Research on the Transformation to SFS Omnichannel and Price Influencing Factors Based on Consumer Channel Preferences

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Abstract. This paper constructs a supply chain consisting of one manufacturer, one offline retailer, and one online retailer. Using the Stackelberg model, it comparatively analyzes the optimal profits of the dual-channel retail model and the SFS(shipping from the store) omnichannel retail model in this supply chain. The analysis reveals that when the SFS channel market expansion coefficient reaches a certain threshold, the total profit of the SFS omnichannel supply chain will always be greater than that of the dual-channel supply chain. Therefore, for traditional offline retailers hoping to transition to omnichannel retail, expanding the SFS channel is a viable option. Furthermore, the paper analyzes the main factors affecting the pricing and profits of each member in the SFS omnichannel supply chain. The study finds that an increase in the SFS channel market expansion coefficient will enhance the supply chain's pricing and profits, and an increase in the level of value-added services will improve the supply chain's profits.

Keywords: Consumer Channel Preferences, dual-channel supply chain, omni-channel, SFS

1 Introduction

With the rapid advancement of mobile internet and digital technologies, consumer demands have become increasingly diverse, propelling the swift emergence of new retail paradigms. Compared to traditional retail, the new retail model integrates online and offline resources more effectively, meeting the personalized needs of consumers. Particularly, the omnichannel model, by merging online and offline channels, not only offers an immersive shopping experience akin to physical stores but also retains the price advantages of online shopping, allowing consumers to switch seamlessly between different channels, thereby gaining increasing market favor. In light of the continuous expansion of new retail paradigms, researching how traditional retail can transform into new retail, as well as determining the optimal pricing strategies and key factors influencing prices under the new retail model, holds profound significance for the industry's

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development. This study constructs a supply chain model that includes manufacturers, offline retailers, and online retailers. By comparing the profit performance of dual-channel retail models with the SFS omnichannel retail model, the study explores the commercial value and necessity of expanding the SFS channel.

With the deep integration of internet technology and the retail industry, the omnichannel retail model has been widely adopted and applied in actual operations, gradually becoming the mainstream trend within the industry. This model has not only led the development of the market but also attracted in-depth research and widespread attention from scholars. PC Verhoef et al. [1] (2015) theoretically explored the development trends of omnichannel retailing and the existing research on multichannel retailing, providing guidance for future research directions in this field. Emmanouela Sfakianaki et al. [2] (2022) comprehensively reviewed relevant literature and developed an interdisciplinary conceptual model focused on marketing and e-commerce domains. This model conceptualizes the impact of green strategies on customer experience in omnichannel retailing. Li Lin et al. [3] (2020), focusing on fresh food retailers operating both online and offline sales channels, considered the demand heterogeneity among different channels and studied their pricing strategies after adopting the "Buy Online Pick up in Store" (BOPS) service model. Wang Hang [4] (2020) deeply investigated two omnichannel retail models—"Shipping From Store"and "Deliver to Store"—analyzing the impact of these models on consumer purchasing behavior and the optimal pricing and ordering strategies of retailers, and identified the key conditions for retailers to implement omnichannel retail models. Liang Hefei et al. [5] (2023), by comparing the situation where omnichannel retailers implement only the BOPS model with the situation where they implement both BOPS and SFS models, discussed the conditions for introducing the SFS model and its potential impact on retailers' pricing decisions, demand, and profits. Zhang Zijian et al. [6] (2023) used the Hotelling model to describe market demand, constructed a Stackelberg supply chain model led by manufacturers, and analyzed the equilibrium pricing and service value under centralized and decentralized dual-channel and omnichannel strategies.

In summary, current research on omnichannel new retail primarily focuses on enterprises that have already adopted the new retail model, while relatively less attention has been given to traditional retail enterprises seeking to transform into new retail. At the same time, although some scholars have conducted research on the common BOPS (Buy Online Pick up in Store) service model in omnichannel retail, there is still insufficient exploration of emerging omnichannel models such as SFS (Store-First Shipment). In light of this, this paper aims to analyze the feasibility of supply chains incorporating SFS services to achieve transformation into omnichannel retail, as well as the key factors influencing supply chain pricing within the omnichannel retail model. Ultimately, this paper will utilize Mathematical software to perform simulation of the model to demonstrate its practicality and effectiveness.

