ingegneria sismica
International Journal of Earthquake Engineering
Anno XLIII - Num. 3 - 2026

The impact of service spillover effect on sales channel structure selection in a supply chain

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SUMMARY: *This paper explores the dynamics of manufacturer-retailer interactions, focusing on how manufacturers can strategically engage with retailers offering supplementary services. Some manufacturers have opened additional sales channel to gain more customers even as their downstream retailers offer services to develop more sales. Then, when should a manufacturer that has its own retailer sales channel use additional sales channel? And what level of service should the retailer provide? To answer the questions, we establish three different supply chain structures considering a service spillover effect: a single channel structure (S); a direct channel structure (D); a dual channel structure (T). Through a game-theoretic approach, we examine the manufacturer's strategic choice of sales channel structure, the retailer's preference for specific channel configurations, and the broader impact of service spillover effects on the overall supply chain. Our analysis demonstrates that the effectiveness of a manufacturer's additional sales channel varies and is neither inherently beneficial to the manufacturer nor inherently detrimental to the service-providing retailer. The net impact depends on the service cost and the degree of competition between the channels. When the retailer offers insufficient service levels as a result of elevated service costs, the manufacturer opts to introduce a direct sales channel. And when the service cost is relatively small but the competition intensity between channels is too fierce, the manufacturer will choose the single channel structure. We further identify Pareto-efficient regions in which both the manufacturer and the service-providing retailer prefer adopting a dual-channel structure, particularly when service costs are low and the intensity of channel competition remains moderate.*

KEYWORDS: *Spillover effect; Sales channel selection; Supply chain; Game theory*

1 Introduction

According to data released by the National Bureau of Statistics of China, the retail sales of goods reached 43,550 billion yuan in 2023, an increase of 0.74 percent over the previous year. Among then, the national online retail sales totaled 154.264 billion yuan, marking an 11.0% increase from the prior year. [1]. In order to attract more customers and stimulate growth,

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https://doi.org/10.65102/is20261175
Published: 10 June , 2026

retailers provide all kinds of high-quality services, such as discount coupon, free trials, giveaways, event specific concessions and even immersive experience. For example, The Lego Group's New York flagship store creates an immersive experience by combining digital innovations with physical interactions, offering a unique and engaging retail environment [2]. This store enables customers of all age groups to explore and decide on their preferred shopping approaches. According to Lego, physical stores remain a cornerstone of its business operations, even as e-commerce continues to expand.

The services offered by offline retailers not only enhance their own sales volumes but also positively influence the sales performance of online channels operated by their upstream manufacturers, a phenomenon referred to as the spillover effect of offline services. From retailers' perspective, on the one hand, services provided by retailers can cultivate customer loyalty and increase sales. On the other hand, retailers must invest significant effort into providing services. However, these services can inadvertently intensify competition from other channels operated by the retailer's upstream manufacturers. It will reduce retailers' incentives to provide services and may indirectly weaken the market for manufacturers. Therefore, the question for retailers is how to determine the level of service?

From the perspective of manufacturers, although they rely on the service-providing retailer's sales channel to distribute products, they may simultaneously pursue the establishment of alternative sales channels, leading to the formation of a more complex channel structure. On the one hand, in order to gain more customers, some manufacturers will implement multi-channel sales strategies and build relationships with other dealers who may not provide value-added services [3]. On the other hand, the manufacturer can establish a sales channel where customers can buy directly from the manufacturer. For example, manufacturers can interact more directly with customers through social media apps such as TikTok, which can increase brand awareness. And customers can buy products through a link in the social media app [4]. It seems that implementing a multichannel sales channel strategy has become a requirement for a manufacturer. Nevertheless, the spillover effect from the service-providing retailer's established channel to the manufacturer's newly developed sales channel poses significant challenges for the manufacturer in determining an optimal channel structure. An intuitive perception is that additional sales channel will increase the competition intensity between channels, but the existence of service spillover effect may intensify or moderate the competition intensity [5]. Thus, under the spillover effect of a retailer's services, how to choose an appropriate channel structure is a real problem for manufacturers.

Inspired by the practices outlined earlier, this paper explores the channel structure selection problem, where the manufacturer's decision-making involves three alternatives, evaluated within a game-theoretic framework. (i) the single channel structure: the manufacturer sells products solely through a service-providing retailer. (ii) the direct channel structure: the manufacturer sells products not only through a service-providing retailer, but also through a direct sales channel. (iii) the dual channel structure: the manufacturer sales products through two heterogeneous retailers with one retailer providing service and the other retailer enjoying the free spillover effect from the former retailer. The primary goal of this research is to determine the conditions for optimal channel structure selection by manufacturers and to deliver practical managerial insights that assist practitioners in making effective channel strategy decisions.

