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Research Article

The Development Strategy of Dual-Channel Supply Chain of Smart Elderly Care Service from the Perspective of Time Perception

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The development of smart elderly industry is an inevitable way to cope with the aging of the population. This research takes the smart elderly care service supply chain as the object, combines the social emotional choice theory for the first time, and uses the time perception to refine the elderly care demand into future-orientation demand and present-orientation demand. This paper analyzes the coordination effect of suppliers' efforts to meet the needs of the elderly under the two conditions of no contract and benefit-sharing contract on the dual-channel supply chain of smart elderly care services. The results show that the benefit-sharing contract is more conducive to maximizing the profit of the supply chain, and the segmentation of elderly demand is conducive to giving full play to the advantages of dual-channel differentiated services, which is conducive to forming a win-win situation of improving the service efficiency of the smart elderly service supply chain and increasing the happiness index of elderly users. The main contributions of this paper are: Using geriatric behavioral psychology to analyze the motivation of the elderly and designing the service effort level index considering the needs of the elderly. Match online and offline channels with personalized services to give full play to the "smart" effect. Based on the game method of Hotelling and Stackelberg, the coordination and optimization of the smart elderly care services dual-channel supply chain, considering the needs of the elderly are realized. This is of great research significance for maximizing the benefits of the smart elderly service supply chain and promoting the development of the smart elderly industry.

1. Introduction

China's 14th Five-Year Plan will upgrade the development of smart elderly care industry as a national strategy. The 20th National Congress of the Communist Party of China in October 2022 proposed to "Implement the national strategy of actively responding to the aging of the population, develop old-age care and elderly care service industry, optimize the services for the elderly who are alone and widowed, and promote the realization of basic elderly services for all the elderly." Today, the aging of the population has become the most distinctive trend of globalization in the current era. The United Nation's 《World Society Report 2023》 shows that the proportion of the global population over the age of 65 will reach 761 million in 2021. China's aging is characterized by large scale, deep degree, and fast speed. It is expected that by 2035, the elderly population over 60 years old will exceed 400 million and will be entering the severe aging stage. China will also become the country with the most serious aging population in the world. So the aging of population is an important factor affecting China's economic development, and actively responding to the aging of population is an inevitable requirement for the realization of Chinese modernization [1, 2].

In order to conform to the development trend of the silver economy era, the smart elderly industry has taken shape under the promotion of modern information technology such as AI. According to the statistics of 《2022–2028 China Smart Pension Industry Development Trend and Investment Decision Proposal Report in 2020》: The scale of China's smart elderly service industry reached 3.75 trillion RMB in 2020 and is expected to expand to 17.5 trillion RMB in 2040. However, from the current development situation, the development of smart elderly industry in China is still in the primary stage, and does not perfectly fit elderly distribution characteristics as 90% of old people choose to be at home, 7% old people choose community, and 3% old people choose institutional, that means the smart elderly industry development and "9073 endowment service pattern" are deviation, make more than 70% of the elderly in 90% of the home elderly population cannot be effectively met, while elderly care institutions and communities provide services with a high rate of empty beds and serious waste of resources. Investigate its root cause: supply and demand do not match; elderly demand will change with time migration. Affected by time perception, when the elderly to life time perception is not obvious, behavior motivation by capture information to increase knowledge growth, namely, to meet the demand of the future-orientation (Fo-stage), and as the elderly's perception time becomes increasingly strong, old people will pay more attention to emotion related to meet the present-orientation demand (Po-stage) [3]. But the current operation mechanism of China's smart elderly care service supply chain does not take into account the migration of elderly demands under time perception, which leads to the imbalance of supply and demand structure. The specific manifestations are the construction of elderly care service platforms and elderly care service institutions has weak basic functions, narrow coverage, and single intelligent service content, which do not fully play the "wisdom" efficiency [4]; the physical heterogeneity of the elderly is enhanced; and the characteristics of personalized, differentiated, and sporadic needs are revealed. However, the elderly care services are still mainly to meet the basic life care needs, but the spiritual needs such as humanistic care are not valued [5]. Limited by multiple factors such as service scope, technology application, ability, and level, elderly service providers are difficult to provide accurate and efficient elderly care services to the elderly [6].

Based on this, it is the focus of the paper to solve the fragmentation of supply resources, give play to the differentiated service advantages of the platform and the elderly service center, and coordinate the main relationship of the elderly service supply chain to meet the diversified needs considering users' time perception of the elderly. Around the above problems, the paper considers the user time perception factors, and from the perspective of meeting the future oriented elderly needs and the current oriented elderly needs, to build the smart elderly service supply chain including elderly service providers and elderly service integrator, to break the flat efficiency limit of online service platform and offline elderly care service center as the means and achieve supply chain coordination as the goal, design smart elderly service dual-channel supply chain include online and offline service channel, so as to meet the demand of elderly, promote smart elderly industry supply and demand matching, elderly service high quality development have important significance.

The rest of the paper is organized as follows. Section 2 reviews and summarizes the literature related to the smart elderly dual-channel supply chain and user time perception, then puts forward the research questions and summarizes the innovation points according to the research gap. Section 3 provides the problem description and the parameter symbol description. Section 4 designs the smart elderly dual-channel supply chain coordination optimization model under no-contract and benefit-sharing contract. Section 5 analyzes the influence of each parameter on the coordination effect of supply chain through example analysis. Section 6 is management insights. Section 7 contains conclusions, research limitations, and future prospects.

2. Literature Review

2.1. Smart Elderly Care Service Supply Chain. The supply chain of elderly care services has always been a hot topic of academic research. For this research, many scholars have studied the coordination and optimization of supply chains including elderly service providers and elderly service integrators from multiple perspectives. For example, Chen is based on the perspective of information incentive mechanism [7], Ma et al. [8] and Zhao [9] are based on the perspective of contract mechanisms such as revenue sharing and punishment contracts, and Zhang et al. [10] are based on the perspective of government incentives. Among them, service quality [9, 11], medical services [12], and nursing staff scheduling [13] are the focus of research on the supply chain of elderly care services.

In the 50s of the twentieth century, the British Trust Fund first put forward the concept of smart elderly care, and a new type of elderly care model began to enter the public eye. Scholars such as Wang et al. and Song et al. have proposed that the information-based comprehensive service platform for elderly care has achieved breakthrough innovation on the supply side of elderly care services, providing conditions for grasping the demand for elderly care [14, 15]. However, at present, there are relatively few studies on the use of intelligence advantages to study the smart elderly care service supply chain, and only Chen designed the operation mechanism of the smart elderly care service supply chain with the service platform as the core [16]. Furthermore, from the perspective of global aging, it is of great significance to study the supply chain of smart elderly care services to alleviate social pressure and promote the development of the silver economy.

2.2. Dual-Channel Supply Chain. The research of distribution channels has always been a very important concept, and the study of dual-channel supply chains has matured [17]. In recent years, scholars such as Jaśkowski et al. [18], He et al. [19], and Ha et al. [20] have focused on the two directions of supply chain channel conflict and coordination strategy. How to effectively deal with channel conflicts caused by the loss of self-interest and other reasons, and improve the efforts of supply chain members to achieve the overall coordination of direct sales and retail channels through the design of contract coordination mechanisms has become an important area of concern [21, 22]. With the rise of e-commerce platforms, such as Zhang et al. [23], Barman et al. [24], and Kazancoglu et al. [25], they have promoted the online agency and resale model and the online and offline dual-channel model to become the research hotspots. The Hotelling and Stackelberg game methods have gradually become the main means to achieve dual-channel supply chain coordination. Among them, Hotelling proposed that under the premise of considering the behavior of other competitors, the utility model should be constructed through the Hotelling game method, and the implementation of product differentiation would be more conducive to maximizing profits [26]. Also, Wang and Chen used Hotelling to build a consumer utility model to achieve dual-channel supply chain coordination [27]. Stackelberg is the most important method to achieve dual-channel supply chain optimization as a sequential game [28, 29]. There are relatively few studies on the issue of dual-channel supply chain for elderly care services, and only one scholar, Zhao has constructed a dual-channel supply chain for elderly medical services, arguing that the community service model of O2O is more conducive to the effective coordination of the elderly care service supply chain [30]. Therefore, there is still a lot of research space for using the Hotelling and Stackelberg game methods to solve the problem of elderly care service supply chain coordination.

2.3. Smart Elderly Care Service Supply Chain considering the Needs of the Elderly. Regarding the research on the smart elderly care service supply chain considering the needs of the elderly, we found that only Cai et al. designed the service-sensitive demand index [31] and Zhang et al. analyzed the quality decision-making problem of the elderly care service supply chain from the perspective of the scale of elderly care demand [32]. But nobody has yet considered the condition that the demand for elderly care will change over time when studying the supply chain of smart elderly care services. Carstensen et al. proposed that the behavioral motivation of the elderly will be affected by the user's time perception, and over time, the elderly will transition from the future-orientation needs that focus on information growth to the present-orientation needs that focus on emotional companionship [3]. At present, user time perception is mostly used to study the emotional changes, judgment and attention, intertemporal choice, and other fields of the elderly [33–35]. If the user's time perception factor can be added to the research scope of the dual-channel supply chain development strategy of smart elderly care services, it will make an important breakthrough for realizing the balance of supply and demand and supply chain coordination of the smart elderly care industry.

To sum up, there are three limitations on the current research about the dual-channel development strategy of smart elderly service supply chain: (1) Most of the existing literature focuses on the pricing or the improvement of service quality level of the elderly care service supply chain, and there is a lot of research space for how to give full play to the "smart" efficiency of the elderly care service. (2) The research on the selection of dual-channel development strategy of supply chain using Stackelberg or other game methods is mostly focused on the manufacturing field. Nevertheless, research on the dual-channel supply chain coordination of the smart elderly care industry relying on the smart elderly service platform is worth more in-depth exploration. (3) Although a few scholars have considered factors such as uncertain elderly demand or demand preference when studying the elderly service supply chain, no literature has studied the coordination and optimization of the dual-channel supply chain of smart elderly service on the premise of subdividing the elderly demand based on the user time perception factors of elderly behavior psychology.

In order to further explore the smart elderly service dual-channel supply chain development strategy, the paper starts from the unique perspective of user time perception, divided the elderly demand into the present-orientation demand and the future-orientation demand two patterns, for discussing how to choose the service channel to bring the elderly better service experience, so as to realize the smart elderly service supply chain efficient coordination. At length to alleviate the mismatch between supply and demand in the smart elderly industry from the root causes. Specifically, the paper mainly focuses on the following three research issues: (1) How does the user time perception time affect the elderly needs? (2) Under the no-contract and benefit-sharing contract, what is the optimal decision and profit of the members of the smart elderly care service supply chain considering the elderly demand? (3) What is the optimal channel choice strategy for the whole supply chain and old people?

The main contributions of the paper are as follows: (1) Combined with the theory of geriatric behavioral psychology, this paper analyzes the time perception of the elderly to identify the future-orientation and the present-orientation of the elderly care needs, and increases the parameters of the level of elderly needs. (2) Proposing the "online + offline" dual-channel parallel mode relying on the smart elderly service care platform, to better elaborating the "smart" efficiency. (3) Putting forward the dual-channel differentiated service strategy, using the Hotelling-Stackelberg coordination of the smart elderly care service dual-channel supply chain, and optimizing the supply and demand structure of the smart elderly care industry.