2 Model Construction and Solution Analysis

2.1 Problem Description and Assumptions

In this paper, a supply chain model is constructed consisting of a manufacturer, an offline retailer and an offline retailer, with the manufacturer in a dominant position and the two retailers in a follower position.

For the convenience of the study, the following assumptions are made:

(1) This paper utilizes a linear city model, represented as a straight line from 0 to 1, with the point 0 denoting the offline retailer and the point 1 representing the online retailer, to simulate consumer preferences for shopping channels. Consumer preferences for online and offline channels are determined by their psychological distance from the ideal shopping point. Consumers who prefer offline shopping are psychologically closer to the offline retailer and thus more inclined to make purchases there; in contrast, those who prefer online shopping are more likely to buy from the online platform.

(2) The offline retailer offers additional value-added service value v to consumers to achieve a competitive advantage in the offline channel. Referring to the theory of cost for value-added services by Zhang et al. [5], let the cost of the value-added service be $c = \beta v^2/2$, where β is the service cost coefficient.

(3) In the omnichannel model, let u $(u>0)$ denote the potential market size, and α represents the proportion of demand for the online channel. Accordingly, $1\text{-}\alpha$ signifies the proportion of demand for the offline channel.

(4) Assuming that consumers with different shopping channel preferences are uniformly distributed within the interval [0,1], the proportion of consumers who place orders online and prefer the SFS channel is x $(0 < x < 1)$. Therefore, the proportion of consumers who prefer purely online shopping is $1 - x$. Since consumers will overcome physical and mental discomfort when choosing shopping channels, which incurs significant psychological costs and expenditures, the level of aversion to different shopping channels can be represented by transportation costs $tx^2 (t>0)$.

(5) The SFS channel facilitates consumers by offering greater flexibility in shopping and efficiency in delivery, stimulating the emergence of new demand. To capture the impact of the SFS model on market share, the market expansion coefficient "γ" is incorporated, reflecting the shift in market share post-implementation of the SFS strategy.

(6) To simplify the research, it is assumed that the manufacturer applies a uniform wholesale price w across various sales channels.

The meanings of all symbols in this paper can be found in Table 1.

Table 1. List of Symbols.

Style Tag	Definition	Style Tag	Definition
d	Market demand	α	The proportion of online consumers
v	Service Value	1-α	The proportion of offline consumers
β	The service cost coefficient	p	Retail Price

u	The potential market size	π	Profit
t	Transportation cost coefficient	D，N	The superscript D for omnichannel and N for dual-channel
γ	The market expansion coefficient for the SFS channel	f, s, o	The subscript f for SFS channel, s for offline channel, o for online channel

2.2 Model Construction

2.2.1 Model for Dual-channel Supply Chain.

In a dual-channel supply chain, the manufacturer sells the products via both offline and online channels. The decision sequence in a dual-channel supply chain is as follows: First, the manufacturer determines the wholesale prices of the goods with the goal of maximizing its own profit. Then, the offline retailer sets the retail price for the offline channel to maximize its own profit. Finally, the online retailer sets the retail price for the online channel. The offline retailer offers a retail price p_s, which is adjusted to p_s-v to reflect the value-added services provided, with v representing the service value. The model is shown in Figure 1. Conversely, the online retailer's price is denoted by p_o. These actual channel prices are integrated into the refined Hotelling model，we get the demand functions for the dual-channel retail scenario are delineated below.

