250 billion yuan compared with 2017. Franchising means that the franchisor provides the franchisor with an opportunity for successful operation by authorizing the franchisor to use its resources and experience such as brand, product and management mode, and establishes a close cooperative relationship between the franchisor and the franchisor to achieve

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common development and win-win situation [14], [15], [16]. In recent years, franchise enterprises have quickly seized the market with low cost, low risk and high efficiency by virtue of standardization, specialization and scale advantages [10], [11]. The head of the InStore business line of Qisheng Technology & the co-founder of Miya Technology have pointed out that the opportunities and challenges of franchise store sales growth under the trend of digital transformation, that is, the brand capability has evolved into a favorable tool for franchise stores to serve consumers, which can enable franchisees to enhance the competitiveness of the business circle. This is the biggest charm and feature of the current digital franchise, but it also brings many new challenges, and the franchise stores in the digital era are facing problems in management decision-making, marketing and many other aspects. As the global market continues to expand and competition intensifies, franchise research is increasingly receiving attention from both academia and practice. The research on the new generation of franchise system is not only a hot issue in the business world, but also a research focus in the academic world [10], [11], [12], [13], [14], [15], [16].

Faced with an increasingly volatile and highly uncertain market environment, franchise systems must innovate in order to grow and survive in a dynamic environment [14], [18], [19], [20]. In fact, the franchise system has been on the path of developing innovative new products. In the franchise system, franchisors will upgrade product technology, mainly focusing on the technology that is most relevant to consumers and most capable of increasing the stock and incremental aspects of consumers, in order to realize product innovation adapted to the consumers in the new era, thus enhancing the competitiveness of the enterprise [5], [19], [20]. The R&D and innovation of new products can not only improve the production line process and resource utilization, but also enhance the service efficiency of the enterprise, which can bring a brand new situation to the franchising enterprise [21]. Such as the coffee chain giant Starbucks often listed new products, while constantly upgrading the old product formula, many times ''listed that fire'' situation. A series of product innovation will have a significant impact on the entire franchise system, in the face of innovation events, how to timely adjust the operating strategy and mode of operation is very important. That is, foresight innovation, foresight innovation is the ability that franchise system members must have when facing future uncertainty. In the fast-changing market environment, franchise system members need to adjust their strategies and operation modes in time to adapt to the changes in market demand by anticipating future successful product innovation events. Therefore, it is important for the long-term development of franchise system members to consider the formulation of their strategies and the selection of cooperative alliance models in anticipation of innovations.

It is worth noting that, with the intensification of market competition and the continuous promotion of technological progress, in order to maintain competitiveness and meet the growing needs of consumers, franchise system members have to choose a cooperative alliance model suitable for their own development while continuously innovating [22], [23], [24]. The choice of cooperative alliance model is one of the key factors for the successful operation of franchise system members [25], [26]. These include horizontal alliances (where franchisors and franchisees work together to develop operational strategies) [27], [28] and vertical alliances (where franchisors and franchisees work together) [29], [30]. Different cooperative models can provide different support and resources, such as brand promotion, advertising hitchhiking, and market development [26]. Numerous scholars have argued that successful franchising requires a cohesive cooperative alliance network to help franchisors and franchisees work together and achieve common goals [22], [23], [24], [31]. A suitable cooperative alliance model can stimulate the innovation and development of enterprises, and the cooperation between members can promote the development of new products and services, promote the innovation of business models to adapt to changes in market demand, and help members in the franchise system to improve operational efficiency to achieve the purpose of improving the overall revenue.

However, the emergence of innovative products (goods, services, business models, etc.) does not happen overnight, and there exists a long or short research and development cycle and process, so the exact time of the emergence of innovative products is unknown [32]. Based on the above understanding, when the franchise enterprise has the consciousness of anticipating innovation, how should it formulate and adjust the operation strategy before and after innovation to ensure the optimal profit? How should franchise system members choose a cooperative alliance model? What are the implications of the likelihood of product innovation realization and the rate of innovation uptake, given that innovation realization can bring about a certain degree of brand image enhancement? To this end, this paper focuses on the ''anticipation of innovation'' part, which portrays the uncertainty of innovation time in the model and distinguishes two different operating environments before and after innovation realization. A differential game model is constructed to solve the above problem.

The main innovation of this paper is that most of the previous research literature on innovation in franchise systems focuses on empirical analysis and less on theoretical analysis, whereas the necessary theoretical analysis can help firms to anticipate the impact of different environmental factors on their operational strategies, and therefore can suggest rationalized managerial insights to firms. It is worth emphasizing that we use the random stopping problem to distinguish the operational strategy problem of a franchise system in two different environments before and after the realization of an innovation, which is rare in the previous literature. We consider and portray the phenomenon that product innovation realization brings about an enhancement in franchise goodwill. In addition, while incorporating the above factors, we also consider different cooperation scenarios among the members of the franchise system to analyze the strategic interactions in the franchise system in anticipation of innovation: how to formulate the operational strategy and the cooperative alliance model. The main contribution of this paper is to give theoretical suggestions on the cooperation mode of enterprises in the face of innovation, to help enterprises rationally optimize their operation strategies, to improve the allocation of resources in different environments before and after product innovation, and to realize the long-term and stable development of the franchise system.

The subsequent content is organized as follows: section II is the literature review part; section III gives the problem description and model assumptions; section IV is the model analysis, which analyzes the optimal strategies and performances of the members under different decision-making modes, and gives the sensitivity analysis of the key parameters and the corresponding managerial implications; section V is the comparative analysis of the different decision-making modes; section VI analyzes the impacts of the innovation realization rate and the enhancement rate on the member's strategies and performances, as well as the Pareto improvement effect of the different cooperative modes on the profitability of the system by means of the numerical arithmetic examples; and finally, it gives the conclusions and the managerial implications.

II. LITERATURE REVIEW

Research areas relevant to this paper include (1) franchising, (2)innovation, and (3) research on cooperative alliance model selection.

A. FRANCHISING

Among the studies on franchising, Ackermann et al [33] used an empirical study to estimate the impact of franchising on store revenues. Hsu et al. [7] investigated the profitability of franchised and non-franchised restaurant companies and found that the profitability of franchised companies was significantly higher than that of non-franchised companies. Sadovnikova et al. [8] empirically studied the impact of refranchising and repurchasing downstream retail units of franchised companies on shareholder value, indicating that both refranchising and repurchasing will have a positive impact on stock returns. Mainardes et al. [12] explored the differences in the impact of customer experience quality on brand credibility, perceived quality and purchase intention between franchise and non-franchise customers, and found that better purchase intentions are often facilitated by the quality of customer experience of franchise customers. Due to the inherent dynamics of franchise marketing and considering the impact of different cooperative alliance modes on the performance of franchising, many scholars have included the franchise system in the perspective of dynamic research, and have launched research on the formulation of members' operating strategies, the selection of cooperative modes and the design of contractual mechanisms in the franchise system with the help of theories such as differential gaming [1], [11], [34], [35], [36]. Luu et al. [1] aimed to investigate to reveal how franchisee performance can be affected by franchisor-owned resources, quality of franchise relationship and franchisee's dynamic capabilities and found that franchisor-owned resources, quality of franchise relationship and franchisee's dynamic capabilities can significantly affect franchisee's performance. Liang et al. [11] constructed a real option model considering the franchisor's provision of guaranteed profits to the franchisee in a dynamic environment to evaluate the franchise contract, and found that if the franchise is profitable, the value of the contract is high for both the franchisor and the franchisee. Sigué et al. [34] analyze the smooth feedback Nash equilibrium when franchisors cooperate and do not cooperate with each other in the context of local advertising competition and show that cooperation among franchisors not only does not affect the franchisor's advertising decisions, but also increases its profits. Sigué et al. [35] studied a two-stage advertising game between a franchisor and two franchisees based on differential game theory and found that cooperation between franchisees is chosen when the franchisor represents brand image advertising and promotional advertising. Martín-Herrán et al. [36] studied the effects of price competition and advertising spillover on franchisors' cooperation decisions and franchisors' contractual preferences, and found that whether franchisors cooperate depends on the type of franchise contract. However, since franchise systems are in a volatile competitive environment and must innovate in order to thrive in a dynamic environment over the long term, this study enriches existing research on franchising by taking a dynamic perspective, incorporating innovation factors, and taking into account the uncertainty of the time to success of an innovation by utilizing the stochastic stopping problem to describe the phenomenon.