3. Problem Description and Symbol Description

3.1. Problem Description. This paper constructs a dual-channel supply chain system for smart elderly care services, including elderly care service providers, elderly care service integrators (offline service channels and online service channels) and elderly care users (shown as Figure 1). Among them, according to the user's time perception coefficient, the elderly service provider divides the level of effort to meet the needs of the elderly into N_{Fo} for the information service effort level to meet the needs of the future-orientation and N_{Po} for the emotional service effort level to meet the needs of the present-orientation, and provides personalized services to the elderly users through online service channels and offline service channels, respectively. Elderly users in the Po-stage will spend the market service price p_r to enjoy the elderly care service with the service level of s_r through offline service channels, and the elderly users in the Fo-stage will spend the market service price p_e to enjoy the elderly care service with the service level of s_e.

Combined with the Hotelling model, this paper implements a differentiated service strategy by expanding the supply channels of elderly care service integrators. Offline elderly care center A and online elderly care service platform B are located at both ends of a linear market. The elderly user O is distributed between AB, and the line OA is the elderly user who chooses the offline service channel (x), and the OB represents the elderly user who chooses the online service channel (1-x). Among them, referring to the research design of Gu et al. [36], Wei and Lu [37], offline service channels and online service channels will generate comprehensive costs such as transportation (t) and search (c), respectively, and the hidden loss cost of the smart elderly care market is divided into the loss cost of offline channels based on transportation costs (t^*x) and the loss cost of online channels based on search costs (c^* (1-x)), as shown in Figure 2.

In response to the above problems, the paper puts forward the following hypotheses:

(1) Elderly users obey an even distribution in the range of the pension market (0, 1).
(2) In order to meet the strategic conditions of service differentiation, it is assumed that there are certain competitive behaviors between online service channels and offline service channels.
(3) In order to meet the laws of reality, set: $0 < c, t < p_r, p_e$; $0 < w < p_r, p_e$.
(4) This research considers the sensitivity of the price of one channel service to the price change of another channel service, and sets the cross-sensitivity coefficient of dual-channel price α and β of the elderly service integrator. Also, $0 < \alpha < 1$, $0 < \beta < 1$.
(5) Considering the heterogeneity of dual-channel services, this paper assumes that the service improvement cost impact coefficients of offline service channels and online service channels are θ and φ, respectively, $0 < \theta < 1$ and $0 < \varphi < 1$. The cost of service improvement is $1/2\mathrm{s}_\mathrm{r}^2$ and $1/2\mathrm{s}_\mathrm{e}^2$.

The research objectives of this paper are to use Hotelling to construct a utility function firstly, then with the online service channel as the leader and the offline service channel as the follower to carry out the Stackelberg game, so as to analyze the impact of the service effort level of the elderly service provider to meet the present and future orientation needs and the service quality of elderly service integrator on the coordination of the smart elderly care service dual-channel supply chain under the no-contract model and the benefit-sharing contract and at last, obtain the optimal decision.

3.2. Symbol Description. The model parameters and variables definition is shown in Table 1.

4. Coordination and Optimization Model of the Dual-Channel Supply Chain of Smart Elderly Care Service

4.1. Hotelling Model and Profit Function. According to the Hotelling model, the utility functions of offline service channels and online service channels can be expressed in the following formulas:

$$U - \alpha p_r + \beta p_e - tx + \mu \mathrm{N}_{\mathrm{Po}} + \theta s_r, \tag{1}$$

$$U - \alpha p_e + \beta p_r - c(1 - x) + (1 - \mu)\mathrm{N}_{\mathrm{Fo}} + \varphi s_e. \tag{2}$$

For elderly at the point of no difference, the total utility obtained by choosing online service channels and choosing offline service channels is equal, which can be expressed in the following formulas:

$$\int_0^x dx = \frac{c + \mathrm{N}_{\mathrm{Po}}\mu + \alpha p_e - \alpha p_r + \beta p_e - \beta p_r - \varphi s_e + \theta s_r + (1 - \mu)\mathrm{N}_{\mathrm{Fo}}}{c + t}, \tag{3}$$

$$\int_x^1 dx = \frac{t - \mathrm{N}_{\mathrm{Po}}\mu - \alpha p_e + \alpha p_r - \beta p_e + \beta p_r + \varphi s_e - \theta s_r - (1 - \mu)\mathrm{N}_{\mathrm{Fo}}}{c + t}. \tag{4}$$

Combined with Figure 2 and formulas (3) and (4) you can see, the elderly who in the left range (0, x) belong to choose offline service channels, and in the right (x, 1) range belong to choose online service channels, respectively, corresponding to offline elderly care service demand $\mathrm{Q_r}$ and online elderly care service demand Q_e, can be expressed in the following formulas:

$$\mathrm{Q_r} = \frac{c + \mathrm{N}_{\mathrm{Po}}\mu + \alpha p_e - \alpha p_r + \beta p_e - \beta p_r - \varphi s_e + \theta s_r - (1 - \mu)\mathrm{N}_{\mathrm{Fo}}}{c + t}, \tag{5}$$

$$\mathrm{Q_e} = \frac{t - \mathrm{N}_{\mathrm{Po}}\mu - \alpha p_e + \alpha p_r - \beta p_e + \beta p_r + \varphi s_e - \theta s_r + (1 - \mu)\mathrm{N}_{\mathrm{Fo}}}{c + t}. \tag{6}$$

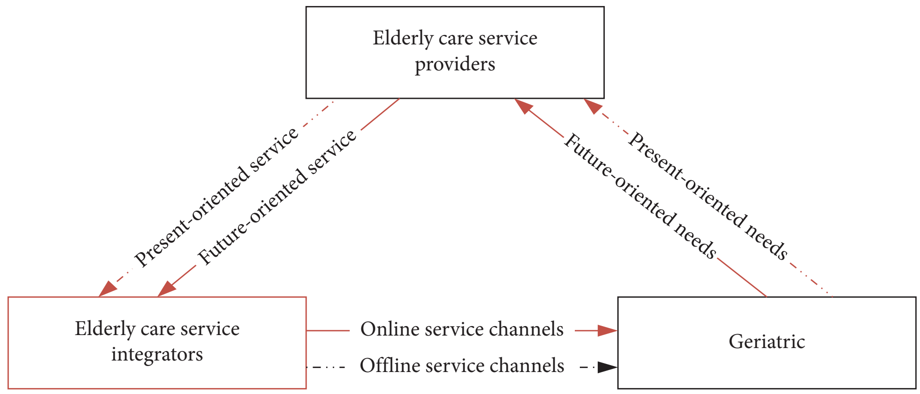

Figure 1: Dual-channel supply chain system of smart elderly care service.

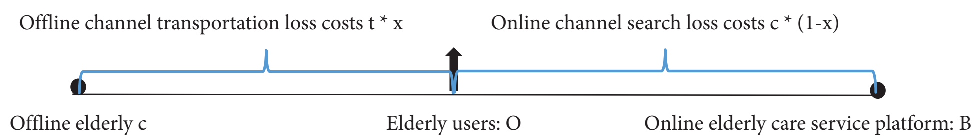

Figure 2: A schematic diagram of the hidden loss cost of the smart elderly care market.

Table 1: Model parameters and variables.

Parameters	
α	Offline service channel price cross-coefficient [38]
β	Online service channel price cross-coefficient [38]
θ	The influence coefficient of the service improvement cost of the offline service channel [39]
φ	The influence coefficient of the service improvement cost of the online service channel [39]
μ	The coefficient of effort paid by elderly care service providers to content the current oriented needs of the elderly [40] $(0 < \mu < 1)$
λ	Benefit sharing coefficient of elderly care service integrators [8]
Variables	
w	The price of basic service from elderly care service providers to elderly care service integrators
x	No difference point [36, 37]
t	The sum of transportation costs such as unit service costs to choose offline service channels [36, 37]
N_{Po}	The level of service efforts paid by elderly care service providers to content the present-orientation needs of the elderly [40]
N_{Fo}	The level of service efforts paid by elderly care service providers to content the future-orientation needs of the elderly [40]
U	The total utility of elderly care services [37]
Q_r	Market demand of offline elderly care service channels
Q_e	Market demand for online elderly care service channels
$Л_s$	Elderly care service provider benefits
$Л_r$	Elderly care service integrator's offline service channel benefits
$Л_e$	Elderly care service integrator's online service channel benefits
$Л$	Total revenue from the smart elderly care service supply chain
Decision variables	
p_r	Service price of offline service channel
p_e	Service price of online service channel
s_r	Service level of offline service channels
s_e	Service level of online service channels

Because the market share is set to 1, the profit function of the elderly care service providers are expressed as: $Л_s = w - c_s$. The offline service channels profit functions $Л_r$ and online service channels profit functions $Л_e$ can be expressed in the following formulas:

$$Л_r = (p_r - w)Q_r - \frac{1}{2}s_r^2, \tag{7}$$

$$Л_e = (p_e - w)Q_e - \frac{1}{2}s_e^2. \tag{8}$$

4.2. No-Contract Decision Model. In the no-contract decision model, the Stackelberg decision order dominated by the online service channels of the elderly care service integrator is: First, the online service channels determine their service price p_e and service level s_e according to the elderly market; the offline service channels determine their service price p_r and service level s_r according to the online service channels. The online and offline channels of elderly care service integrator meet the master and slave game relationship. In order to simplify the calculation, the service cost is only expressed as the basic elderly care service price w paid to elderly care service providers. The no-contract decision model is represented by superscript "d," and the optimal solution is represented by superscript "*."

In the no-contract decision model, we count the first partial derivatives of p_r, s_r, p_e, and s_e as formulas (7) and (8) according to the backward induction method. Combined with $(\partial Л_r/\partial p_r) = 0$, $(\partial Л_r/\partial s_r) = 0$, $(\partial Л_e/\partial p_e) = 0$, $(\partial Л_e/\partial s_e) = 0$, the optimal service price and the optimal service level of the online service channels and the offline service channels of elderly care service integrator are obtained, as shown in the following formulas:

$$p_r^{d*}\left(p_e^{d*}, s_e^{d*}\right) = \frac{\left(3c^2 + 2t^2 + 5ct - w\varphi^2 - 2w\theta^2\right)}{\left(4\alpha c + 4\beta c + 4\alpha t + 4\beta t - 2\theta^2 - \varphi^2\right)} + \frac{(c+t)\left(4w(\alpha+\beta)^2 - \theta^2 - \varphi^2 + (\alpha+\beta)\left(\mu N_{Po} - (1-\mu)N_{Fo}\right)\right)}{(\alpha+\beta)\left(4\alpha c + 4\beta c + 4\alpha t + 4\beta t - 2\theta^2 - \varphi^2\right)}, \tag{9}$$

$$s_r^{d*}\left(p_e^{d*}, s_e^{d*}\right) = \frac{\theta\left(3\alpha c + 3\beta c - \alpha N_{Fo} - \beta N_{Fo} + 2\alpha t + 2\beta t + \alpha\mu N_{Fo} + \alpha\mu N_{Po} + \beta\mu N_{Fo} + \beta\mu N_{Po} - \theta^2 - \varphi^2\right)}{(\alpha+\beta)\left(4\alpha c + 4\beta c + 4\alpha t + 4\beta t - 2\theta^2 - \varphi^2\right)}, \tag{10}$$

$$\begin{aligned} p_e^{d*} = {} & \frac{\left(2c^2 + 4t^2 + 6ct - w\varphi^2 - 2w\theta^2 + 2tN_{Fo} + 2cN_{Fo} - 2\mu(t+c)\left(N_{Fo} + N_{Po}\right)\right)}{\left(4\alpha c + 4\beta c + 4\alpha t + 4\beta t - 2\theta^2 - 2\varphi^2\right)} \\ & + \frac{\theta^2\left(\theta^2 + (\alpha+\beta)\left(\mu N_{Fo} + \mu N_{Po} - N_{Fo} - 4t - 3c\right)\right)}{(\alpha+\beta)^2\left(4\alpha c + 4\beta c + 4\alpha t + 4\beta t - 2\theta^2 - 2\varphi^2\right)}, \end{aligned} \tag{11}$$

$$s_e^{d*} = \frac{\varphi\left(\alpha c + \beta c + \alpha N_{Fo} + \beta N_{Fo} + 2\alpha t + 2\beta t - \alpha\mu N_{Fo} - \alpha\mu N_{Po} - \beta\mu N_{Fo} - \beta\mu N_{Po} - \theta^2\right)}{(\alpha+\beta)\left(4\alpha c + 4\beta c + 4\alpha t + 4\beta t - \theta^2 - \varphi^2\right)}. \tag{12}$$