The demand function for the offline channel is as shown in Equation (1):

$$d_s=\frac{2(1-\alpha)u+p_o+t-3(p_s-v)}{2t} \tag{1}$$

The demand function for the online channel is as shown in Equation (2):

$$d_o=\frac{2\alpha u+(p_s-v)+t-3p_o}{2t} \tag{2}$$

The profit of the manufacturer in a dual-channel supply chain consists of the wholesale revenue from products sold through offline and online channels. The profit function is expressed as Equation (3):

$$\pi_m^N=w(d_s+d_o) \tag{3}$$

The profit of the offline retailer is derived from the retail revenue of the offline channel, minus the wholesale cost of the products and the cost of value-added services provided by the offline retailer. The profit function is expressed as Equation (4):

$$\pi_s^N=(p_s-w)d_s-\frac{\beta v^2}{2} \tag{4}$$

The profit of the online retailer is derived from the retail revenue of the online channel, minus the wholesale cost of the products. The profit function is expressed as Equation (5):

$$\pi_o^N=(p_o-w)d_o \tag{5}$$

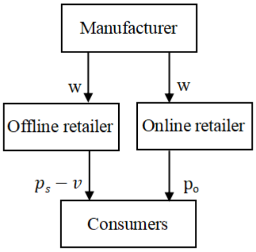

Fig. 1. The structure of Dual-channel supply chain.

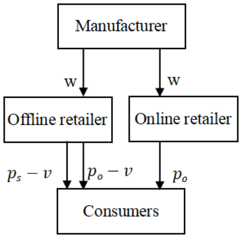

Fig. 2. The structure of SFS omnichannel supply chain

2.1.2 Model for SFS Omnichannel Supply Chain.
In the SFS omnichannel supply chain, consumers place orders online to purchase goods, which are then "delivered to home" by offline retailers. Consumers buy goods at online prices while also enjoying the value-added services provided by offline retailers. Therefore, the actual price of goods in the SFS channel is p_o-v. Let γ represent the market expansion coefficient of the SFS channel; thus, the proportion of consumers preferring online channels in the SFS omnichannel retail expands to $\alpha+\gamma$. The supply chain model is shown in Figure 2. Let d_s^f denote the offline channel demand in the omnichannel, d_o^f denote the online channel demand in the omnichannel, and d_f denote the SFS channel demand in the omnichannel. The demand functions are as Equations (6)-(8):

$$d_s^f = \frac{2(1\text{-}\alpha)u+p_o+t\text{-}3(p_o\text{-}v)}{2t} \tag{6}$$

$$d_o^f = \frac{2(\alpha+\gamma)xu+(p_s\text{-}v)+t\text{-}3(p_o\text{-}v)}{2t} \tag{7}$$

$$d_f = \frac{2(\alpha+\gamma)(1\text{-}x)u+(p_s\text{-}v)+t\text{-}3(p_o\text{-}v)}{2t} \tag{8}$$

The decision sequence in this model is as follows: First, the manufacturer aims to maximize its own profit by setting the wholesale price of the goods. Next, the offline retailer seeks to maximize its profit by determining the retail price for the offline channel. Finally, the online retailer confirms the retail price for the online channel.

In the SFS omnichannel retail supply chain, the manufacturer's profit consists of the wholesale revenue from both offline and online channels. The profit function can be expressed as Equation (9):

$$\pi_m^N = w\left(d_s^f + d_o^f + d_f\right) \tag{9}$$

The profit of offline retailers includes the retail revenue from the offline channel and the SFS channel, minus the value-added service costs and the wholesale cost of goods. The profit function can be expressed as Equation (10):

$$\pi_s^N = (p_s - w)d_s^f - \frac{\beta v^2}{2} + (p_s - w)d_f \tag{10}$$

The profit of online retailers is the online sales revenue minus the wholesale cost of goods. The profit function can be expressed as Equation (11):

$$\pi_o^N = (p_o - w)d_o^f \tag{11}$$

2.3 Solution of the Model.

The dual-channel supply chain and omnichannel supply chain are solved using backward induction, leading to Conclusion 1.

Conclusion 1*: (1) The optimal solution for the dual-channel supply chain is:*

$$w^{D*} = \frac{121t + 120u + 119v + 2u\alpha}{484}$$

$$p_s^{D*} = \frac{726t + 1026u + 1326v - 600u\alpha}{2057}$$

$$p_o^{D*} = \frac{17303t + 10244u + 3145v + 14158u\alpha}{49368}$$

$$\pi_m^{D*} = \frac{(121t + 119v + 120u + 2u\alpha)^2}{197472t}$$

$$\pi_s^{D*} = \frac{(847t + 3281v + 2064u - 2434u\alpha)^2}{47788224t}$$

$$\pi_o^{D*} = \frac{[4961t - 8993v + 2u(6977\alpha - 1008)]^2}{1624799616t}$$

The optimal solution for the omnichannel supply chain is:

$$w^{N*} = \frac{31t + 24u + 68v + 10u\alpha + 34u\gamma - 30ux(\alpha + \gamma)}{124}$$

$$p_s^{N*} = \frac{49t}{132} + \frac{158}{341}u + \frac{878v}{1023} + \frac{413u\gamma}{2046} - \frac{535u\alpha}{2046} - \frac{85}{682}ux\alpha - \frac{85}{682}ux\gamma$$

$$p_o^{N*} = \frac{35t}{99} + \frac{178}{1023}u + \frac{769}{3069}v - \frac{10}{3069}u\alpha + \frac{196}{1023}ux\alpha + \frac{524u\gamma}{3069} + \frac{196ux\gamma}{1023}$$

$$\pi_m^{D*} = \frac{(31t + 68v + 24u + 10u\alpha - 30ux\alpha + 34u\gamma - 30ux\gamma)^2}{8928t}$$

$$\pi_s^{D*} = \frac{\begin{array}{c} -154721t^2+248t[v(6209-2025554v\beta)+10266u+(27948x-32411)u\alpha-22145u\gamma+27948ux\gamma] \\ +4\{10508512v^2-4uv[(3657183x-315814)\alpha-(3657183x-752527)\gamma]+u^2[(1728565-861666x+10085337x^2)\alpha^2-746352 \\ +24\gamma(62493x-49330)+\gamma^2(1290997-7116834x+10085337x^2)+2\alpha[154392+x(749916-7866750\gamma)+1882957\gamma+10085337x^2\gamma]]\} \end{array}}{100466784t}$$

$$\pi_o^{N*} = \frac{[1271t - 3656v - 240u - 1030u\alpha + 5322ux\alpha - 1270u\gamma + 5322ux\gamma]^2}{100466784t}$$

3 Sensitivity Analysis

This paper primarily analyzes the impact of offline service levels on pricing in two supply chain models, as well as the effects of market expansion coefficients and the proportion of pure online consumers on pricing in the omnichannel supply chain. The conclusions drawn are as follows:

Conclusion 2: *In the dual-channel supply chain, the manufacturer's wholesale price, the optimal retail price of the offline retailer, and the optimal retail price of the online retailer all increase with the improvement of service levels.*

Taking the first derivatives with respect to service levels for the manufacturer's wholesale price w^{D*}, *the optimal retail price of the offline retailer* p_s^{D*}, *and the optimal retail price of the online retailer* p_o^{D*}, *we obtain the following:* $\partial w^{D*}/\partial v > 0, \partial p_s^{D*}/\partial v > 0, \partial p_o^{D*}/\partial v > 0$. This indicates that higher levels of service from offline retailers can simultaneously increase the manufacturer's wholesale price, the retail price of offline retailers, and the retail price of online retailers. Therefore, while service levels can have a positive impact on pricing decisions among members of the dual-channel supply chain, the associated increase in service costs may limit the effective enhancement of total supply chain profits.

Conclusion 3*: In the SFS omnichannel supply chain, the manufacturer's wholesale price, the optimal retail price of the offline retailer, and the optimal retail price of the online retailer all increase with the improvement of service levels.*

Taking the first derivatives with respect to service levels for the manufacturer's wholesale price w^{N*}, the optimal retail price of the offline retailer p_s^{D*}, and the optimal retail price of the online retailer p_o^{D*}, we obtain $\partial w^{N*}/\partial v > 0$, $\partial p_s^{N*}/\partial v > 0, \partial p_o^{N*}/\partial v > 0$.

This indicates that higher levels of service from offline retailers can simultaneously increase the manufacturer's wholesale price, the retail price of offline retailers, and the retail price of online retailers. It suggests that in the SFS omnichannel supply chain, the manufacturer's wholesale price, the retail price of offline retailers, and the retail price of online retailers all increase with the improvement of service levels. Regarding pricing decisions among supply chain members, service levels can have a positive impact.

Offline retail channels are motivated to enhance service levels to improve competitiveness and gain higher profits.