B. INNOVATION

Currently, research on innovation is not only the focus of attention in the business world, but academics have also followed the pace of the times to investigate different aspects of it, while most of the academic research on innovation in recent years has focused on empirical analysis [37], [38], [39], [40]. Wang et al. [37] selected data from 2019 listed companies in China's manufacturing industry from 757 to 1995, explored the relationship between open innovation and knowledge reorganization and innovation performance, and found that open innovation, knowledge reorganization and creation, and knowledge reorganization and reuse all had an inverted U-shaped relationship with innovation performance. Sun et al. [38] found that the relational governance of innovation platform can positively influence the green innovation of manufacturing SMEs by collecting data from 270 manufacturing SMEs in Zhejiang Province. Shi et al. [39] selected five electronic information enterprises and conducted a qualitative study, and found that there are three dimensions of innovation generation: genetic, metabolic and inspection. Stephan et al. [40] investigated the strategic goals and innovation performance of several companies and found that external sources of knowledge and innovation performance of firms benefit the most when social goals are aligned with economic goals. Paparoidamis et al. [41] investigated how the degree of innovation in eco-innovation design, among others, has a significant impact on consumers' willingness to adopt, and showed that the degree of innovation in eco-innovation attributes has a positive impact on consumers' perception of product eco-friendliness and willingness to adopt. Jiang et al. [42] explored how network breadth and network depth affect dynamic capabilities and thus product innovation based on the perspective of dynamic capabilities, showing that both network breadth and depth are important drivers of dynamic capabilities, and that dynamic capabilities are mediators of translating the benefits of business networks into successful product innovation. Shockley et al. [20] found that targeting distributional equity helped improve the ability of independent operators to promote innovation by measuring how franchisors' perceptions of fairness contributed to innovation in retail franchise organizations. Abdul et al. [43] study the influences that can make franchises grow and show that product and service innovation and government support are factors that can drive the growth of franchise companies. Hao et al. [32] investigated how key innovation characteristics affect a company's operational strategy and profitability and found that, in general, a firm's total expected profit always tends to decline relative to the timing of new product releases. While much of the previous research literature on innovation has focused on empirical analysis, little theoretical research has been reported on product innovation. There are even fewer theoretical analyses that incorporate innovation factors into franchise systems. Therefore, in this paper, we will use the random stop problem to describe the uncertainty of the success time of product innovation and analyze the choice of strategies and cooperation modes of the members of the franchise system in this situation from a dynamic perspective.

C. COOPERATIVE ALLIANCE MODEL SELECTION

The issue of cooperative alliance model selection has also been a hot topic of concern in the business community, and franchise systems are no exception; good cooperative model selection can effectively improve firm performance [22], [23], [24], [25], [26]. Academics have also conducted studies on the selection of cooperative alliance models. Rindfleisch et al. [44] found that organizational trust in vertical alliances enhances cooperation, whereas in horizontal alliances, trust is not related to cooperation. Seipenbusch et al. [45] applied innovation to the traditional food sector in horizontal and vertical innovation networks. Zeng et al. [46] used a game theory approach to reveal the relationship between asymmetric spillovers and R&D investment in horizontal and vertical R&D cooperation. The above literature has examined the horizontal and vertical cooperative alliances between firms in different contexts without analyzing them simultaneously in the franchise system, while most of the studies on the cooperative alliance model within the franchise system have focused on horizontal cooperative alliances between franchisors [33], [34], [35], [36], with little consideration of vertical cooperative alliances among the members of the franchise system. This paper simultaneously considers the horizontal cooperative alliance, non-cooperative, and vertical cooperative alliance patterns among franchise system members, which enriches the relevant research on cooperative patterns in franchise system. In summary, while current research on franchising is relatively mature, it does not simultaneously take into account the uncertainty of the success of the innovation and the different cooperative alliance models. The exact time of innovation success is often unknown, and this randomness and uncertainty will have an important impact on the operation strategy of the franchise system, which becomes a difficult problem to be solved by the franchise system. In this paper, we will utilize the stochastic stopping problem to describe the uncertainty of the time of success of a product innovation, distinguishing between two different operating environments before and after the success of the innovation, which is more realistic. In addition, while incorporating the innovation factor, it considers different cooperative alliance models of members within the franchise system and constructs differential game models under different scenarios, aiming to provide theoretical guidance and suggestions for enterprises.

III. MODEL DESCRIPTION AND ASSUMPTION

A. MODEL DESCRIPTION

The dynamic franchise system considered in this paper consists of a franchisor (Z) and two symmetric franchisees (P, Q). Franchising means that the franchisor licenses its brand, product, design, etc. to multiple franchisees under certain conditions, allowing them to engage in the same business as the franchisor in a certain area. In this study, we only consider two symmetric franchisors in order to reduce the complexity of the model and to sharply focus on the impact of innovation factors. This is also used in many research papers on franchising, such as Sigué and Chintagunta [35], Martín-Herrán et al. [36]. In this dynamic system, the franchisor will continue to carry out research and development and innovation, and is committed to developing more innovative products, which will then be awarded to franchisees for sale. For example, 711 launched the ''Ice Dun Dun'' ice-cream new product, KFC launched a new creative staple food - K-sa. This innovative initiative of the franchisor to attract consumers' attention to the brand or company and gain their favor aims to maintain and develop the brand image and enhance the goodwill of the franchise [14], [35]. Franchisors, on the other hand, take advantage of their stores to provide local services, such as standard product guides, detailed product presentations to customers, understanding customers' shopping needs and personalizing product recommendations to customers [34]. Franchising, as a mainstream business operation model in the 21st century, has been rapidly expanding in various industry sectors. In order to keep up with market trends, franchise systems are also constantly developing innovations, but the exact time of product realization is unknown [32]. The purpose of this paper is to study how franchisors and franchisees should realize strategic interaction when product innovations are predicted to be realized: i.e., formulate reasonable operation strategies and choose reasonable cooperation models. The system schematic of the franchising system is shown in Fig. 1.

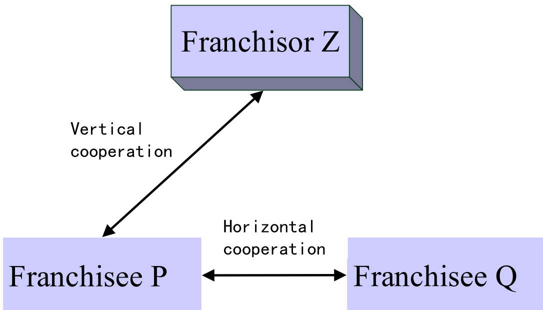

FIGURE 1. System schematic.

As a result, the decision-making of the members of the franchise system consists of the franchisor deciding on the R&D and innovation effort $v(t)$ and each of the two franchisees deciding on the local service level $s(t)$. In order to distinguish between the two different market environments of pre-innovation and post-innovation realization, we consider the respective franchise system members' strategies as well as profitability in two phases, i.e., the franchisor will decide on the pre-innovation R&D and innovation efforts, $v_{x1}(t)$, and the post-innovation R&D and innovation efforts, $v_{x2}(t)$, respectively. The franchisee x will develop a pre-innovation local service level $s_{x1}(t)$ and a post-innovation local service level $s_{x2}(t)$ respectively, where $x, y \in \{P, Q\}$ and $x \neq y$ denote Franchisor P and Franchisor Q, respectively. $i = 1, 2$ indicates two different market environments before and after the realization of the product innovation. The decision time line for the franchise system is shown in Fig. 2. In addition, Table 1 summarizes the key symbols and their detailed meanings in this paper.

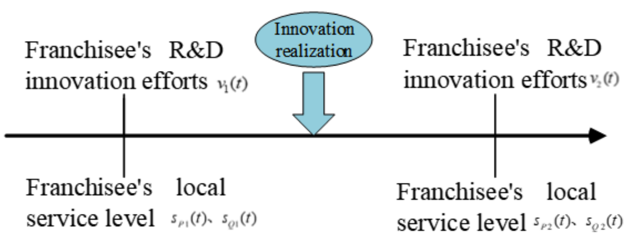

FIGURE 2. Decision timeline.

Table 1 summarizes the key symbols and their detailed meanings in this paper.

TABLE 1. Parameters and variables.