In the no-contract decision model, the following conclusions are drawn:

Theorem 1. *There must be p_r^{d*} and s_r^{d*} to maximize the profit of offline service channels.*

Prove: Using formula (8) to count the first partial derivative of p_r and s_r: $(\partial Л_r/\partial p_r)$ and $(\partial Л_r/\partial s_r)$, obtain the following formulas:

$$\frac{\partial Л_r}{\partial p_r} = \frac{\left(c + \alpha p_e - \alpha p_r + \beta p_e - \beta p_r - \varphi s_e + \theta s_r + \mu N_{Po} - (1-\mu)N_{Fo}\right) - (\alpha+\beta)\left(p_r - w\right)}{c+t}, \tag{13}$$

$$\frac{\partial Л_r}{\partial s_r} = \frac{\theta\left(p_r - w\right)}{c+t} - s_r. \tag{14}$$

Calculate the second partial derivatives of p_r and s_r, we obtain

$$\frac{\partial^2 Л_r}{\partial {p_r}^2} = -\frac{2(\alpha+\beta)}{c+t}, \tag{15}$$

$$\frac{\partial^2 Л_r}{\partial {s_r}^2} = -1. \tag{16}$$

According to formula (15), if $2(\alpha + \beta) > 0$ and $(c + t) > 0$, $\partial^2 Л_r/\partial {p_r}^2 < 0$ is established. According to formula (16), $-1 < 0$ and $\partial^2 Л_r/\partial {p_r}^2 < 0$ is established.

On this basis, make formulas (13) and (14) equal to 0, can obtain

$$p_r^d = \frac{c - N_{Fo} + \alpha p_e + \beta p_e + \alpha w + \beta w - \varphi s_e + \mu N_{Po} + \mu N_{Fo}}{2(\alpha + \beta)},$$
$$s_r^d = \frac{\theta (p_r - w)}{c + t}. \tag{17}$$

Solve the optimal offline service price p_r^{d*} and the optimal offline service level s_r^{d*} of the offline service channels, as shown in the following formulas.

$$p_r^{d*} = \frac{ct - cN_{Fo} - tN_{Fo} - \theta^2 w + c^2 + \alpha c p_e + \beta c p_e + \alpha c w + \beta c w - c\varphi s_e + c\mu N_{Fo} + c\mu N_{Po} + \alpha t p_e + \beta t p_e + \alpha t w + \beta t w - t\varphi s_e + t\mu N_{Fo} + t\mu N_{Po}}{2\alpha c + 2\beta c + 2\alpha t + 2\beta t - \theta^2}, \tag{18}$$

$$s_r^{d*} = \frac{\theta \left(c - N_{Fo} + \alpha p_e + \beta p_e - \alpha w - \beta w - \varphi s_e + \mu N_{Fo} + \mu N_{Po}\right)}{2\alpha c + 2\beta c + 2\alpha t + 2\beta t - \theta^2}. \tag{19}$$

Therefore, the optimal offline service price p_r^{d*} and the optimal offline service level s_r^{d*} can maximize the offline optimal profit $Л_r^{d*}$, Theorem 1 proof complete.

Theorem 2. *There may be p_e^{d*} and s_e^{d*} to maximize the profit of online service channels $Л_e^{d*}$. The restriction was: $2\alpha c + 2\beta c + 2\alpha t + 2\beta t > \theta^2$.*

Prove: Substitute the optimal service price p_r^{d*} and the optimal service level s_r^{d*} of offline service channels into formula (8), and get the reaction function $Л_e(p_r^{d*}, s_r^{d*})^d$ of the profit function of the online service channels of the elderly service integrator, as shown in the following formula:

$$Л_e\left(p_r^{d*}, s_r^{d*}\right)^d = \frac{2(\alpha + \beta)\left(\left(\varphi s_e - \mu N_{Fo} - \mu N_{Po}\right)(p_e - w) - w(c + 2t + N_{Fo}) - s_e^2 (t + c)\right) - \theta^2 (p_e + s_e + w) - (\alpha + \beta)^2 \left(2p_e^2 + w^2\right) + 2\alpha\beta w p_e}{4\alpha c + 4\beta c + 4\alpha t + 4\beta t - 2\theta^2}. \tag{20}$$

Next, solve the first derivative of online elderly care service price p_e and online elderly care service level s_e: $(\partial Л_e(p_r^{d*}, s_r^{d*})^d/\partial p_e)$ and $(\partial Л_e(p_r^{d*}, s_r^{d*})^d/\partial s_e)$, as shown in the following formulas:

$$\frac{\partial Л_e\left(p_r^{d*}, s_r^{d*}\right)^d}{\partial p_e} = \frac{\alpha c + \beta c + \alpha N_{Fo} + \beta N_{Fo} + 2\alpha t + 2\beta t - 2\alpha^2 p_e - 2\beta^2 p_e + 2\alpha^2 w + 2\beta^2 w - \theta^2 - 4\alpha\beta p_e + 4\alpha\beta w + \alpha\varphi s_e + \beta\varphi s_e - \alpha\mu N_{Fo} - \alpha\mu N_{Po} - \beta\mu N_{Fo} - \beta\mu N_{Po}}{2\alpha c + 2\beta c + 2\alpha t + 2\beta t - \theta^2}, \tag{21}$$

$$\frac{\partial Л_e\left(p_r^{d*}, s_r^{d*}\right)^d}{\partial s_e} = \frac{\theta^2 s_e - 2\alpha c s_e - 2\beta c s_e + \alpha\varphi s_e + \beta\varphi s_e - \alpha\varphi w - \beta\varphi w - 2\alpha t\varphi s_e - 2\beta t\varphi s_e}{2\alpha c + 2\beta c + 2\alpha t + 2\beta t - \theta^2}. \tag{22}$$

Order$(\partial Л_e(p_r^{d*}, s_r^{d*})^d/\partial p_e) = 0$, $(\partial Л_e(p_r^{d*}, s_r^{d*})^d/\partial s_e) = 0$, obtain the following formulas:

$$\frac{\partial Л_e\left(p_r^{d*}, s_r^{d*}\right)^d}{\partial p_e} = \frac{\alpha c + \beta c + \alpha N_{Fo} + \beta N_{Fo} + 2\alpha t + 2\beta t + 2\alpha^2 w + 2\beta^2 w - \theta^2 + 4\alpha\beta w + \alpha\varphi s_e + \beta\varphi s_e - \alpha\mu N_{Fo} - \alpha\mu N_{Po} - \beta\mu N_{Fo} - \beta\mu N_{Po}}{2(\alpha+\beta)^2}, \tag{23}$$

$$\frac{\partial Л_e\left(p_r^{d*}, s_r^{d*}\right)^d}{\partial s_e} = \frac{\varphi(\alpha+\beta)(p_e - w)}{2\alpha c + 2\beta c + 2\alpha t + 2\beta t - \theta^2}. \tag{24}$$

Calculate the second partial derivative of p_e and s_e, we can obtain

$$\frac{\partial^2 Л_e}{\partial p_e{}^2} = -\frac{2(\alpha+\beta)^2}{2\alpha c + 2\beta c + 2\alpha t + 2\beta t - \theta^2}, \tag{25}$$

$$\frac{\partial^2 Л_e}{\partial s_e{}^2} = -1. \tag{26}$$

According to formula (25), because $2(\alpha+\beta)^2 > 0$, $\partial^2 Л_e/\partial p_e{}^2 < 0$ is valid, only if $2\alpha c + 2\beta c + 2\alpha t + 2\beta t - \theta^2 > 0$ exists. According to formula (26), $\partial^2 Л_e/\partial s_e{}^2 = -1 < 0$ constant is true. Based on this, it can be determined that optimal service price of Online service channels has an equilibrium solution in $2\alpha c + 2\beta c + 2\alpha t + 2\beta t - \theta^2 > 0$, at this time, exist p_e^{d*} and s_e^{d*}, can make $Л_e^{d*}$ maximize. Theorem 2 has been proven.

Finally, the optimal profit of offline service channels $Л_r^{d*}$ and the optimal profit of online service channel $Л_e^{d*}$ of elderly care service integrator under no-contract decision are obtained as shown in the following formulas:

$$Л_r^{d*} = \frac{\left(2\alpha c + 2\beta c + 2\alpha t + 2\beta t - \theta^2\right)\left(3\alpha c + 3\beta c - \theta^2 - \varphi^2 - \alpha N_{Fo} - \beta N_{Fo} + 2\alpha t + 2\beta t + \alpha\mu N_{Fo} + \alpha\mu N_{Po} + \beta\mu N_{Fo} + \beta\mu N_{Po}\right)^2}{2(\alpha+\beta)^2\left(4\alpha c + 4\beta c + 4\alpha t + 4\beta t - 2\theta^2 - \varphi^2\right)^2}, \tag{27}$$

$$Л_e^{d*} = \frac{\left(\alpha c + \beta c - \theta^2 + \alpha N_{Fo} + \beta N_{Fo} + 2\alpha t + 2\beta t - \alpha\mu N_{Fo} - \alpha\mu N_{Po} - \beta\mu N_{Fo} - \beta\mu N_{Po}\right)^2}{2(\alpha+\beta)^2\left(4\alpha c + 4\beta c + 4\alpha t + 4\beta t - 2\theta^2 - \varphi^2\right)}. \tag{28}$$

Because the diversity and quality services provided by elderly care service providers are closely related to the satisfaction of geriatric, moreover the satisfaction of geriatric has a direct impact on the service price and service level. Based on this, under the no-contract decision model, we further analyze the relationship between the optimal service price (p_r^{d*} and p_e^{d*}), the optimal service level (s_r^{d*} and s_e^{d*}) and the present-orientation and Future-orientation service effort level (N_{Po} and N_{Fo}), get Inferences 3 and 4.

Inference 3. Under certain conditions, p_r^{d*} is the increasing function of N_{Po} and the minus function of N_{Fo}, the limit condition is $4(\alpha+\beta)(c+t) > 2\theta^2 + \varphi^2$; at the same time, there may be the increasing function of p_e^{d*} is N_{Fo} and the minus function of N_{Po}, the limit condition is $0 < 2(\alpha+\beta)(c+t) - \theta^2 < \varphi^2/2$.