Conclusion 4*: The manufacturer's wholesale price, the optimal retail price of the offline retailer, and the optimal retail price of the online retailer all increase with the increase in the market expansion coefficient of the SFS channel.*

Taking the first derivatives with respect to the market expansion coefficient of the SFS channel for the manufacturer's wholesale price, the optimal retail price of the offline retailer, and the optimal retail price of the online retailer, we obtain: when $u > 0, 0 < x < 1$, hence $\partial w^{N*}/\partial\gamma > 0, \partial p_s^{N*}/\partial\gamma > 0, \partial p_o^{N*}/\partial\gamma > 0$, indicating that the manufacturer's wholesale price w^{N*}, the optimal retail price of the offline retailer p_s^{N*}, and the optimal retail price of the online retailer p_o^{N*} will all monotonically increase with the increase in γ . This implies that in the SFS omnichannel retail, as the market share of the SFS channel increases, the manufacturer's wholesale price, the retail price of offline channels, and the retail price of online channels will all rise.

Conclusion 5*: The manufacturer's wholesale price and the optimal retail price of the offline retailer decrease with the increase in the proportion of pure online consumers. Conversely, the optimal retail price of the online retailer increases with the increase in the proportion of pure online channel consumers.*

Taking the first derivatives with respect to the market expansion coefficient of the SFS channel for the manufacturer's wholesale price, the optimal retail price of the offline retailer, and the optimal retail price of the online retailer, we obtain $\partial w^{N*}/\partial x < 0, \partial p_s^{N*}/\partial x < 0, \partial p_o^{N*}/\partial x > 0$. This indicates that as the proportion of pure online consumers increases, the manufacturer's wholesale price w^{N*} and the optimal retail price of the offline retailer p_s^{N*} monotonically decrease, while the optimal retail price of the online retailer p_o^{N*} monotonically increases. This suggests that in a scenario where manufacturers take the lead, the supply chain needs to provide sufficient services and high-quality products to enhance consumer preference for offline channels, thereby increasing the manufacturer's wholesale and offline retail prices, and overall supply chain profits. Simultaneously, promotional efforts for online channels should be maintained to ensure competitive retail prices online, achieving the optimal consumer channel preference ratio that benefits the entire supply chain.

4 Numerical Simulation

This section employs numerical simulation to validate and substantiate the model's effectiveness, as well as the reasonableness of the aforementioned conclusions. It also compares and analyzes the profitability of traditional retail supply chains and SFS omnichannel supply chains, along with differences in pricing among supply chain members under consumer preferences. Referring to relevant literature [6], let $u = 20, \alpha = 0.6, x = 0.7, t = 2$, let $\gamma \in (0,1)$ denote the market expansion coefficient of the SFS channel, $\beta \in (0.6,1.4)$ denote the service cost coefficient, and ensure that these parameters satisfy the model's constraints.

The following analysis will use total profits and prices of each member in the dual-channel supply chain and SFS omnichannel supply chain as indicators. This aims to address whether the dual-channel supply chain can transition to an omnichannel supply chain by introducing SFS services directly, and to explore factors influencing SFS omnichannel retail prices.