Symbol	Descescriptions
Parameter	
Z,P,Q	franchise system members, where Z represents the franchisor and P,Q epresents each of the two symmetrical franchisees
x,y	$x,y \in \{P,Q\}$ and $x \neq y$ denote Franchisor P and Franchisor Q, respectively
A,B,C	possible scenarios, representing horizontal cooperation model, non-cooperative model, vertical cooperation model
$i=1,2$	two different environments before and after successful product innovation
θ_i	expressing the effectiveness of R&D innovation efforts in improving franchising, $\theta_i > 0$
α_i	coefficient of the impact of local services on franchise goodwill, $\alpha_i > 0$
δ_i	decay factor of franchise goodwill, $\delta_i > 0$
η_i	indicates the impact of franchisors' local services on their own demand, $\eta_i > 0$
ξ_i	the impact of competitors' local services on their own demand, using the standard assumption that the cross-service effect is lower than the direct service effect [52], so $0 \le \xi_i \le \eta_i$
$\omega_i > 0$	coefficient of impact of franchise goodwill on demand, $\omega_i > 0$
ρ_Z,ρ_P,ρ_Q	Marginal profit for the franchisor and the two franchisees, respectively
k_Z,k_{xs}	cost factors for franchisee R&D innovation, franchisee x's promotional advertising campaign and local services, respectively
r	the discount rate
χ	likelihood of success of product innovation innovation, i.e. realization rate
ϕ	rate of improvement of franchise goodwill by innovative products
Decision variables	
$v_i(t)$	R&D innovation efforts of concessionaires in the i environment
$s_{xi}(t)$	local service level of franchisee x in i environment
State variables	
$G(t)$	franchise goodwill, where $G_0 > 0$ is the initial brand goodwill

B. MODEL ASSUMPTION

Previous literature has shown that a successful franchise system requires a good reputation, which provides consumers with a large amount of valid information related to the quality of the goods and the level of service provided by the franchisor, and therefore can be considered as franchise goodwill [26], [33], [34], [35], [36]. Franchise goodwill is not static, but rather changes from time to time in a dynamic system where the franchisor's R&D and innovation efforts can drive the introduction of innovative products that help to build the overall franchise goodwill [33], [34], [35]. Local services provided by franchisees that result in a good shopping experience for consumers are effective in promoting franchisee goodwill [34]. Thus, franchise goodwill is established by the franchisor's R&D and innovation efforts and the level of local services provided by the franchisee, and it is assumed that the effectiveness of the local services provided by the franchisees in enhancing franchise goodwill is the same [34]. In addition, franchise goodwill can decay due to consumer forgetfulness or competition from brands in the same industry [47], [48], so that $G(t)$ denotes franchise goodwill. Here we draw on the modified Nerlove- Arrow goodwill model [49], so that the kinetic equation for $G(t)$ can be described as

$$\dot{G}(t) = \theta_i a_i(t) + \alpha_i s_{Mi}(t) + \alpha_i s_{Ni}(t) - \delta_i G, \quad G(0) = G_0 > 0 \tag{1}$$

as R&D innovation efforts contribute to the success of product innovation, they invariably enhance the production line process, resource utilization and improve the efficiency of the company's services. Also drawing on Heerde [50] and Rubel [51] and others, it is assumed that $\theta_1 < \theta_2, \alpha_1 < \alpha_2, \delta_1 > \delta_2$.

The services sector has become a major engine of growth in the domestic and global economy, and the level of local services provided by franchisees can influence corporate image and effectively drive demand, but is equally affected by the negative impact of local services provided by competitors [36]. In addition, the R&D and innovation efforts of the franchisor and the local services provided by the franchisees can indirectly affect demand through the accumulation of franchise goodwill. Therefore, the demand function is set according to the description of Dan et al. [52] on service competition:

$$D_x = \eta_i s_{xi} - \xi_i s_{yi} + \lambda_i u_{xi} + \gamma_i u_{yi} + \omega_i G \tag{2}$$

without loss of generality, it is assumed that the two franchisees are symmetrical and therefore face the same marginal profit and demand functions with the same impact coefficients [35]. Similarly, the success of product innovation leads to an increase in service efficiency and process optimization of advertising placement, so $\eta_2 > \eta_1, \xi_2 > \xi_1, \lambda_2 > \lambda_1, \gamma_2 > \gamma_1, \omega_2 > \omega_1$.

In order to reduce the accountability of the model it is assumed that the marginal profit $\rho_Z, \rho_P, \rho_Q$of both the franchisor and the franchisee is constant [53].

Innovation realization process is unknown, innovation realization of the specific time is also an uncertain event [32], so that $\{\Gamma(t) : t \geqslant 0\}$ represents the process of innovation, in any moment t, the probability of innovation realization for $\chi \in (0, 1)$. Assuming that T is the actual date of successful innovation, the operating time of the franchise system is therefore divided into two intervals, pre-innovation $t \in [0, T]$ and post-innovation $t \in [T, \infty)$. Drawing on the formulas in studies such as Heerde [50] and Rubel [51], the $\{\Gamma(t) : t \geqslant 0\}$ is a jump process, which can be expressed as

$$\lim_{\Delta \to 0} \frac{P\left[\Gamma(t+\Delta) = 2 \,|\, \Gamma(t) = 1\right]}{\Delta} = \chi$$
$$\lim_{\Delta \to 0} \frac{P\left[\Gamma(t) = 1 \,|\, \Gamma(t+\Delta) = 2\right]}{\Delta} = 0 \tag{3}$$

Some of the dramatic response to innovative products can make the franchise goodwill instantly enhance, for example, a year Hong Kong Starbucks and fashion designer Vivienne Tam cooperation to launch a limited series of co-branded, Vivienne Tam designed Bird and Flora classic pattern set as a blueprint for the product packaging printed in the form of ink paintings to create the plum blossom and other oriental characteristics of the pattern, once launched on the capture a large number of Chinese consumers prefer, the business goodwill quickly soared. Meanwhile, drawing on equations from studies such as Heerde [50] and Rubel [51], the launch of innovative products leads to an increase in franchise goodwill, i.e., so the process can be portrayed as

$$G(T^+) = (1+\phi) G(T^-) \tag{4}$$

where $G(T^-)$ and $G(T^+)$ denote the franchise goodwill before the realization of product innovation (hereinafter referred to as pre-innovation) and after the realization of product innovation, respectively.

Assuming that the cost function is quadratic [36], the franchisor's R&D innovation cost is $k_Z v^2(t)/2$ and the franchisee's local service cost are $k_{xs} s_x^2(t)/2$, respectively.

In order to differentiate between studying two different market environments, pre and post innovation realization, we will differentiate between the two phases of operational strategy. Similarly, it is important to distinguish between the profitability of the two phases, pre- and post-innovation realization.

The exact time T at which the innovation is realized is unknown, and the pre-innovation and post-innovation profits are denoted by π_i. The net present value of its profit is $J_1 = \int_0^T e^{-rt} \pi_1 \mathrm{d}t$ and $J_2 = \int_T^\infty e^{-rt} \pi_2 \mathrm{d}t$, respectively, and the expected net present value of profit in the two environments is $J = \mathrm{E}(J_1 + e^{-rt} J_2)$, which is simplified to obtain the long-term profit function as

$$J = \int_0^\infty e^{-(r+\chi)} \{\pi_1 + \chi J_2\} \mathrm{d}t \tag{5}$$

IV. MODEL ANALYSIS

Based on the above problem description and assumptions, this section solves for each strategy and profit of the members of the franchise system in the three modes of horizontal cooperative alliance (A), non-cooperative (B), and vertical cooperative alliance (C), respectively, and conducts a sensitivity analysis of the key parameters. To distinguish the models, the three cooperative alliance models are denoted by superscripts A, B, and C, respectively, and the subscripts Z, P, and Q denote the franchisor and the two franchisees.

A. HORIZONTAL COOPERATIVE ALLIANCE MODEL (C)

In the horizontal cooperation model, franchisors cooperate horizontally with each other, and as a whole they jointly determine their local service levels to limit local competition and maximize their joint profits. The horizontal cooperation model is denoted by the superscript A. When the decision maker distinguishes between pre-innovation and post-innovation strategies, the model can be summarized as follows (6) and (7), as shown at the bottom of the next page.