Prove: From formulas (12) and (14), respectively, count the first partial derivatives for N_{Po} and N_{Fo}, obtained: $(\partial p_r^{d*}/\partial N_{Po}) = (\mu(c+t))/(4(\alpha+\beta)(c+t) - 2\theta^2 - \varphi^2)$; $(\partial p_r^{d*}/\partial N_{Fo}) = (-(1-\mu)(c+t))/(4(\alpha+\beta)(c+t) - 2\theta^2 - \varphi^2)$; $(\partial p_r^{d*}/\partial N_{Po}) = -(\mu(2(\alpha+\beta)(c+t) - \theta^2))/(4(\alpha+\beta)(c+t) - 2\theta^2 - \varphi^2)$; $(\partial p_r^{d*}/\partial N_{Fo}) = ((1-\mu)(2(\alpha+\beta)(c+t) - \theta^2)/4(\alpha+\beta)(c+t) - 2\theta^2 - \varphi^2)$ obviously, $\mu(c+t) > 0, -(1-\mu)(c+t) < 0$. Therefore, when $4(\alpha+\beta)(c+t) > 2\theta^2 + \varphi^2$, there is $(\partial p_r^{d*}/\partial N_{Po}) > 0$, $(\partial p_r^{d*}/\partial N_{Fo}) < 0$, that is, p_r^{d*} is the increasing function of N_{Po} and the minus function of N_{Fo}; when $4(\alpha+\beta)(c+t) - 2\theta^2 - \varphi^2 > 0$, there must be $2(\alpha+\beta)(c+t) - \theta^2 > 0$, $-\mu(2(\alpha+\beta)(c+t) - \theta^2) < 0$, $(1-\mu)(2(\alpha+\beta)(c+t) - \theta^2) > 0$, there is $(\partial p_r^{d*}/\partial N_{Po}) < 0$ and $(\partial p_r^{d*}/\partial N_{Fo}) > 0$, p_e^{d*} is the increasing function of N_{Fo}, and the minus function of N_{Po}. Inference 3 has been proven.

Inference 4. Under certain conditions, s_r^{d*} is the increasing function of N_{Po} and the minus function of N_{Fo}, s_e^{d*} is the increasing function of N_{Fo} and the minus function of N_{Po}, and the limit condition is $4(\alpha+\beta)(c+t) > 2\theta^2 + \varphi^2$.

Prove: According to formula (11), count the first partial derivatives for N_{Po} and N_{Fo}, $(\partial s_r^{d*}/\partial N_{Po}) = (\mu\theta)/(4(\alpha+\beta)(c+t) - 2\theta^2 - \varphi^2)$; $(\partial s_r^{d*}/\partial N_{Fo}) = (-(1-\mu)\theta)/(4(\alpha+\beta)(c

$+ t) - 2\theta^2 - \varphi^2)$; $(\partial s_r^{d*}/\partial N_{Po}) = (-\varphi\theta)/(4(\alpha + \beta)(c + t) - 2\theta^2 - \varphi^2)$; $(\partial s_e^{d*}/\partial N_{Fo}) = ((1 - \mu)\varphi)/(4(\alpha + \beta)(c + t) - 2\theta^2 - \varphi^2)$. The proof process is similar to Inference 3, and will not be repeated.

Under the no-contract model, the service price (p) and the service level (s) of dual-channel elderly care service are closely related to the elderly care service providers' service effort level (N) to meet the present-orientation and future-orientation needs of elderly. Generally, the elderly care service providers efforts to satisfy the demand of present-orientation (N_{Po}) will directly improve the price (p_r) and service level (s_r) of offline service channels, it means that as the geriatric for emotional company of humanistic care demand increase, can promote the service level of offline service channels, and also will bring more profits for offline service channels. Similarly, when the elderly care service providers to meet the demand of future-orientation (N_{Fo}) will directly improve the price (p_e) and service level (s_e) of online service channels, it means that when the elderly demand related to learning and growth increase, online service channels need to provide more quality service. At the same time, with the improvement of market service prices will make it get more profits.

However, under certain conditions, the level of efforts made by elderly care service providers for different elderly needs will also be negatively correlated with the service price and service quality of the dual-channels. Influenced by the price cross-coefficient, the more the value of α and β approaches to 1, the stronger substitution of online service channels and offline service channels becomes. At this time, no matter how high the level of effort paid by N_{Po} and N_{Fo} is, it cannot attract geriatric. Under this condition, take offline service channels as an example: if the geriatric pay offline transportation costs (t) increase, the demand of offline service channels will decrease, and the demand of online service channels will increase, will inevitably affect the elderly users of offline service channels, cause offline service price (p_r) and service level reduction (s_r). Offline service channels need to pay more service improvement costs to maintain the service level.

4.3. Benefit-Sharing Contract Decision Model. In the dual-channel supply chain of smart elderly care service, the development of online service channels has seized the market share of some offline service channels. In this scenario, designing a benefit-sharing contract can help the whole dual-channel supply chain of smart elderly care service to be greater than that of the no-contract decision model. Further realize the coordination and optimization of the smart elderly care service supply chain. Thus, elderly care service providers still provide elderly care services to elderly care service integrators at the reasonable price w, and the online and offline channels of elderly care service integrators take the form of cooperation. Elderly care service integrators recommend corresponding service channels to elderly users according to the needs of different stages, and a certain proportion will income subsidies from online service channels to offline service channels. In the context of benefit-sharing contract, the needs of elderly users in different stages can match different service channels, which can not only increase the satisfaction of elderly users, but also bring more benefits to the smart elderly care service supply chain. Assuming that the benefit-sharing coefficient of the online service channel of the elderly care service integrator is λ, and the benefit-sharing coefficient of the offline service channel is (1-λ). The decision result is represented by the superscript "c."

At this point, the profit function of the offline service channel and the offline service channel can be expressed in the following formulas:

$$\Pi_r^c = (p_r - w)Q_r + (1 - \lambda)p_e Q_e - \frac{1}{2}s_r^2, \tag{29}$$

$$\Pi_e^c = \lambda p_e Q_e - w Q_e - \frac{1}{2}s_e^2. \tag{30}$$

In the case of benefit-sharing contract, according to the backward induction method, count the first partial derivative of p_r, s_r, p_e, and s_e in formulas (29) and (30), combined $(\partial\Pi_r^c/\partial p_r) = 0$, $(\partial\Pi_r^c/\partial s_r) = 0$, $(\partial\Pi_e^c/\partial p_e) = 0$, $(\partial\Pi_e^c/\partial s_e) = 0$, and obtain the optimal service price and the optimal service level of the elderly care service integrator, as shown in the following formulas:

$$\begin{aligned} p_r^{c*} &= \frac{\lambda((c + t)(\mu N_{Fo} + \mu N_{Po} - N_{Fo}) - ct) - w\varphi^2 + (c + t)^2 - t^2\lambda}{(2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2} \\ &\quad + \frac{\theta^2(\lambda(c + t)(1 - \lambda) - w(\alpha + \beta)) - \varphi^2(\lambda^2 t + c\theta^2) + w(\alpha^2 + \beta^2)(c + t)(2 + \lambda)}{\lambda(\alpha + \beta)((2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2)}, \end{aligned} \tag{31}$$

$$s_r^{c*} = \frac{\theta(c + \lambda(c + t) + \mu N_{Fo} + \mu N_{Po} - N_{Fo})}{(2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2} - \frac{\theta\lambda\varphi^2}{(\alpha + \beta)(2\alpha c + 2\beta c + 2\alpha t + 2\beta t - 2\theta^2 - \lambda\varphi^2 + \lambda\theta^2)}, \tag{32}$$

$$p_e^{c*} = \frac{(c + t)(N_{Fo} - \mu N_{Fo} - \mu N_{Po}) + 3ct - w\varphi^2 + (c + t)^2 + t^2 + ct}{(2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2} + \frac{w(\alpha^2 + \beta^2)(c + t)(2 + \lambda) - \theta^2(\lambda(c + t) + w(\alpha + \beta))}{\lambda(\alpha + \beta)((2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2)}, \tag{33}$$

$$s_e^{c*} = \frac{\lambda\varphi(c + 2t + N_{Fo} - \mu N_{Fo} - \mu N_{Po})}{(2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2} - \frac{\lambda\theta^2\varphi}{(\alpha + \beta)\left(2\alpha c + 2\beta c + 2\alpha t + 2\beta t - 2\theta^2 - \lambda\varphi^2 + \lambda\theta^2\right)}. \tag{34}$$

Under the benefit-sharing contract decision model, the following conclusions are drawn:

Theorem 5. *In the context of benefit-sharing contract, there must be p_r^{c*} and s_r^{c*} to maximize the profit $Л_r^{c*}$ of the offline service channel of the elderly care service integrators.*

Prove: Evidence: using formulas (29) and (30) to calculate the first and second-order partial derivatives of p_r and s_r, we obtain

$$\frac{\partial Л_r^c}{\partial p_r} = \frac{\mu N_{Po} + \mu N_{Fo} - N_{Fo} + c + \theta s_r + (\alpha + \beta)(2p_e - \lambda p_e - 2p_r + w)}{c + t}, \tag{35}$$

$$\frac{\partial Л_r^c}{\partial s_r} = \frac{\theta(p_r - w + \lambda p_e - p_e)}{c + t} - s_r, \tag{36}$$

$$\frac{\partial^2 Л_r^c}{\partial {p_r}^2} = -\frac{2(\alpha + \beta)}{c + t}, \tag{37}$$

$$\frac{\partial^2 Л_r^c}{\partial {s_r}^2} = -1. \tag{38}$$

According to formula (37), if $2(\alpha + \beta) > 0$ and $(c + t) > 0$, $\partial^2 Л_r^c/\partial {p_r}^2 < 0$ is established. According to formula (38), if $-1 < 0, \partial^2 Л_r^c/\partial {s_r}^2 < 0$ is established. Theorem 5 has been proven.

Theorem 6. *In the context of benefit-sharing contract, there must be p_e^{c*} and s_e^{c*} to maximize the profit $Л_e^{c*}$ of the online service channel of the elderly care service integrator.*

Prove: consistent with the above steps, further calculate the second partial derivative of p_e and s_e, get: $\partial^2 Л_e^c/\partial {p_e}^2 = -(2\lambda(\alpha + \beta))/(c + t) < 0; \partial^2 Л_e^c/\partial {p_e}^2 = -1 < 0$. Based on this, there must be p_e^{c*} and s_e^{c*} that maximize the $Л_e^{c*}$. Theorem 6 has been proven.

Similarly, under the profit-sharing contract scenario, to further analyze the relationship between the level of elderly demand effort (N_{Po} and N_{Fo}) and the price of elderly care services (p_r^{c*} and p_e^{c*}) and the level of elderly care services (s_r^{c*} and s_e^{c*}), we can draw the following inferences:

Inference 7. Under certain conditions, p_r^{c*} is the increasing function of N_{Po} and the subtraction function of N_{Fo}; p_e^{c*} is the increasing function of N_{Fo} and the subtraction function of N_{Po}. The limit condition is $(2 + \lambda)(\alpha + \beta)(c + t) > \theta^2 + \lambda\varphi^2$.