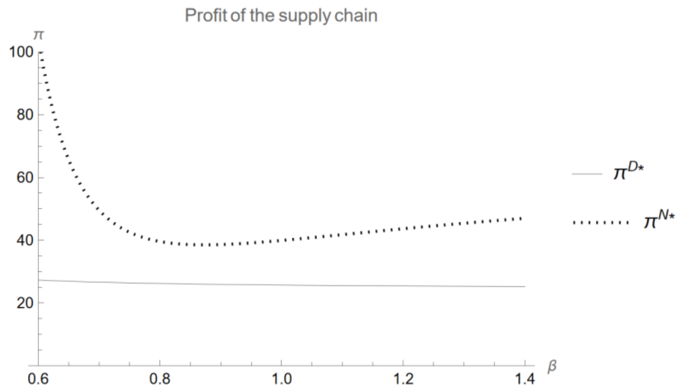

Fig. 3. The Impact of β on Supply Chain Profits

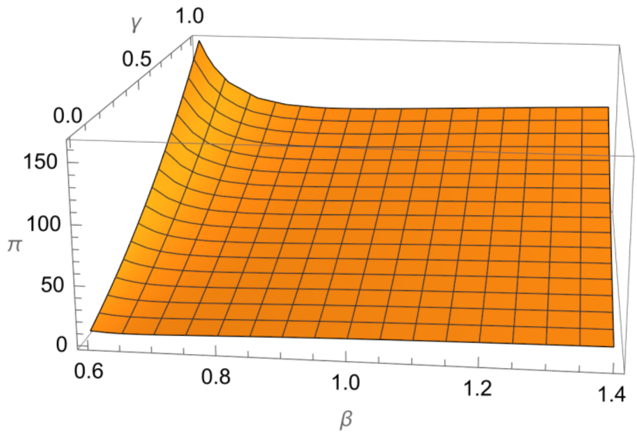

Fig. 4. The Impact of β and γ on Omnichannel Supply Chain Profits

From Figure 3, it is evident that regardless of how the service cost coefficient varies, the total profit of the SFS omnichannel supply chain consistently exceeds that of the dual-channel supply chain. This indicates that integrating SFS channel retailing can effectively increase the total supply chain profit for the dual-channel setup. Therefore, for the entire supply chain, adopting SFS represents a worthwhile choice for expanding into new retail formats and transitioning towards new retail business models. Additionally, from Figure 3, it can be observed that the total profit of the dual-channel supply chain consistently decreases as the service cost coefficient β increases. In contrast, for the SFS omnichannel supply chain, the total profit initially decreases with an increase in the service cost coefficient, but beyond a critical threshold, the total profit starts to increase with further increases in the service cost coefficient. This indicates that maintaining a higher level of value-added services is beneficial for the SFS omnichannel supply chain as well.

Figure 4 depicts the analysis of the impact of the service cost coefficient and the market expansion coefficient of the SFS channel on the total profit of the omnichannel supply chain. From Figure 4, it can be observed that as long as the market expansion coefficient of the SFS channel remains at 0.2 or higher, the total profit of the SFS omnichannel supply chain consistently exceeds that of the dual-channel supply chain. Therefore, when transitioning from a dual-channel supply chain to an SFS omnichannel supply chain by introducing SFS services, various marketing strategies need to be utilized to ensure that the number of consumers on the SFS sales channel reaches and maintains the aforementioned scale for achieving the expected profit.

Figure 5 illustrates the impact of the market expansion coefficient of the SFS channel on prices across supply chain members. The figure demonstrates that the manufacturer's wholesale price, the retail prices in offline channels, and the retail prices in online channels all increase with the market expansion coefficient of the SFS channel. Moreover, the retail prices in offline channels generally exceed those in online channels due to the positive effect of value-added services on pricing. Therefore, purchasing goods at online prices, which include these services, is highly cost-effective for consumers. The "store-to-home delivery" channel offered by SFS is likely to be favored by more consumers. From the perspective of omnichannel supply chain members, SFS services can attract more consumers and enable them to set higher prices. However, it is crucial to note that when the market expansion coefficient reaches 0.76, online channel prices equal offline channel prices. Further increases in the market expansion coefficient would lead to online prices eventually surpassing offline prices. This signifies that the omnichannel supply chain needs to manage the number of consumers in the SFS channel, ensuring that prices on the SFS channel remain lower than those in offline channels. This ensures the core competitiveness of offering high value-for-money products on the SFS channel.

Figure 6 compares and analyzes the impact of the market expansion coefficient of the SFS channel on the profits of all members in the omnichannel supply chain. In the SFS omnichannel supply chain, the profits of supply chain members and the total supply chain profit increase with the market expansion coefficient of the SFS channel. This aligns with the expectations of expanding the SFS channel with "store-to-home delivery," enabling supply chain members to further increase their revenue in the SFS channel and generate profits for upstream and downstream enterprises in the supply chain. From the consumer's perspective, expanding the SFS channel allows companies to offer more consumption channels and value-added services, providing greater convenience and enhancing the consumer experience. Additionally, from Figure 6, it can be observed that the profit growth of offline retailers is smaller compared to manufacturers and online channel retailers. This is because offline retailers incur higher costs in providing value-added services, thereby reducing their profit margins.