Proposition 1: According to Bellman's continuous type dynamic programming theory, we solve to obtain: The R&D innovation efforts of the franchisee before and after the innovation were

$$v_1^A = \frac{\theta_1 d_4}{k_Z} \tag{8}$$

and

$$v_2^A = \frac{\theta_2 d_{11}}{k_Z} \tag{9}$$

The local service levels of partner franchisees before and after the innovation are

$$s_{x1}^A = \frac{\rho_{x1}\eta_1 - \rho_{y1}\xi_1 + \alpha_1 d_3}{k_{xs}} \tag{10}$$

and

$$s_{x2}^A = \frac{\rho_{x2}\eta_2 - \rho_{y2}\xi_2 + \alpha_2 d_{22}}{k_{xs}} \tag{11}$$

The time evolution path of franchise goodwill is

$$G^A(t) = \begin{cases} G_{1\infty}^A + (G_0 - G_{1\infty}^A)e^{-\delta_1 t} & t \in [0, T] \\ G_{2\infty}^A + \left[(1+\phi)\, G_T^A - G_{2\infty}^A\right] e^{-\delta_2 (t-T)} & t \in [T, \infty) \end{cases} \tag{12}$$

where

$$G_T^A = G_{1\infty}^A + (G_0 - G_{1\infty}^A)e^{-\delta_1 T} \tag{13}$$

$$G_{1\infty}^A = \frac{1}{\delta_1}\left[\frac{\theta_1^2 d_4}{k_Z} + \frac{\alpha_1(\rho_{M1}\eta_1 - \rho_{N1}\xi_1 + \alpha_1 d_3)}{k_{Ps}} + \frac{\alpha_1(\rho_{N1}\eta_1 - \rho_{M1}\xi_1 + \alpha_1 d_3)}{k_{Qs}}\right] \tag{14}$$

$$G_{2\infty}^A = \frac{1}{\delta_2}\left[\frac{\theta_2^2 d_{11}}{k_Z} + \frac{\alpha_2(\rho_{M2}\eta_2 - \rho_{N2}\xi_2 + \alpha_2 d_{22})}{k_{Ps}} + \frac{\alpha_2(\rho_{N2}\eta_2 - \rho_{M2}\xi_2 + \alpha_2 d_{22})}{k_{Qs}}\right] \tag{15}$$

The profits of the franchisor and co-franchisee for the entire program period are

$$V_Z^A = d_4 G + d_{04} \tag{16}$$

and

$$V_{PQ}^A = d_3 G + d_{03} \tag{17}$$

The post-innovation profits of the franchisor and the co-franchisee are respectively

$$W_Z^A = d_{11} G + d_{01} \tag{18}$$

and

$$W_{PQ}^A = d_{22} G + d_{02} \tag{19}$$

where

$$d_4 = \frac{2\rho_{Z1}\omega_1 + \chi d_{11}(1+\phi)}{r + \chi + \delta_1} \tag{20}$$

$$d_3 = \frac{\rho_{P1}\omega_1 + \rho_{Q1}\omega_1 + \chi d_{22}(1+\phi)}{r + \chi + \delta_1} \tag{21}$$

$$d_{11} = \frac{2\rho_{Z2}\omega_2}{r + \delta_2} \tag{22}$$

$$d_{22} = \frac{(\rho_{P2} + \rho_{Q2})\,\omega_2}{r + \delta_2} \tag{23}$$

$$d_{04} = \frac{1}{r+\chi}\left[\frac{(\rho_{Z1}\eta_1 + \alpha_1 d_4 - \rho_{Z1}\xi_1)(\rho_{P1}\eta_1 - \xi_1\rho_{Q1} + \alpha_1 d_3)}{k_{Ps}} + \frac{(\theta_1 d_4)^2}{2k_Z} + \frac{(\rho_{Z1}\eta_1 + \alpha_1 d_4 - \rho_{Z1}\xi_1)(\rho_{Q1}\eta_1 - \xi_1\rho_{P1} + \alpha_1 d_3)}{k_{Qs}} + \chi d_{01}\right] \tag{24}$$

$$d_{03} = \frac{1}{r+\chi}\left[\frac{(\rho_{P1}\eta_1 - \xi_1\rho_{Q1} + \alpha_1 d_3)^2}{2k_{Ps}} + \frac{(\eta_1\rho_{Q1} - \xi_1\rho_{P1} + \alpha_1 d_3)^2}{2k_{Qs}} + \frac{\theta_1^2 d_3 d_4}{k_Z} + \chi d_{02}\right] \tag{25}$$

$$d_{01} = \frac{1}{r}\left[\frac{(\rho_{Z2}\eta_2 + \alpha_2 d_{11} - \rho_{Z2}\xi_2)(\rho_{P2}\eta_2 - \rho_{Q2}\xi_2 + \alpha_2 d_{22})}{k_{Ps}} + \frac{(\rho_{Z2}\eta_2 + \alpha_2 d_{11} - \rho_{Z2}\xi_2)(\rho_{Q2}\eta_2 - \rho_{P2}\xi_2 + \alpha_2 d_{22})}{k_{Qs}} + \frac{(\theta_2 d_{11})^2}{2k_Z}\right] \tag{26}$$

$$d_{02} = \frac{1}{r}\left[\begin{array}{c} \dfrac{(\rho_{P2}\eta_2 - \rho_{Q2}\xi_2 + \alpha_2 d_{22})^2}{2k_{Ps}} \\ +\dfrac{(\rho_{Q2}\eta_2 - \rho_{P2}\xi_2 + \alpha_2 d_{22})^2}{2k_{Qs}} \\ +\dfrac{\theta_2^2 d_{11} d_{22}}{k_Z} \end{array}\right] \quad (27)$$

Property 1: From Proposition 1, the results of the sensitivity analysis of the R&D innovation effort of the pre-innovation franchisee and the local service level of the partner franchisee with respect to the innovation realization rate χ and the improvement rate ϕ in the horizontal cooperative alliance model are obtained as follows. The strategies in the other environments are not related to the innovation realization rate χ and the improvement rate ϕ.

$$\frac{\partial v_1^A}{\partial \chi} > 0; \frac{\partial s_{x1}^A}{\partial \chi} > 0; \frac{\partial v_1^A}{\partial \phi} > 0; \frac{\partial s_{x1}^A}{\partial \phi} > 0. \quad (28)$$

Before giving our analysis, we restate the decision dilemma: How should franchisors and franchisees adjust their level of strategy as the likelihood of innovation realization increases? One view is that members of the franchising system should increase their investment in service levels prior to the introduction of an innovative product, thereby reinforcing the expected profit improvement from the innovation. Another view is that investment in services should be increased after the innovative product is introduced, thereby accelerating the post-innovation profit improvement. Indeed, both views are valid because the long-term profits of a franchise system include both pre-innovation and post-innovation profits. However, our Property 1 suggests that the prediction of the likelihood of innovation realization affects the decision maker's pre-innovation decision, while the post-innovation decision is not directly affected. That is, the prediction of innovation realization changes the decision maker's time preference to focus more on pre-innovation profits and less on post-innovation profits.

Property 2: The sensitivity analysis of pre- and post-innovation franchisee's R&D innovation efforts, and local service level of the partner franchisee regarding key exogenous parameters in the horizontal cooperative alliance model is presented in the table below.

Property 2 suggests that, both pre-innovation and post-innovation, as the effectiveness of R&D and innovation efforts in improving franchising increases, franchisors are incentivized to invest more in R&D and innovation to improve their brand image, which in turn improves franchise goodwill and increases profits, creating a positive cycle. The decision maker's prediction of innovation realization affects the decision maker's level of pre-innovation strategy, causing him or her to focus not only on the decay of franchise goodwill in the pre-innovation period, but also on the decay of franchise goodwill in the post-innovation period.

TABLE 2. **Sensitivity analysis of exogenous parameters under horizontal cooperation model.**

	θ_1	θ_2	α_1	α_2	δ_1	δ_2	η_1	η_2	ξ_1	ξ_2	ω_1	ω_2
v_1^A	↗	—	—	—	↘	↘	—	—	—	—	↗	↗
v_2^A	—	↗	—	—	—	↘	—	—	—	—	—	↗
s_{x1}^A	—	—	↗	—	↘	↘	↗	—	↘	—	↗	↗
s_{x2}^A	—	—	—	↗	—	↘	—	↗	—	↘	—	↗

Note: ↗ indicates positive correlation, ↘ indicates negative correlation, — indicates no correlation.