According to formulas (31)–(33), the first partial derivative for N_{Po} and N_{Fo}, respectively, to obtain: $(\partial p_r^{c*}/\partial N_{Po}) = (\lambda\mu(c + t))/((2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2)$; $(\partial p_r^{c*}/\partial N_{Fo}) = -(\lambda(1 - \mu)(c + t))/(2(\alpha + \beta)(c + t) - 2\theta^2 - \lambda\varphi^2 + \lambda\theta^2)$; $(\partial p_e^{c*}/\partial N_{Po}) = -(\mu(c + t))/((2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2)$; $(\partial p_e^{c*}/\partial N_{Fo}) = ((1 - \mu)(c + t))/((2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2)$, it shows that $\lambda\mu(c + t) > 0, -\lambda(1 - \mu)(c + t) < 0, -\mu(c + t) < 0, (1 - \mu)(c + t) > 0$. Therefore, when $(2 + \lambda)(\alpha + \beta)(c + t) > \theta^2 + \lambda\varphi^2$, there are $(\partial p_r^{c*}/\partial N_{Po}) > 0$, $(\partial p_r^{c*}/\partial N_{Fo}) < 0$, $(\partial p_e^{c*}/\partial N_{Po}) < 0$, $(\partial p_e^{c*}/\partial N_{Fo}) > 0$. Inference 7 has been proven.

Inference 8. Under certain conditions, s_r^{c*} is an increasing function of N_{Po} and a decreasing function of N_{Fo}; s_e^{c*} is a decreasing function of N_{Po} and an increasing function of N_{Fo}. The limit condition is $(2 + \lambda)(\alpha + \beta)(c + t) > \theta^2 + \lambda\varphi^2$.

Prove: according to formulas (32) and (34), count the first partial derivative of N_{Po} and N_{Po}, respectively: $(\partial s_r^{c*}/\partial N_{Po}) = (\mu\theta)/((2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2)$; $(\partial s_r^{c*}/\partial N_{Fo}) = -(\theta(1 - \mu))/(2(\alpha + \beta)(c + t) - 2\theta^2 - \lambda\varphi^2 + \lambda\theta^2)$; $(\partial s_e^{c*}/\partial N_{Po}) = -(\varphi\lambda\mu)/((2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2)$; $(\partial s_e^{c*}/\partial N_{Fo}) = ((1 - \mu)\lambda\varphi)/((2 + \lambda)(\alpha + \beta)(c + t) - \theta^2 - \lambda\varphi^2)$, it shows that $\mu\theta > 0, -\theta(1 - \mu) < 0, -\varphi\lambda\theta < 0, (1 - \mu)\lambda\varphi > 0$. Therefore, when $(2 + \lambda)(\alpha + \beta)(c + t) > \theta^2 + \lambda\varphi^2$, there are $(\partial s_r^{c*}/\partial N_{Po}) > 0$, $(\partial s_r^{c*}/\partial N_{Fo}) < 0$, $(\partial s_e^{c*}/\partial N_{Po}) < 0$, $(\partial s_e^{c*}/\partial N_{Fo}) > 0$. Inference 8 has been proven.

Under the benefit-sharing contract mechanism, the decision-making status of offline service channel has changed, and the optimal service price (p_r^{c*} and p_e^{c*}) and the optimal service level (s_r^{c*} and s_e^{c*}) maximize the profit of elderly care service integrators ($Л_r^{c*}$ and $Л_e^{c*}$) simultaneously. $Л_r^{c*}$ and $Л_e^{c*}$ are shown in the following formulas :

$$\text{Л}_{\mathrm{r}}^{c*}=\frac{(\alpha+\beta)\left[2\lambda^2(c+t)^2(3-\lambda)\left(\mu\mathrm{N}_{\mathrm{Po}}-(1-\mu)\mathrm{N}_{\mathrm{Fo}}\right)+\lambda(c+t)\left(4\mathrm{w}\left(\theta^2\left(4(\lambda+1)+\varphi^2(\lambda+2)^2-6\right)\right)+\left(\mu\mathrm{N}_{\mathrm{Po}}-(1-\mu)\mathrm{N}_{\mathrm{Fo}}\right)^2+2t^2+6(c+t)^2+4t(1-\mu)\mathrm{N}_{\mathrm{Fo}}-2\theta^2w\right]}{2\left((2-\lambda)(\alpha+\beta)(c+t)-\theta^2-\lambda\varphi^2\right)}$$
$$+\frac{2\lambda^2(c+t)\left((1-\mu)\mathrm{N}_{\mathrm{Fo}}-\mu\mathrm{N}_{\mathrm{Po}}\right)\left(\varphi^2(\lambda+1)+2\theta^2\right)+\theta^2\left(\lambda\left(\mu^2\left(\mathrm{N}_{\mathrm{Fo}}+\mathrm{N}_{\mathrm{Po}}\right)^2+2\mu\mathrm{N}_{\mathrm{Po}}\left(\mathrm{N}_{\mathrm{Fo}}+t\right)+\mathrm{N}_{\mathrm{Fo}}\left((\mu-1)\left(\mathrm{N}_{\mathrm{Fo}}+2t\right)-\mu\mathrm{N}_{\mathrm{Fo}}\right)+\lambda^2c(c+2t)\right)+t\left(3+t\lambda^2\right)+c\right)}{2\left((2-\lambda)(\alpha+\beta)(c+t)-\theta^2-\lambda\varphi^2\right)}$$
$$+\frac{2w\left(\theta^4-\lambda^3\varphi^4\right)-\varphi^2(3c+2t)}{2\left((2-\lambda)(\alpha+\beta)(c+t)-\theta^2-\lambda\varphi^2\right)}+\frac{\lambda\left[(\mathrm{c}+\mathrm{t})\left(\varphi^4\lambda^2+\theta^4(1-2\lambda)\right)+\theta^2\varphi^2\left(2(c+t)+\mu\mathrm{N}_{\mathrm{Po}}-(1-\mu)\mathrm{N}_{\mathrm{Fo}}\right)\right]}{(\alpha+\beta)\left((2-\lambda)(\alpha+\beta)(c+t)-\theta^2-\lambda\varphi^2\right)}++\frac{w(\alpha+\beta)^2(c+t)^2\left(4-\lambda^2(\lambda+3)\right)}{(2-\lambda)(\alpha+\beta)(c+t)-\theta^2-\lambda\varphi^2}, \tag{39}$$

$$\text{Л}_{\mathrm{e}}^{c*}=\frac{\lambda\left(2(\alpha+\beta)(c+t)-\lambda\varphi^2\right)\left((\alpha+\beta)\left(\mathrm{c}+2\mathrm{t}+(1-\mu)\mathrm{N}_{\mathrm{Fo}}-\mu\mathrm{N}_{\mathrm{Po}}\right)-\theta^2\right)^2}{2(\alpha+\beta)^2\left((2+\lambda)(\alpha+\beta)(c+t)-\theta^2-\lambda\varphi^2\right)}. \tag{40}$$

At the same time, carding Theorems 1, 2, 5, and 6, found: At the same time, comparing Theorems 1, 2, 5, and 6, it is found that in the no-contract decision mode, the second-order partial derivatives of the optimal price p_r^{d*} and optimal service level s_r^{d*} of the offline service channel in Theorem 1$\partial^2\text{Л}_r/\partial p_r{}^2<0$ and $\partial^2\text{Л}_r/\partial s_r{}^2<0$ are constant establishment. Also, second partial derivative of the optimal price p_e^{d*} and optimal service level s_e^{d*} in Theorem 2: $\partial^2\text{Л}_e/\partial p_e{}^2<0$ and $\partial^2\text{Л}_e/\partial s_e{}^2<0$ are only at $2(\alpha+\beta)(\mathrm{c}+\mathrm{t})-\theta^2>0$ can be established. After joining the benefit-sharing contract, it is not difficult to find through the proof results of Theorems 5 and 6 that the second derivative of the optimal price (p_r^{c*} and p_e^{c*}) and the optimal service level (s_r^{c*} and s_e^{c*}) of dual-channels are constant establishment. This means that after adding the benefit-sharing coefficient λ, the profit optimization of online service channels breaks through the limit of $2(\alpha+\beta)(c+t)-\theta^2>0$. This is due to the fact that the dual-channels of elderly service integrators realize the efficient matching of channels and elderly demands in the context of benefit-sharing, so as to further optimize the conditions for profit maximization. So that there must be the optimal service price and the optimal service level, make the profit optimal.

Finally, according to the results of Inferences 3, 4, 7, and 8, we found that after adding parameters about meeting the elderly demands of Future-orientation and present-orientation of service providers' service effort level (N_{Fo} and N_{Po}), which can optimize the price and level of elderly services. So as to promote the coordination of the smart elderly services dual-channel supply chain, whether it is the no-contract decision-making model (Inferences 3 and 4) or the benefit-sharing contract decision-making model (Inferences 7 and 8). Next, the research will further demonstrate the feasibility of the conclusion through example analysis.

5. Example Analysis

5.1. Sensitivity Analysis of the Decision Model in No-Contract. In this section, MATLAB software is used to verify the effectiveness of benefit-sharing contract for coordinating the smart elderly care service supply chain through numerical examples, and the relevant parameters are set as: $w=20$; $c_s=10$; $c=12$; $\alpha=0.6$; $\beta=0.4$; $\theta=0.4$; $\varphi=0.3$; $t=18$.

5.1.1. No-Contract Decision Model. In the no-contract situation, the impact of the level of effort paid to satisfy the two-stage needs of the elderly on the optimal service price and the optimal service level was further analyzed. Figures 3(a) and 3(b), respectively, show the sensitivity analysis of the effort level (N_{Po} and N_{Fo}) paid by elderly care service providers to satisfy the present-orientation needs and future-orientation needs to the optimal market price ($\mathrm{p}_{\mathrm{r}}^{\mathrm{d}*}$ and $\mathrm{p}_{\mathrm{e}}^{\mathrm{d}*}$) of elderly care service integrators.

In general, under the influence of China 9073 pension model, 90% of elderly users choose the home care model. Therefore, after opening online service channels, home care is more convenient, and various functional services tend to be more convenient and intelligent. As can be clearly seen from Figures 3(a) and 3(b), the optimal market price ($\mathrm{p}_{\mathrm{e}}^{\mathrm{d}*}$) of online service channels is always higher than the optimal market price ($\mathrm{p}_{\mathrm{r}}^{\mathrm{d}*}$) of offline service channels, that is, $\mathrm{p}_{\mathrm{e}}^{\mathrm{d}*}>\mathrm{p}_{\mathrm{r}}^{\mathrm{d}*}$.

From the changing trend: in Figure 3(a), as elderly care service providers make increasing efforts of (N_{Po}) to satisfy the present-orientation needs of the elderly, the elderly are increasingly satisfied with the present-orientation of humanistic care such as emotional companionship, and will stimulate the market share (Q_r) of elderly care service integrators. At this time, the service price ($\mathrm{p}_{\mathrm{r}}^{\mathrm{d}*}$) of offline service channels will lead to an upward trend. The service price ($\mathrm{p}_{\mathrm{e}}^{\mathrm{d}*}$) of the online service channel has an obvious declining trend; opposite, when N_{Fo} increasing, the trend of $\mathrm{p}_{\mathrm{e}}^{\mathrm{d}*}$ is rising. However, the $\mathrm{p}_{\mathrm{r}}^{\mathrm{d}*}$ showed a decreasing trend. The outcome is consistent with the Inference 3.

Figures 4(a) and 4(b), respectively, show the sensitivity analysis of the effort level (N_{po} and N_{Fo}) paid by elderly care service providers to satisfy the present-orientation needs and future-orientation needs to the optimal service level ($\mathrm{s}_{\mathrm{r}}^{\mathrm{d}*}$ and $\mathrm{s}_{\mathrm{e}}^{\mathrm{d}*}$) of elderly care service integrators.