Cross-comparing Figures 5 and 6, it is evident in the SFS omnichannel supply chain that the retail prices of offline and online retailers are similar. However, online retailers achieve higher profits, and their profit margins increase more significantly with an increase in market share. Therefore, priority should be given to sales through online channels and the SFS channel. However, the supply chain also relies on offline retailers to enhance service levels, increase retail prices, improve customer retention, and expand market share.

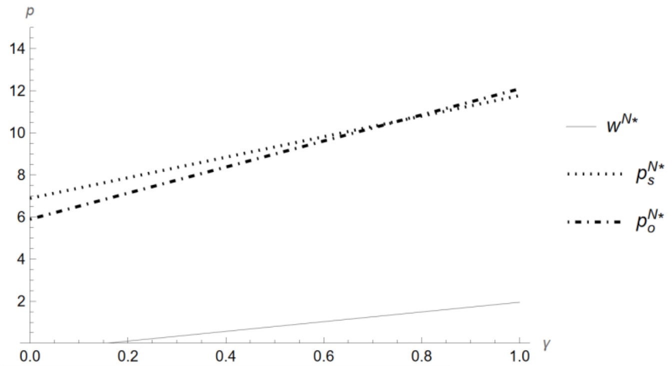

Fig. 5. The Impact of γ on Omnichannel Supply Chain Prices

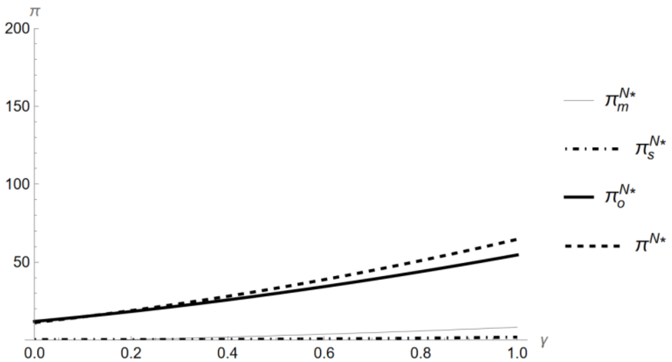

Fig. 6. The Impact of γ on Omnichannel Supply Chain Profits

5 Conclusion

Based on consideration of consumer channel preferences, this paper employs the Hotelling model to characterize market demand functions under the SFS omnichannel mode. It further constructs Stackelberg game models for both a manufacturer-led dual-channel supply chain and an SFS omnichannel supply chain. The study calculates and analyzes pricing, profits of supply chain members, and the total supply chain profit function for these scenarios. The insights gained are as follows:

(1) When the market expansion coefficient of the SFS channel reaches a certain threshold, the total profit of the SFS omnichannel supply chain will consistently exceed that of the dual-channel supply chain. Therefore, for traditional offline retailers intending to transition towards omnichannel retailing, expanding into the SFS channel is feasible.

(2) For the SFS omnichannel supply chain, the market expansion coefficient of the SFS channel primarily influences pricing and profits of all members. Introducing the SFS channel allows supply chain members to set higher prices as consumer demand increases on the SFS channel, thereby increasing pricing flexibility. Moreover, as the market expansion coefficient of the SFS channel increases, the profits obtained by supply chain members also increase, encouraging enterprises to consider adopting the omnichannel model more comprehensively.

(3) Maintaining a higher level of value-added services in the SFS omnichannel supply chain is beneficial. From a pricing perspective, there is a positive correlation between pricing by supply chain members and the level of value-added services. From a profit perspective, the total supply chain profit initially decreases and then increases with an increase in the service cost coefficient. Higher levels of value-added services not only attract more consumers to the supply chain but also enhance overall profitability.

This study focuses on the cost-effectiveness demonstrated by the SFS model in practice, using consumer preferences to investigate whether a dual-channel supply chain can transition directly to an omnichannel supply chain through the introduction of SFS services and factors influencing omnichannel pricing. The factors considered are simpler than reality, suggesting future research could expand to more accurately study the market expansion coefficient of the SFS channel.

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