B. NON-COLLABORATIVE MODEL (B)

In the non-cooperative model, the three parties in the franchise system are independent individuals, each making decisions with the goal of maximizing profits. Using the superscript B to denote the non-cooperative model, when the decision maker distinguishes between pre-innovation and post-innovation strategies, the model can be summarized as follows

$$\max\left\{J_Z = \int_0^\infty e^{-rt}\left[\begin{array}{c}\rho_{Z1}\left(D_{P1}(t)+D_{Q1}(t)\right)-\dfrac{1}{2}k_Z {v_1}^2(t) \\ +\chi W_Z^B\left((1+\phi)G(t)\right)\end{array}\right]\mathrm{d}t\right\} \quad (29)$$

$$\max\left\{J_P = \int_0^\infty e^{-rt}\left[\begin{array}{c}\rho_{P1}D_{P1}(t)-\dfrac{1}{2}k_{Ps}s_{P1}^2(t) \\ +\chi W_P^B\left((1+\phi)G(t)\right)\end{array}\right]\mathrm{d}t\right\} \quad (30)$$

$$\max\left\{J_Q = \int_0^\infty e^{-rt}\left[\begin{array}{c}\rho_{Q1}D_{Q1}(t)-\dfrac{1}{2}k_{Qs}s_{Q1}^2(t) \\ +\chi W_Q^B\left((1+\phi)G(t)\right)\end{array}\right]\mathrm{d}t\right\} \quad (31)$$

Proposition 2: According to Bellman's continuous type dynamic programming theory, we solve to obtain: The R&D innovation efforts of the franchisee before and after the

$$\max\left\{J_Z = \int_0^\infty e^{-rt}\left[\begin{array}{c}\rho_{Z1}\left(D_{P1}(t)+D_{Q1}(t)\right)-\dfrac{1}{2}k_Z {v_1}^2(t) \\ +\ \chi W_Z^C\left((1+\phi)G(t)\right)\end{array}\right]\mathrm{d}t\right\} \quad (6)$$

$$\max\left\{J_{PQ} = \int_0^\infty e^{-rt}\left[\begin{array}{c}\rho_{P1}D_{P1}(t)+\rho_{Q1}D_{Q1}(t)-\dfrac{1}{2}k_{Ps}s_{P1}^2(t) \\ -\dfrac{1}{2}k_{Qs}s_{Q1}^2(t)+\chi W_{PQ}^C\left((1+\phi)G(t)\right)\end{array}\right]\mathrm{d}t\right\} \quad (7)$$

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innovation were

$$v_1^B = \frac{\theta_1 d_8}{k_Z} \tag{32}$$

and

$$v_2^B = \frac{\theta_2 d_5}{k_Z} \tag{33}$$

The local service levels of each franchisee before and after the innovation are

$$s_{x1}^B = \frac{\rho_{x1}\eta_1 + \alpha_1 d_9}{k_{xs}} \tag{34}$$

and

$$s_{x2}^B = \frac{\rho_{x2}\eta_2 + \alpha_2 d_6}{k_{xs}} \tag{35}$$

The time evolution path of franchise goodwill is

$$G^B(t) = \begin{cases} G_{1\infty}^B + (G_0 - G_{1\infty}^B)e^{-\delta_1 t} & t \in [0, T] \\ G_{2\infty}^B + \left[(1+\phi)\, G_T^B - G_{2\infty}^B\right] e^{-\delta_2(t-T)} & t \in [T, \infty) \end{cases} \tag{36}$$

where

$$G_T^B = G_{1\infty}^B + (G_0 - G_{1\infty}^B)e^{-\delta_1 T} \tag{37}$$

$$G_{1\infty}^B = \frac{1}{\delta_1}\left[\frac{\theta_1^2 d_8}{k_Z} + \frac{\alpha_1(\rho_{P1}\eta_1 + \alpha_1 d_9)}{k_{Ps}} + \frac{\alpha_1(\eta_1\rho_{Q1} + \alpha_1 d_{10})}{k_{Qs}}\right] \tag{38}$$

$$G_{2\infty}^B = \frac{1}{\delta_2}\left[\frac{\theta_2^2 d_5}{k_Z} + \frac{\alpha_2(\rho_{P2}\eta_2 + \alpha_2 d_6)}{k_{Ps}} + \frac{\alpha_2(\rho_{Q2}\eta_2 + \alpha_2 d_7)}{k_{Qs}}\right] \tag{39}$$

The profits of the franchisor and franchisee for the entire plan period are

$$V_Z^B = d_8 G + d_{08} \tag{40}$$

and

$$V_P^B = d_9 G + d_{09} \tag{41}$$

and

$$V_Q^B = d_{10} G + d_{010} \tag{42}$$

The profits of the post-innovation franchisor and the two independent franchisees are respectively

$$W_Z^B = d_5 G + d_{05} \tag{43}$$

and

$$W_P^B = d_6 G + d_{06} \tag{44}$$

and

$$W_Q^B = d_7 G + d_{07} \tag{45}$$

where

$$d_8 = \frac{2\omega_1\rho_{Z1} + \chi d_5(1+\phi)}{r + \chi + \delta_1} \tag{46}$$

$$d_9 = \frac{\rho_{P1}\omega_1 + \chi d_6(1+\phi)}{r + \chi + \delta_1} \tag{47}$$

$$d_{10} = \frac{\rho_{Q1}\omega_1 + \chi d_7(1+\phi)}{r + \chi + \delta_1} \tag{48}$$

$$d_5 = \frac{2\omega_2\rho_{Z2}}{r + \delta_2} \tag{49}$$

$$d_6 = \frac{\rho_{P2}\omega_2}{r + \delta_2} \tag{50}$$

$$d_7 = \frac{\rho_{Q2}\omega_2}{r + \delta_2} \tag{51}$$

$$d_{08} = \frac{1}{r+\chi} \times \left[\frac{(\rho_{Z1}\eta_1 + d_8\alpha_1 - \rho_{Z1}\xi_1)(\rho_{P1}\eta_1 + \alpha_1 d_9)}{k_{Ps}} + \frac{(\rho_{Z1}\eta_1 + \alpha_1 d_8 - \rho_{Z1}\xi_1)\left(\eta_1\rho_{Q1} + \alpha_1 d_{10}\right)}{k_{Qs}} + \frac{(\theta_1 d_8)^2}{2k_Z} + \chi d_{05}\right] \tag{52}$$

$$d_{09} = \frac{1}{r+\chi} \times \left[\frac{(\rho_{P1}\eta_1 + \alpha_1 d_9)^2}{2k_{Ps}} + \frac{(\alpha_1 d_9 - \rho_{P1}\xi_1)\left(\eta_1\rho_{Q1} + \alpha_1 d_{10}\right)}{k_{Qs}} + \frac{\theta_1^2 d_9 d_8}{k_Z} + \chi d_{06}\right] \tag{53}$$

$$d_{010} = \frac{1}{r+\chi} \times \left[\frac{(\eta_1\rho_{Q1} + \alpha_1 d_{10})^2}{2k_{Qs}} + \frac{\left(d_{10}\alpha_1 - \rho_{Q1}\xi_1\right)(\rho_{P1}\eta_1 + \alpha_1 d_9)}{k_{Ps}} + \frac{d_{10} d_8 \theta_1^2}{k_Z} + \chi d_{07}\right] \tag{54}$$

$$d_{05} = \frac{1}{r} \times \left[\frac{(\rho_{Z2}\eta_2 + \alpha_2 d_5 - \rho_{Z2}\xi_2)(\rho_{P2}\eta_2 + \alpha_2 d_6)}{k_{Ps}} + \frac{(\rho_{Z2}\eta_2 + \alpha_2 d_5 - \rho_{Z2}\xi_2)\left(\rho_{Q2}\eta_2 + \alpha_2 d_7\right)}{k_{Qs}} + \frac{(\theta_2 d_5)^2}{2k_Z}\right] \tag{55}$$

$$d_{06} = \frac{1}{r} \times \left[\begin{array}{c} \frac{(\rho_{P2}\eta_2 + \alpha_2 d_6)^2}{2k_{Ps}} \\ + \frac{(\alpha_2 d_6 - \rho_{P2}\xi_2)\left(\rho_{Q2}\eta_2 + \alpha_2 d_7\right)}{k_{Qs}} \\ + \frac{d_6 d_5 \theta_2^2}{k_Z} \end{array} \right] \tag{56}$$

$$d_{07} = \frac{1}{r} \times \left[\begin{array}{c} \frac{(\rho_{Q2}\eta_2 + \alpha_2 d_7)^2}{2k_{Qs}} \\ + \frac{\left(d_7\alpha_2 - \rho_{Q2}\xi_2\right)(\rho_{P2}\eta_2 + \alpha_2 d_6)}{k_{Ps}} \\ + \frac{d_7 d_5 \theta_2^2}{k_Z} \end{array} \right] \tag{57}$$

Property 3: From Proposition 2, the results of the sensitivity analysis of the pre-innovation franchisee's R&D innovation effort and the franchisor's local service level regarding the innovation realization rate χ and the enhancement rate ϕ in the non-cooperative model are obtained as follows. The strategies in other environments are not related to the innovation realization rate χ and the enhancement rate ϕ .

$$\frac{\partial a_1^B}{\partial \chi} > 0; \frac{\partial s_{x1}^B}{\partial \chi} > 0; \frac{\partial a_1^B}{\partial \phi} > 0; \frac{\partial s_{x1}^B}{\partial \phi} > 0. \tag{58}$$

Property 3 shows that in the non-cooperative model, the franchisor's R&D and innovation efforts, and the local service levels of both franchisees are positively related to the likelihood of innovation realization and the rate of improvement in the pre-innovation environment. In the pre-innovation period, as the likelihood of innovation realization increases, the franchisor will increase its R&D and innovation efforts, and both franchisors will improve their local service levels.