In general, the experience brought by offline service channels to elderly users is more intuitive and specific, so the service level of offline service channels is often higher than that of online service channels, that is, $\mathrm{s}_{\mathrm{e}}^{\mathrm{d}*}>\mathrm{s}_{\mathrm{r}}^{\mathrm{d}*}$. The changing trend of $\mathrm{s}_{\mathrm{r}}^{\mathrm{d}*}$ and $\mathrm{s}_{\mathrm{e}}^{\mathrm{d}*}$ shown in Figures 4(a) and 4(b) is consistent with Figure 3. The larger N_{Po} is the enthusiasm of offline service channels and $\mathrm{s}_{\mathrm{r}}^{\mathrm{d}*}$ will be increasing; the larger N_{Fo} is, the increasing trend of $\mathrm{s}_{\mathrm{e}}^{\mathrm{d}*}$ is more obviously, in stent with Inferences 3 and 4.

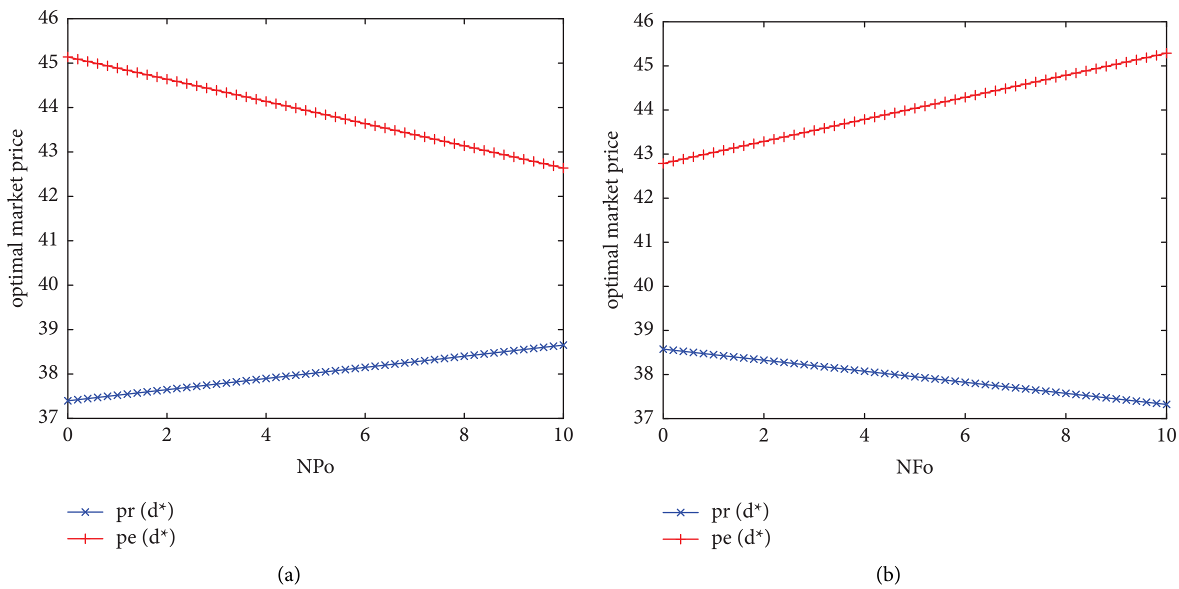

Figure 3: (a) N_{Po} sensitivity analysis to service price of dual-channels. (b) N_{Fo} sensitivity analysis to service price of dual-channels.

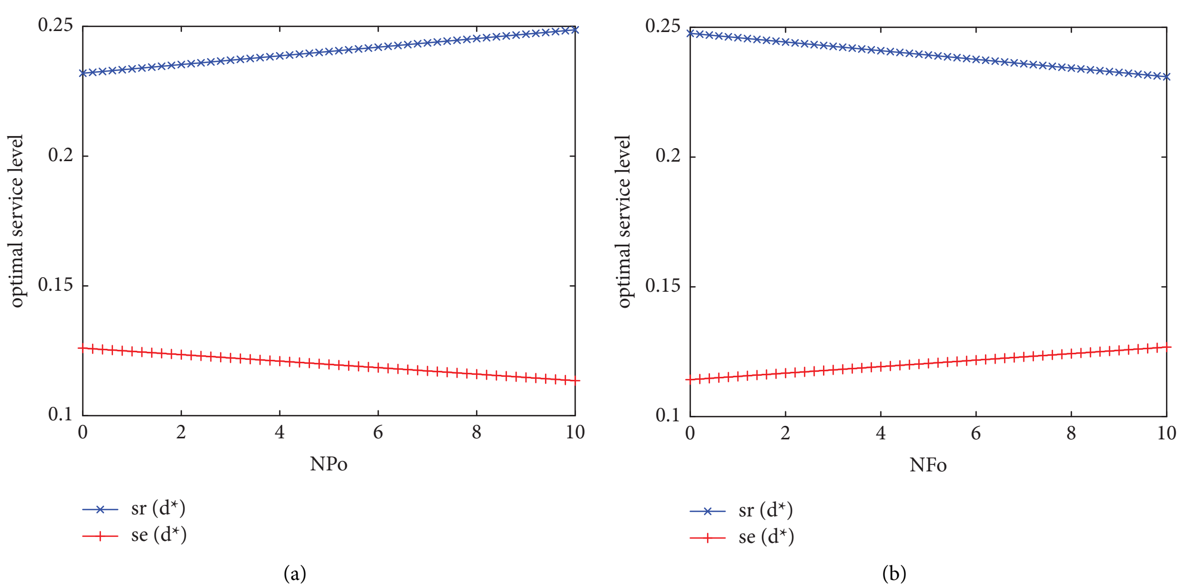

Figure 4: (a) N_{po} sensitivity analysis to service level of dual-channels. (b) N_{Fo} sensitivity analysis to service level of dual-channels.

Continue to discuss the impact of the changes in the parameters such as the price cross-coefficient (α, β) related to the elderly care service price (p) and the level of elderly care service (s) with the cost coefficient of service improvement (θ, φ) on the supply chain of smart elderly care service as shown in Figures 5 and 6.

Figures 5(a) and 5(b) on the price cross-coefficient (α and β) analyzes the influence of elderly care service price effect, you can see whether offline service channel price cross-coefficient α or online service channel price cross-coefficient of β, also means that as α and β infinite approach to 1, alternative online service channels and offline service channels will be stronger, both channels cannot give full play to their own advantages, will inevitably lead to the price (p_r^{d*} and p_e^{d*}), hope by reducing its price to get more market share.

Figures 6(a) and 6(b) analyze the effect of the service improvement coefficient (θ and φ) on the service level. It can be seen that with the service improvement of Offline service channels, the greater the cost impact coefficient θ, the service level of Offline service channels is getting higher and higher. The dual channels achieve equilibrium at $\theta = 0.2$. Similarly, with the greater the service improvement coefficient of the online service channel, the online service level of the service channel φ is also on the rise, and the dual channels achieve equilibrium at $\varphi = 0.59$. At the same time, Figure 6 shows that the influence coefficient of the cost of service improvement of

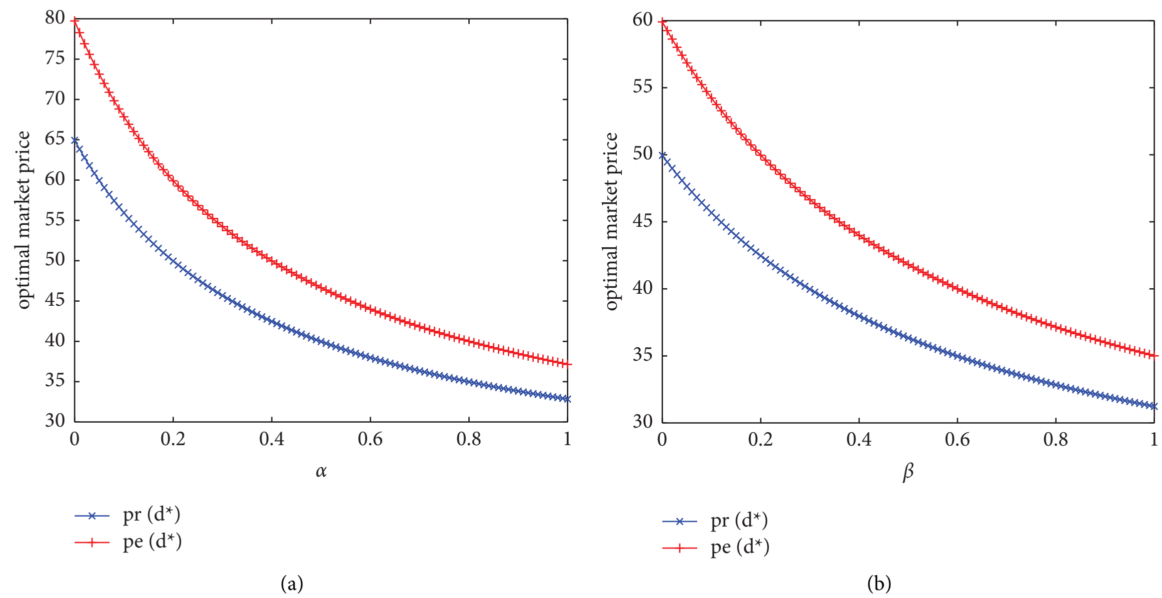

FIGURE 5: (a) α sensitivity analysis to service price of dual-channels. (b) β sensitivity analysis to service price of dual-channels.

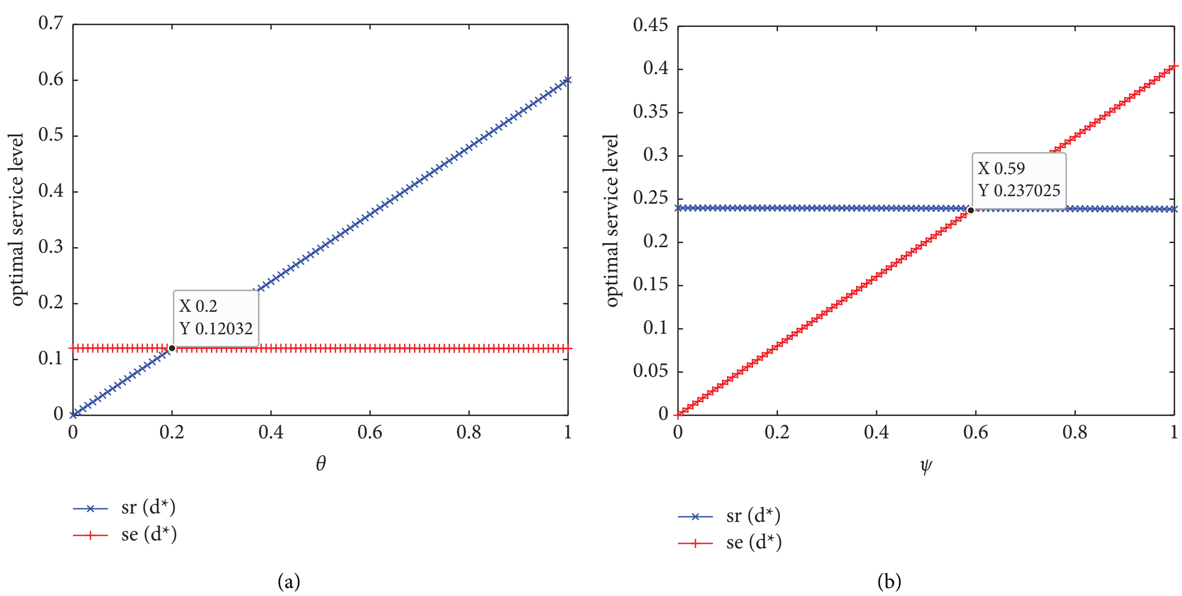

FIGURE 6: (a) θ sensitivity analysis to service level of dual-channels. (b) φ sensitivity analysis to service level of dual-channels.

the dual channels only has an impact on their own service level, which means that the elderly care service integrator can only adjust the service level of offline service channels or online service channels by controlling the size of θ or φ.

5.2. Sensitivity Analysis of Each Parameter of the Benefit-Sharing Contract. After adding the benefit-sharing contract, the effect of the effort level to meet the elderly on the optimal service price and the optimal service level are as follows:

Figures 7(a) and 7(b), respectively, show the sensitivity analysis of the effort level (N_{Po} and N_{Fo}) of the elderly care service providers to the offline and online optimal market price (p_r^{c*} and p_e^{c*}) after joining the benefit-sharing contract.

Figures 7(a) and 7(b) can clearly see, to join the benefit-sharing contract, the future-orientation demand and present-orientation demand of elderly users have achieved a more accurate match with service supply dual channels. While the demand for the elderly is effectively satisfied, makes the dual channels of the optimal service price (p_r^{c*} and p_e^{c*}) are significantly improved. Also, it is still in line with the development trend of China's 9073 elderly care model, $p_r^{c*} > p_e^{c*}$.

From the perspective of the growth trend, with the efforts (N_{Po}) made by elderly service providers to meet the present-orientation needs of the elderly are creasing, the price of elderly service in offline service channels p_r^{d*} is still on the upward trend, while the price of elderly service in online service channels p_e^{d*} shows a downward trend; on the other

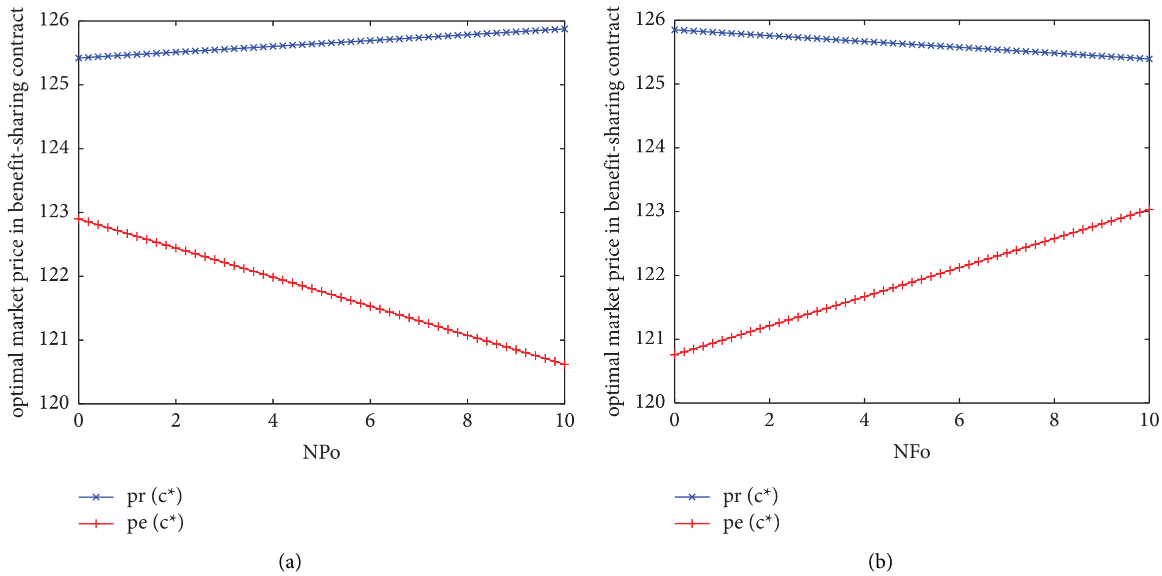

Figure 7: (a) N_{Po} sensitivity analysis to service price of dual-channels with benefit-sharing contract. (b) N_{Fo} sensitivity analysis to service price of dual-channels with benefit-sharing contract.

hand, elderly care service providers to meet the needs of the future-orientation of elderly care efforts ($\mathrm{N_{Fo}}$) is more and more bigger, offline service channels of elderly care service price $\mathrm{p_r^{d*}}$ is still declining, and online service channels of elderly care service prices are on the rise, and the growth of online service channels compared with offline service channels is more obvious. The outcome is consistent with the Inference 7.

Figures 8(a) and 8(b), respectively, show the sensitivity analysis of the effort level ($\mathrm{N_{Po}}$ and $\mathrm{N_{Fo}}$) on the offline and online optimal service level ($\mathrm{s_r^{c*}}$ and $\mathrm{s_e^{c*}}$) of the elderly care service integrators after joining the benefit-sharing contract.

From the level of service (s) change, online service channels and offline service channel docking elderly user demand more clearly, make service improvement cost decreased, and offline service level ($\mathrm{s_r^{d*}}$) is still rising, even the rising trend is more obvious, and it representative the benefit-sharing contract has a significant effect on reducing service improvement costs and improving service level $\mathrm{s_r^{d*}}$ effect is significant. The influence route of $\mathrm{N_{fo}}$ change on the optimal service price and the optimal service level is basically consistent with $\mathrm{N_{po}}$, which will not be repeated here.

Continue to discuss the impact of the changes in the price cross-coefficient (α, β) and the service price (p) and the service level (s) of the service on the supply chain of the smart elderly care service under the benefit-sharing contract as shown in Figures 9 and 10.

The effect of the price cross-coefficient (α and β) on the price of elderly care services in Figures 9(a) and 9(b) show that: After the original loss of offline service channels is subsidized by online service channel, price advantage increasing obviously, although there is still a price war between dual channels, but the price gap narrowed under the benefit-sharing contract. Proving that the benefit-sharing contract not only can improve the profits but also reduce the damage brought about by the price war. In Figures 10(a) and 10(b), the impact of service improvement coefficient (θ and φ) on service level is analyzed. It can be seen that θ and φ balance online and offline service channels at 0.16 and 0.74, respectively, and the service improvement cost is reduced.

5.3. Comparative Analysis of the Optimal Profit. In the case of the benefit-sharing contract, as the income-sharing coefficient λ changes within the (0, 1) interval, the equilibrium solution of each variable is shown in Table 2.

Through Table 1 can clearly see: first of all, as λ gradually smaller, the benefit ratio (1-λ) from online service channels share to offline service channel gradually bigger, means that the elderly demand will match to more suitable supply channels, so that the equilibrium solution of optimal service price p_r^c and p_e^c is higher and higher. In $\lambda = 0.1$, offline service channel optimal service price p_r^c is 50.95, and the online service channels of optimal service price p_e^c reached 50.47. Second, as λ gradually decrease, both offline optimal service level s_r^c or online optimal service level s_e^c basically presents a downward trend, this is due to the influence of benefit-sharing contract, channel recommended behavior between dual channels have a clear demand for geriatric, under the benefit-sharing contract mechanism, dual channels can have more energy to satisfy the specific needs of the geriatric, which spend less service improvement cost for higher elderly satisfaction. Finally, because the benefit-sharing contract mechanism set for the online service channel benefit in proportion to offline service channels, so the offline service channels of optimal profit $Л_r^c$ more and more increasing, and the offline service channels of optimal profit $Л_e^c$ has a slight downward trend, but for the supply chain total profit $Л^c$ is better than no-contract mode of supply chain total profit $Л^d$.

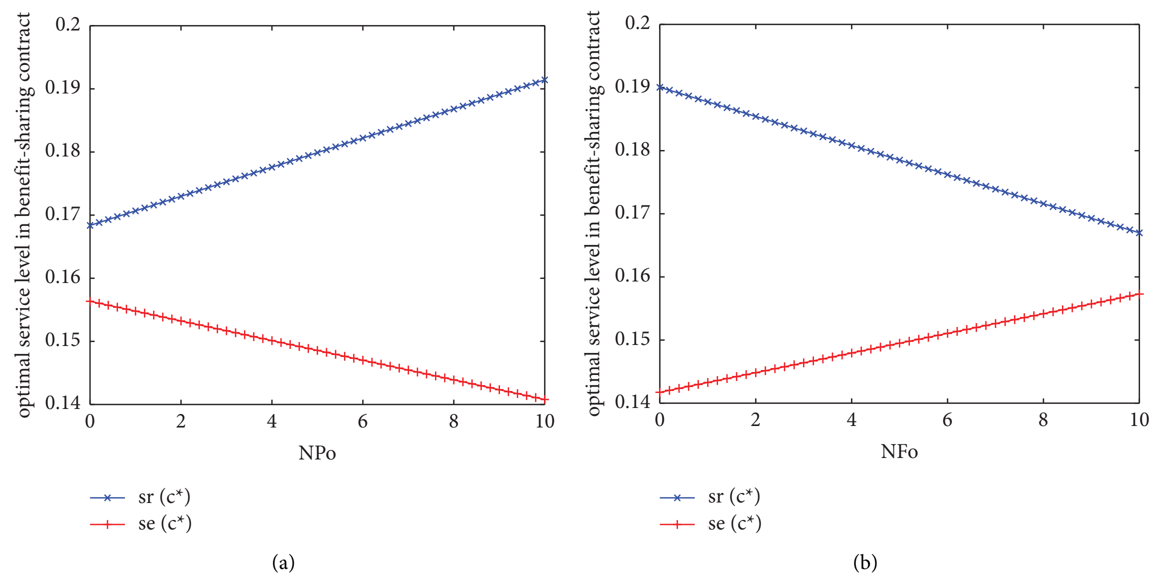

Figure 8: (a) N_{Po} sensitivity analysis to service level of dual-channels with benefit-sharing contract. (b) N_{Fo} sensitivity analysis to service level of dual-channels with benefit-sharing contract.

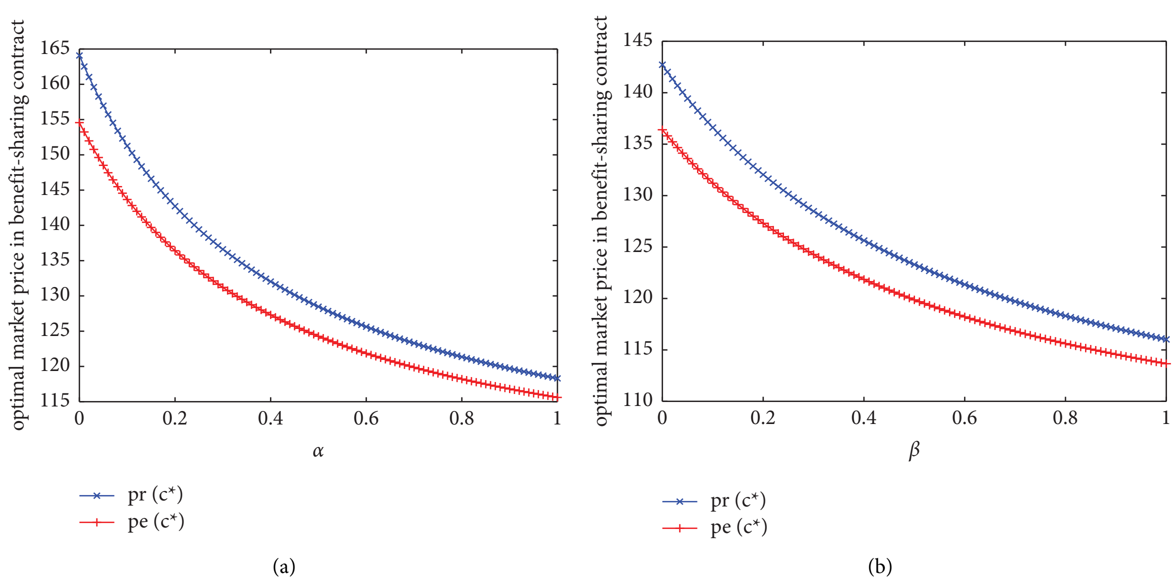

Figure 9: (a) α sensitivity analysis to service price of dual-channels with benefit-sharing contract. (b) β sensitivity analysis to service price of dual-channels with benefit-sharing contract.