Property 4: The sensitivity analysis of the pre- and post-innovation franchisor's R&D and innovation efforts, and each franchisee's local service level with respect to the key exogenous parameters in the non-cooperative model is shown in the following table

Property 4 shows that in this case, compared to property 2, the coefficient of influence of the franchisor's local service level and the competitor's service level on its own demand is not relevant. The reason for this is that in the non-cooperative model, the franchisor is only concerned with its own sales and profits.

C. VERTICAL COOPERATIVE ALLIANCE MODEL (*H*)

Under the vertical cooperative alliance model, the franchisor believes that its own management experience can yield higher profits than the franchise fee alone in future cooperative operations based on its confidence in its own brand and management capabilities. For the franchisee, being able to operate the business with the franchisor's management power

TABLE 3. Sensitivity analysis of exogenous parameters in non-cooperative mode.

	θ_1	θ_2	α_1	α_2	δ_1	δ_2	η_1	η_2	ξ_1	ξ_2	ω_1	ω_2
v_1^B	↗	—	—	—	↘	↘	—	—	—	—	↗	↗
v_2^B	—	↗	—	—	—	↘	—	—	—	—	—	↗
s_{x1}^B	—	—	↗	—	↘	↘	↗	—	—	—	↗	↗
s_{x2}^B	—	—	—	↗	—	↘	—	↗	—	—	—	↗

Note: ↗ indicates positive correlation, ↘ indicates negative correlation, — indicates no correlation.

may give it an advantage over its competitors. Moreover, this model is widely used in the franchise system because the franchisor and the cooperating franchisee share the benefits and risks, which can provide incentives for both parties. In this model, the franchisor cooperates with one of the franchisors in deciding the optimal strategy to maximize its joint profits, while the other franchisor makes decisions independently. The vertical cooperation model is denoted by the superscript C, and when the decision maker distinguishes between pre-innovation and post-innovation strategies, the model can be summarized as follows

$$\max \left\{ J_{ZP} = \int_0^\infty e^{-rt} \left[\begin{array}{c} \rho_{Z1}\left(D_{P1}(t) + D_{Q1}(t)\right) + \rho_{P1} D_{P1}(t) \\ -\frac{1}{2} k_Z {v_1}^2(t) - \frac{1}{2} k_{Ps} s_{P1}^2(t) \\ + \chi W_{ZP}^C\left((1+\phi)G(t)\right) \end{array} \right] \mathrm{d}t \right\} \tag{59}$$

$$\max \left\{ J_Q = \int_0^\infty e^{-rt} \left[\begin{array}{c} \rho_{Q1} D_{Q1}(t) - \frac{1}{2} k_{Qs} s_{Q1}^2(t) \\ + \chi W_Q^C\left((1+\phi)G(t)\right) \end{array} \right] \mathrm{d}t \right\} \tag{60}$$

Proposition 3: According to Bellman's continuous type dynamic programming theory, we solve to obtain: The R&D innovation efforts of the franchisee before and after the innovation were

$$v_1^C = \frac{\theta_1 d_{14}}{k_Z} \tag{61}$$

and

$$v_2^C = \frac{\theta_2 d_{12}}{k_Z} \tag{62}$$

The local service levels of each franchisee before and after the innovation are

$$s_{p1}^C = \frac{\rho_{z1}(\eta_1 - \xi_1) + \rho_{p1}\eta_1 + \alpha_1 d_{14}}{k_{ps}} \tag{63}$$

and

$$s_{Q1}^C = \frac{\rho_{Q1}\eta_1 + \alpha_1 d_{15}}{k_{Qs}} \tag{64}$$

and

$$s_{P2}^{C} = \frac{\rho_{Z2}(\eta_2 - \xi_2) + \rho_{P2}\eta_2 + d_{12}\alpha_2}{k_{Ps}} \tag{65}$$

and

$$s_{Q2}^{C} = \frac{\rho_{Q2}\eta_2 + \alpha_2 d_{13}}{k_{Qs}} \tag{66}$$

The time evolution path of franchise goodwill is

$$G^C(t) = \begin{cases} G_{1\infty}^C + (G_0 - G_{1\infty}^C)e^{-\delta_1 t} & t \in [0, T] \\ G_{2\infty}^C + \left[(1+\phi)\, G_T^C - G_{2\infty}^C\right] e^{-\delta_2(t-T)} & t \in [T, \infty) \end{cases} \tag{67}$$

where

$$G_T^C = G_{1\infty}^C + (G_0 - G_{1\infty}^C)e^{-\delta_1 t} \tag{68}$$

$$G_{1\infty}^C = \frac{1}{\delta_1}\left[\frac{\theta_1^2 d_{14}}{k_Z} + \frac{\alpha_1(\rho_{Z1}(\eta_1 - \xi_1) + \rho_{P1}\eta_1 + \alpha_1 d_{14})}{k_{Ps}} + \frac{\alpha_1(\rho_{Q1}\eta_1 + \alpha_1 d_{15})}{k_{Qs}}\right] \tag{69}$$

$$G_{2\infty}^C = \frac{1}{\delta_2}\left[\frac{\theta_2^2 d_{12}}{k_Z} + \frac{\alpha_2(\rho_{Z2}(\eta_2 - \xi_2) + \rho_{P2}\eta_2 + d_{12}\alpha_2)}{k_{Ps}} + \frac{\alpha_2(\rho_{Q2}\eta_2 + \alpha_2 d_{13})}{k_{Qs}}\right] \tag{70}$$

The profits of cooperating franchisees and franchisors and independent franchisees for the entire program period are

$$V_{ZP}^C = d_{14}G + d_{014} \tag{71}$$

and

$$V_Q^C = d_{15}G + d_{015} \tag{72}$$

The profits of franchisors and franchisees and independent franchisees who cooperate after the innovation are

$$W_{ZP}^C = d_{12}G + d_{012} \tag{73}$$

and

$$W_Q^C = d_{13}G + d_{013} \tag{74}$$

where

$$d_{14} = \frac{(2\rho_{Z1} + \rho_{P1})\omega_1 + \chi d_{12}(1+\phi)}{r + \chi + \delta_1} \tag{75}$$

$$d_{15} = \frac{\rho_{Q1}\omega_1 + \chi d_{13}(1+\phi)}{r + \chi + \delta_1} \tag{76}$$

$$d_{12} = \frac{(2\rho_{Z2} + \rho_{P2})\omega_2}{r + \delta_2} \tag{77}$$

$$d_{13} = \frac{\rho_{Q2}\omega_2}{r + \delta_2} \tag{78}$$

$$d_{014} = \frac{1}{r+\chi}\left[\frac{(\rho_{Z1}(\eta_1 - \xi_1) + \rho_{P1}\eta_1 + \alpha_1 d_{14})^2}{2k_{Ps}} + \frac{(\rho_{Z1}(\eta_1 - \xi_1) - \rho_{P1}\xi_1 + \alpha_1 d_{14})(\rho_{Q1}\eta_1 + \alpha_1 d_{15})}{k_{Qs}} + \frac{(\theta_1 d_{14})^2}{k_Z} + \chi d_{012}\right] \tag{79}$$

$$d_{015} = \frac{1}{r+\chi}\left[\frac{(\rho_{Q1}\eta_1 + \alpha_1 d_{15})^2}{2k_{Qs}} + \frac{(d_{15}\alpha_1 - \rho_{Q1}\xi_1)(\rho_{Z1}(\eta_1 - \xi_1) + \rho_{P1}\eta_1 + \alpha_1 d_{14})}{k_{Ps}} + \frac{d_{15}d_{14}\theta_1^2}{k_Z} + \chi d_{013}\right] \tag{80}$$

$$d_{012} = \frac{1}{r}\left[\frac{(\rho_{Z2}(\eta_2 - \xi_2) + \rho_{P2}\eta_2 + \alpha_2 d_{12})^2}{2k_{Ps}} + \frac{(\rho_{Z2}(\eta_2 - \xi_2) - \rho_{P2}\xi_2 + \alpha_2 d_{12})\left(\rho_{Q2}\eta_2 + \alpha_2 d_{12}\right)}{k_{Qs}} + \frac{(\theta_2 d_{12})^2}{2k_Z}\right] \tag{81}$$

$$d_{013} = \frac{1}{r}\left[\frac{(\rho_{Q2}\eta_2 + \alpha_2 d_{13})^2}{2k_{Qs}} + \frac{(d_{13}\alpha_2 - \rho_{Q2}\xi_2)(\rho_{Z2}(\eta_2 - \xi_2) + \rho_{P2}\eta_2 + \alpha_2 d_{12})}{k_{Ps}} + \frac{\theta_2^2 d_{12} d_{13}}{k_Z}\right] \tag{82}$$