Table 3 shows the analysis of the influence of N_{Po} and N_{Fo} on the decision variables paid by elderly care service providers to satisfy the present-orientation and future-orientation demands.

Through the change of time perception by elderly users, when the elderly demand for information increment is greater than the demand for emotional increment, often need to pay more related to the future-orientation service level N_{Fo}, otherwise need to elderly care service providers to pay more related to the present-orientation service effort level N_{Po}. As can be seen from Table 2 (top half), as N_{Fo} gradually increasing, whether there is a contract, offline service channel profit increased. Moreover, under the benefit-sharing contract, the offline service channel of optimal profit is significantly higher than that of offline service channel under the no-contract mode, namely, $\Pi_r^d > \Pi_r^c$. At the same time, the supply chain total profit is higher under the benefit-sharing contract, $\Pi^c > \Pi^d$. As can be seen from Table 2 (bottom half), as N_{Po} gradually increasing, whether there is a contract, online service channel profit also increased. It is different from the left side, because of the benefit-sharing contract, the online service channel revenue is distributed to offline service channels, so the optimal profit is slightly lower than the online service channel in no-contract mode on offline service channel of optimal profit, namely, $\Pi_e^c < \Pi_e^d$. But join the benefit-sharing

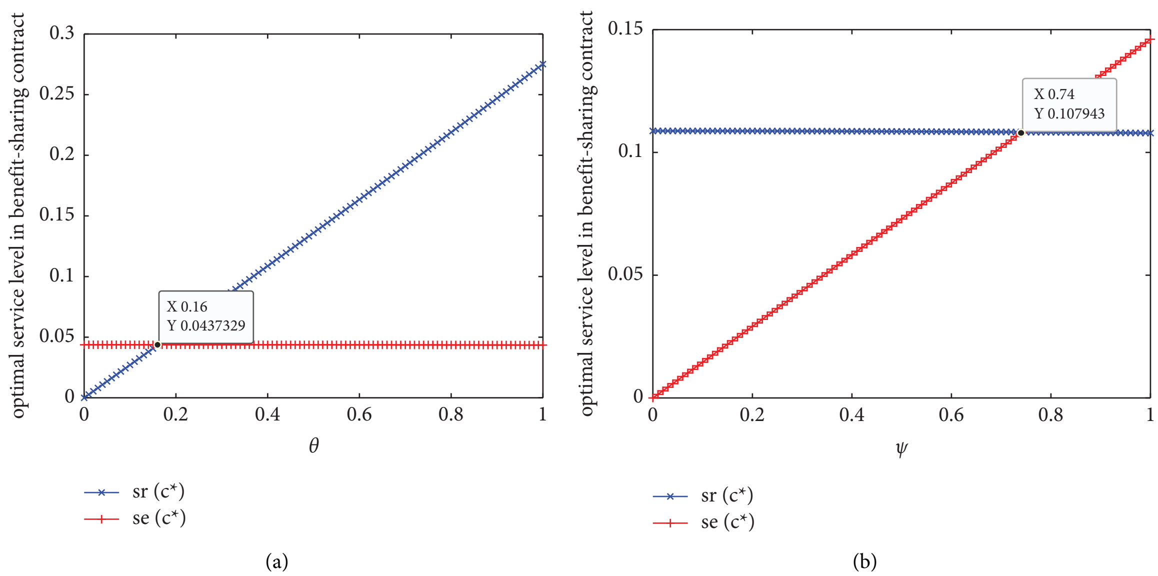

Figure 10: (a) θ sensitivity analysis to service level of dual-channels with benefit-sharing contract. (b) φ sensitivity analysis to service level of dual-channels with benefit-sharing contract.

Table 2: The optimal decision with the benefit-sharing coefficient λ in [0, 1].

λ	p_r^c	p_e^c	s_r^c	s_e^c	Π_r^c	Π_e^c	Π^c
0.9	9.62	12.03	0.15	0.17	2.82	4.30	17.12
0.8	10.72	12.85	0.14	0.16	3.99	4.10	18.09
0.7	12.01	13.86	0.13	0.14	5.39	3.86	19.25
0.6	13.59	15.12	0.12	0.13	7.09	3.57	20.66
0.5	15.60	15.80	0.11	0.11	9.25	3.22	22.47
0.4	18.34	19.16	0.09	0.09	12.16	2.79	24.95
0.3	22.46	22.89	0.08	0.07	16.58	2.28	28.86
0.2	30	30	0.07	0.05	24.33	1.67	36
0.1	50.95	50.47	0.05	0.03	45.62	0.91	56.53

Table 3: Optimal decision when the elderly demand changes.

	Π_r^d	Π_e^d	Π^d	Π_r^c	Π_e^c	Π^c
N_{Fo}						
1	10.18	10.39	30.57	18.51	7.99	46.50
2	10.32	10.19	30.51	18.6	7.83	36.43
3	10.47	9.97	30.44	18.69	7.67	36.36
4	10.62	9.77	30.39	18.78	7.51	36.29
5	10.77	9.57	30.34	18.88	7.36	36.64
6	10.92	9.37	30.29	18.97	7.21	36.18
7	11.07	9.17	30.24	19.07	7.05	36.12
8	11.23	8.98	30.2	19.17	6.90	36.07
9	11.38	8.79	30.17	19.28	6.76	36.04
N_{Po}						
1	11.33	8.86	40.18	19.23	6.81	36.04
2	11.16	9.06	30.22	19.13	6.96	36.09
3	11.01	9.25	30.26	19.03	7.11	36.14
4	10.86	9.45	30.31	18.93	7.27	36.20
5	10.71	9.65	30.36	18.84	7.42	36.26
6	10.56	9.85	30.41	18.75	7.58	36.33
7	10.41	10.05	30.46	18.65	7.73	36.39
8	10.27	10.26	30.53	18.57	7.89	36.46
9	10.12	10.47	30.59	18.48	8.05	36.53

contract, supply chain profits compared with no-contract mode of total profit is higher, $Л^c > Л^d$. To sum up, after adding the benefit-sharing contract, no matter how N_{Fo} and N_{Po} change, the total profit of the supply chain is higher than the total profit of the supply chain under the no-contract, that is, $Л^c > Л^d$ is constant established, which verifies the effectiveness of the revenue-sharing contract for maximizing the profit of the supply chain.

In general, compared with the noncontract model, the benefit-sharing contract has a more obvious effect on the optimal service price p_r^* and p_e^*, but the impact on the optimal service level s_r^* and s_e^* is relatively weak. The optimal profit under the benefit-sharing contract $Л^c$ is higher than that under the noncontract optimal profit $Л^d$. However, regardless of whether there is a contract or not, the larger the price cross-coefficient α and β, the smaller the channel characteristics and differences, the higher the substitution, and the lower the satisfaction of differentiated elderly services. From the perspective of elderly demands, the service effort level of elderly service providers to meet the present-orientation needs of elderly users N_{Po} is higher, the market share of offline service channels Q_r is greater, and then the service satisfaction of elderly users in the Po-stage is higher. In the same way, if the level of service effort made by the elderly care service providers to meet the future-orientation needs of the elderly care users N_{Fo} is higher, the market share of the online service channel Q_e is greater, and the service experience of the elderly care users in the Fo-stage is stronger. It can be seen that the service quality of the smart elderly service supply chain has an increasingly important impact on the sales Q, and the improvement rate of service improvement cost $1/2s_r^2$ and $1/2s_e^2$ is less than the growth rate of sales volume and supply chain profits, and the smart elderly service dual-channel supply chain, considering the needs of the elderly can obtain more profits.

6. Managerial Insights

According to the research results, this paper puts forward the following insights for improving the service level of the smart elderly care services dual-channel supply chain and realizing the efficient coordination of the whole supply chain.

First, the benefit-sharing contract mechanism has a limited coordination effect for the whole supply chain, and mainly improves the profit of the supply chain by affecting the service price. In the application of the contract, more reasonable restrictions should be designed by combining with the actual situation of the smart elderly care service supply chain. When necessary, it can be integrated into other contracts to achieve the coordination effect of the supply chain by improving the service level, so as to continue to optimize the supply chain system of smart elderly care service and achieve the goal of profit maximization.

Second, although the elderly care service mainly supplied by elderly care service providers, elderly care service integrators is the main elderly access to service, so in addition to the root of rich elderly care services and improve the quality of service at the same time, also should pay attention to the construction of online and offline service channels, give full play to the offline service channel experience and convenience of online service channels, take advantage of differentiated service to expand dual-channel market share, in order to realize the purpose of maximizing profit of supply chain.

Again, under the action of time perception, according to the change of the elderly needs in different times, further refine elderly care service providers provided by multiple elderly care services, such as the elderly daily life care preferences, through online service channels providing door-to-door companion service or accompanying to the hospital services, and offline service channels can mainly for disability or half disabled elderly provide 24 hours care and company services.

Finally, with the improvement of material living standards, the price is no longer the main factors for the elderly; therefore, when improving service quality need to pay service improvement cost and should consider the comprehensive benefits of service quality improvement to ensure smart elderly care service supply chain to achieve effective coordination, promote the smart elderly care service industry good sequence development, comprehensively improve the elderly's life happiness.

7. Conclusion and Future Directions

This paper combines the user's time perception to depict the present-orientation demands and future-orientation demands and further analyzes the coordinated effect of elderly service providers to meet the present-orientation demands and future-orientation demands of elderly users on the whole dual-channel supply chain of smart elderly care service. We found that: Compared with the no-contract model, the benefit-sharing contract is more conducive to the smart elderly care service supply chain to achieve win-win benefits through cooperation. At the same time, the elderly care service providers should choose different channels to provide personalized services to the elderly users according to the degree of time perception, which can give full play to the differentiated advantages of the two channels. In addition, improving the service level, strengthening the channel construction, and implementing the information and resource sharing between channels are of great significance for realizing the balance between supply and demand in the smart elderly care service supply chain, maximizing the benefits, and improving the happiness of the elderly.

However, there are still some limitations in our study. For example, when we build the utility model, we only subdivide the elderly demands into two deterministic needs: future-orientation demand and present-orientation demand according to the user's time perception, and do not consider other influencing factors such as region, economic development level, and education level. Nevertheless, these questions also provide research directions for more in-depth research in the future, such as the coordination of the smart elderly services supply chain considering regional, economic, and other factors, and the coordination of smart elderly supply chain considering smart elderly services and products at the same time.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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