Property 5: From Proposition 3, the results of the sensitivity analysis of the pre-innovation franchisee's R&D innovation effort and the franchisee's local service level on the innovation realization rate χ and the enhancement rate ϕ in the vertical cooperative alliance model are obtained as follows. The strategies in the other environments are not related to the realization rate χ and the enhancement rate ϕ.

$$\frac{\partial a_1^H}{\partial \chi} > 0; \frac{\partial s_{x1}^H}{\partial \chi} > 0; \frac{\partial a_1^H}{\partial \phi} > 0; \frac{\partial s_{x1}^H}{\partial \phi} > 0. \tag{83}$$

Property 6: The sensitivity analysis of the pre-innovation and post-innovation franchisor's R&D and innovation efforts, and franchisor's local service level regarding the key exogenous parameters under the vertical cooperation model is shown in the table below.

Property 6 shows that in the vertical cooperative alliance model, the local service level of the franchisee that cooperates

TABLE 4. Sensitivity analysis of exogenous parameters in a vertical cooperative alliance model.

	θ_1	θ_2	α_1	α_2	δ_1	δ_2	η_1	η_2	ξ_1	ξ_2	ω_1	ω_2
v_1^C	Z	—	—	—	]	]	—	—	—	—	Z	Z
v_2^C	—	Z	—	—	—	]	—	—	—	—	—	Z
s_{P1}^C	—	—	Z	—	]	]	Z	—	]	—	Z	Z
s_{P2}^C	—	—	—	Z	—	]	—	Z	—	]	—	Z
s_{Q1}^C	—	—	Z	—	]	]	Z	—	—	—	Z	Z
s_{Q1}^C	—	—	—	Z	—	]	—	Z	—	—	—	Z

Note: Z indicates positive correlation,] indicates negative correlation, — indicates no correlation.

vertically with the franchisor is positively correlated with the coefficient of its impact on its own demand and negatively correlated with the coefficient of the impact of the local service level of its rival on its own demand, regardless of before and after the innovation. The franchisee's local service level is positively related to its own demand and is not related to its rival's local service level.

V. COMPARATIVE ANALYSIS

Based on the previous modeling and sensitivity analyses, this subsection compares the magnitude of the relationship between R&D and innovation efforts, local service levels, and profits under the three models.

Proposition 4: The relationship between the magnitude of the franchisor's R&D innovation effort before and after innovation realization for the three different decision-making models are

$$v_1^C > v_1^A = v_1^B, v_2^C > v_2^A = v_2^B.$$

Proposition 5: The relationship between the magnitude of the franchisee's local service level before and after the innovation when$\alpha_1\omega_2\chi(1+\phi)+\alpha_1\omega_1(r+\delta_2)-\xi_1(r+\chi+\delta_1)(r+\delta_2) > 0$, $\alpha_2\omega_2-\xi_2(r+\delta_2) > 0$ *is satisfied under the three different decision models are:* $s_{P1}^C > s_{P1}^A > s_{P1}^B$, $s_{P2}^C > s_{P2}^A > s_{P2}^B$, $s_{Q1}^A > s_{Q1}^B = s_{Q1}^C$, $s_{Q2}^A > s_{Q2}^B = s_{Q2}^C$.

Proposition 6: The relationship between the size of the profits of each member of the franchise system under the three decision-making models are$V_{PQ}^A > V_P^B+V_Q^B$,$V_{ZP}^C > V_Z^B+V_P^B$.

Proposition 7: The total profit of the franchise system under the horizontal cooperation, non-cooperation, and vertical cooperation modes are represented byV^A,V^B, *and*V^C, *respectively. The relationship between the magnitude of the total profit of the franchise system under different decision models is*$V^H > V^C > V^B$.

Propositions 4-7 show that: (1) The realization of product innovation does not affect the order of magnitude of the strategies in the different models. For the franchisor, Pareto improvements are realized in the franchisee's R&D innovation efforts when working with franchisee$P$(vertical cooperation). (2) Franchisees' local service levels are highest in the vertical cooperative model, followed by the horizontal cooperative model, and the non-cooperative model. (3) In the horizontal cooperative alliance model, the total profit of two franchisors is greater than the total profit of two franchisors in the non-cooperative model. Therefore, for franchisors, choosing a horizontal cooperative alliance strategy with a franchisor is preferable to independent operation. In addition, when the franchisor is in a cooperative alliance with one franchisee, the total cooperative profit (the total profit of the franchisor and the cooperative franchisee) is greater than the corresponding total profit in the non-cooperative model. This suggests that the choice of a vertical cooperative alliance strategy with a franchisor is preferable to independent operation for a franchisor.4) Overall, both horizontal cooperative alliance and vertical cooperative alliance strategies achieve a Pareto improvement in the total profitability of the franchising system, but the improvement effect of vertical cooperative alliances is greater than the improvement effect of horizontal cooperative alliances.

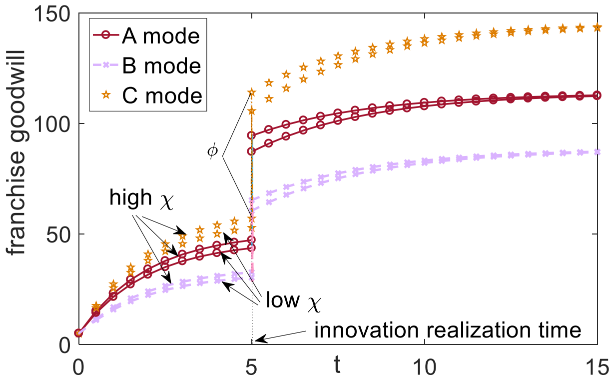
VI. NUMERICAL ANALYSIS

Based on the model analysis and comparative analysis, in order to make the previous results clearer, this section will further validate the conclusions obtained in the previous paper with the help of numerical examples, study the impact of innovation realization rate and enhancement rate on franchise goodwill and system profit, analyze the effect of different decision-making modes on the improvement of profit, in order to study the strategic interactions in the franchise system when foreseeing the innovations: how to formulate the operation strategies and cooperative alliance modes. References [54] and [55] on the setting of parameters, while combining the research background of this paper, the parameters are set as:

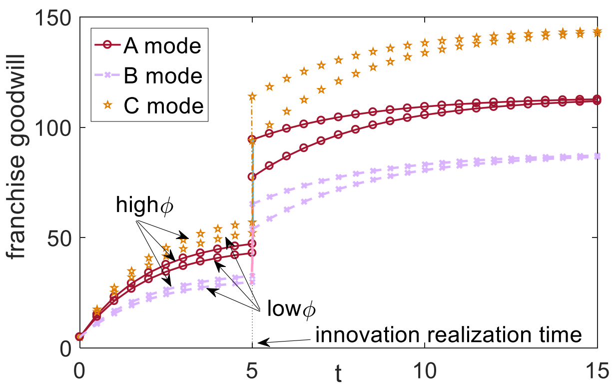
$$r = 0.1, \theta_1 = 0.7, \theta_2 = 1, \alpha_1 = 0.8, \alpha_2 = 1, \delta_1 = 0.5,$$
$$\delta_2 = 0.3, \omega_1 = 0.7, \omega_2 = 1, \eta_1 = 0.7, \eta_2 = 1, \xi_1 = 0.5,$$
$$\xi_2 = 0.6, \rho_{Z1} = 2, \rho_{Z2} = 3, \rho_{P1} = 2, \rho_{P2} = 3,$$
$$\rho_{Q1} = 2, \rho_{Q2} = 3, k_Z = 1.2, k_{Ps} = 1.5, k_{Qs} = 1.5,$$
$$\chi = 0.6, \phi = 0.6$$

A. TIME TRAJECTORY OF FRANCHISE GOODWILL UNDER DIFFERENT SCENARIOS

Fig. 3 shows that: (1) In all three decision models, franchise goodwill evolves over time and rises gradually until it stabilizes. (2) When the product innovation is successful, the steady-state value of franchise goodwill is much



(a) franchise goodwill at different realization rates



(b) franchise goodwill at different uplift rates

FIGURE 3. **Franchise goodwill in different situations.**

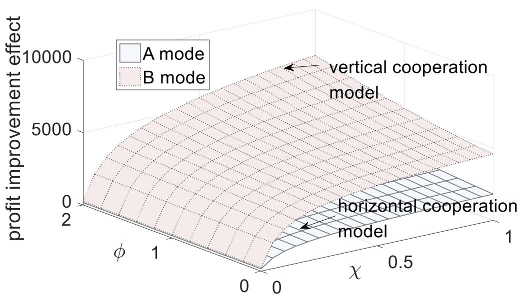
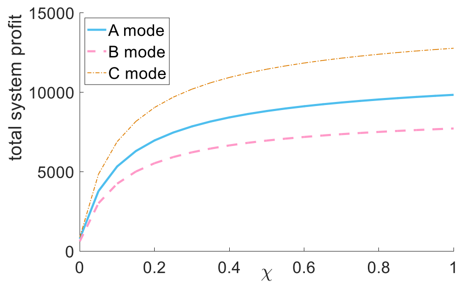
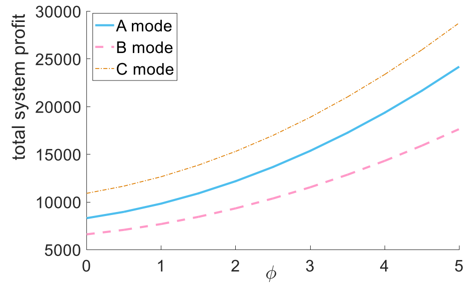


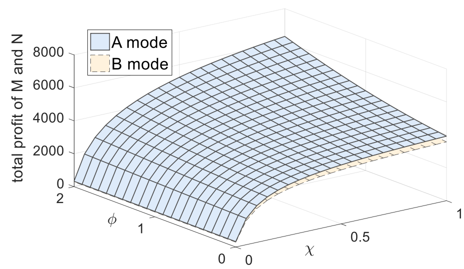
FIGURE 4. **Comparison of total profit of franchisor Z and franchisee P under different scenarios.**



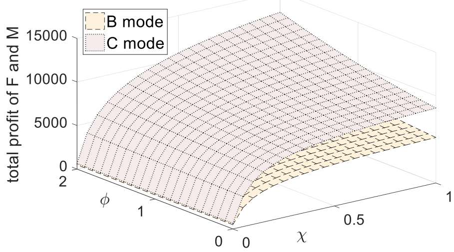
(a) impact of realization rate on total system profit



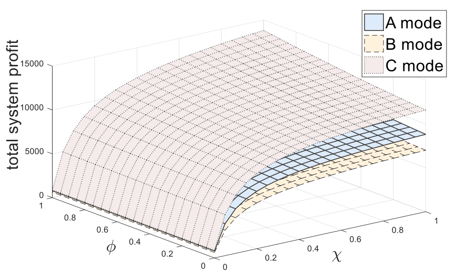
(b) impact of lift rate on total system profit



(c) impact of realization rate and lift rate on franchisee's total profit



(d) effect of realization rate and lift rate on total profit of Z and P



(e) impact of realization rate and lift rate on total system profit

FIGURE 5. **Impact of realization rate and lift rate on profit.**

higher than the steady-state value before the successful innovation. This is consistent with reality. For example, AB InBev's Corona Tropical, an innovative product, was launched and received rave reviews from consumers, causing the brand's goodwill to skyrocket. (3) Further comparison reveals that the rate of innovation realization determines the level of pre-innovation franchise goodwill, which indirectly affects the level of post-innovation franchise goodwill. The higher the innovation realization rate is, the higher the pre-innovation franchise goodwill is, but it does not affect the trend of its change, and the final steady-state value of franchise goodwill tends to be consistent. Similarly, the higher the uplift rate, the higher the pre-innovation franchise goodwill and the greater the rise in franchise goodwill when the innovation is realized. This shows that the positive impact of enhancement rate on franchise goodwill is greater than that of realization rate. (4) Regardless of the pre and post-innovation period, franchise goodwill is highest in the vertical cooperation model, second highest in the horizontal cooperation model, and lowest in the non-cooperation model.

B. IMPROVEMENT EFFECT OF THE TWO COOPERATION MODELS ON THE TOTAL PROFITABILITY OF THE SYSTEM

Figure 4 shows that (1) it is obvious that the vertical cooperation model has a stronger Pareto improvement effect on the total system profit. (2) The Pareto improvement effect of horizontal and vertical cooperation on the total profit of the franchise system increases as the cost coefficient decreases. In other words, the larger the cost coefficient of innovation and R&D efforts, the more costs are invested in carrying out innovations, and the less significant is the improvement effect of the cooperation strategy on profits. The same applies to the cost coefficient of franchisee services, so both franchisors and franchisees should pay attention to the cost issue when operating their enterprises, establish a flexible cost control mechanism, strengthen the management of expense budgets, and avoid the waste of resources. (3) The Pareto improvement effect of both cooperation models on the total profit of the system increases with the increase of the possibility of innovation realization and increases with the increase of the enhancement rate, and the degree of improvement is more obvious at high realization rate-high enhancement rate.

C. THE IMPACT OF INNOVATION REALIZATION RATE AND ENHANCEMENT RATE ON PROFIT

Fig. 5 shows that: Both franchisors, franchisees and total system profits increase with the rate of innovation realization and eventually stabilize; they rise with the rate of franchise goodwill enhancement. The reason for this is that visionary managers consider the positive impact that successful product innovations can have on their organizations in the future, and will adjust their strategies and allocate resources to prepare for future performance before the innovation is successful. Franchisor will increase their R&D and innovation efforts, and franchisees will capitalize on their strengths by leveraging their storefronts to improve local service levels. And the higher the realization rate and increase rate, the greater the positive effect.

VII. CONCLUSION

This paper takes a franchise system as the research object, explores the impact of innovation realization rate and enhancement rate on franchise goodwill and system profit when predicting that the product innovation will be realized, and analyzes the improvement effect of different decision-making modes on the profit in order to study the strategic interactions in the franchise system when foreseeing the innovation: how to formulate the operation strategy and cooperative alliance mode. A differential game model is constructed according to the problems under different modes, and the optimal strategies and system profits of franchise system members under different decision-making modes are solved with the help of Bellman's continuous dynamic programming theory, and the sensitivity and comparative analyses are carried out accordingly to examine the effects of key values. Finally, the effects of innovation realization rate and innovation enhancement rate on franchise goodwill and system profit are verified through numerical examples, and the effects of different decision-making modes on the Pareto improvement effect of total system profit are also examined. The following conclusions are drawn:

(1) Decision makers in franchises have different preferences when formulating their operational strategies, however the move to forecast the innovation realization event changes their decision-making preferences, making them more focused on pre-innovation realization profits. That is, decision makers will be more motivated to invest in their current strategies to maximize their pre-innovation mobility. The prediction of product innovation events mobilizes decision makers' pre-innovation decision-making agency, and the franchisor's R&D and innovation efforts, the franchisor's local service level, and the franchisor's goodwill will all increase as the rate of innovation realization and upgrading increases.

(2) The level of franchise goodwill before the innovation is realized is directly affected by the rate of innovation realization and the rate of uplift. Not only that, the rise of franchise goodwill at the time of innovation realization is also directly affected by the uplift rate. After the innovation is realized, the trend of franchise goodwill will be indirectly affected by the uplift rate. Similarly, the total profit of the franchise system will be directly affected by the innovation realization rate and the uplift rate before the innovation is realized, and indirectly affected by the innovation realization rate and the uplift rate after the innovation is realized.

(3) Both horizontal and vertical cooperation models are effective in realizing Pareto improvement on the total profit of the franchise system. And the innovation realization rate and improvement rate positively affect this improvement effect. It is worth noting that the improvement effect of vertical cooperation model on total system profit is stronger and better in the case of high realization rate-high promotion rate.

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