The results indicate that manufacturers don't always benefit from opening additional channel. Firstly, the manufacturer should opt for the direct channel structure when the retailer provides low levels of service due to high service costs. Secondly, if the service cost is minimal and the level of competition between channels is not excessively high, the dual-channel structure becomes the optimal choice for the manufacturer. Thirdly, under conditions of low service costs but excessively fierce competition between channels, the manufacturer is recommended to adopt the single-channel structure as the preferred strategy. The service-providing retailer is likely to view the manufacturer’s decision to implement a direct-channel structure as the least desirable outcome. If the service cost coefficient is relatively low, implying a high return on service investment for the retailer, the service-providing retailer will achieve higher profits when the manufacturer selects the dual-channel structure. It means that the service-providing retailer and the manufacturer can achieve a Pareto improvement under this scenario.

The structure of this paper is as follows: Section 2 reviews the related literature. Section 3 defines the model notations and describes the key assumptions. Section 4 analyzes the equilibrium outcomes of the three channel structures and assesses the influence of exogenous parameters on the results. In Section 5, we compare the manufacturer’s profits across various scenarios to determine the optimal channel structure and the conditions under which it is achieved. Section 6 concludes the paper with a summary of the main findings.

2 Literature review

Our study is connected to two primary streams of research, which can be categorized as follows:

The first stream is the literature on dual-channel distribution in supply chain. As online shopping continues to gain popularity, more manufacturers are establishing online channels, a trend that has garnered considerable interest from the research community. On the one hand, introducing new channels may bring some benefits to supply chain members. Hua et al. have studied that when manufacturers add online sales channels to the traditional channels, they can not only increase profits and improve the bargaining power, but also set a lower wholesale prices for the downstream retailers [6]. Rodríguez and Aydn adopt the nested-logit model to model customer demand, focusing on pricing and assortment decisions in a supply chain where the manufacturer distributes products via an independent retailer as well as its own direct channel[7]. On the other hand, Manufacturers operating dual channels may have adverse effects on supply chain members, such as more competition intensity, sales channel conflicts, and double marginal effects [8-10]. Some scholars study the influencing factors of operating dual channels by manufacturers. Xiao, Choi, and Cheng constructed a retailer-Stackelberg pricing model to examine the manufacturer's decisions regarding product variety and channel structure in a circular spatial market, focusing on a case where standard products are sold through the indirect channel, while customized products are offered through the direct channel [11]. Shen et al. investigate how a manufacturer can effectively partner with a platform retailer and a traditional reseller. This involves the manufacturer paying a slotting fee and a share of its sales revenue to the platform retailer, in return for the ability to control its own space within the retailer's establishment [12]. Li et al. analyzed the strategic decisions of retailers regarding channel sharing, specifically addressing whether to cease reselling manufacturers' national brand products to counter the threat posed by manufacturers entering the online market through direct selling [13]. Erjiang et al. examined how manufacturers implement channel coordination strategies to mitigate conflicts, particularly by comparing scenarios where wholesale prices are either uniform across offline and online retailers or differentiated between the two [14].

What’s more, manufacturers’ channel selection has also received much attention. Zheng et al. analyze the relationship between an online retailer and a supplier, focusing on the retailer’s information-sharing strategy when the supplier is already selling products via the retailer’s platform. Additionally, the study evaluates whether the supplier should establish a commission-based channel on the retailer's marketplace [15]. Zheng et al. develop game-theoretical models to analyze the manufacturer's optimal sales channel strategy within the context of a closed-loop supply chain (CLSC). In this system, the manufacturer handles the recycling and remanufacturing of used products, while the retailer manages a conventional retail channel [16].

From the above literature review, it can be seen that the existing research mainly focuses on the effects of dual channels, key factors of adopting additional channel, and sales channel selection. However, limited research has addressed how service spillover effects from downstream independent retailers influence the manufacturer's decision-making regarding channel structure. In this study, the impact of downstream retailers' service spillover effects on the manufacturer's selection of channel structure is analyzed, focusing on single, direct, and dual channel configurations.

The second stream is the cross-channel spillover effect. Cross-channel spillover is fairly common in practice [17, 18]. With the continuous development of e-commerce and network technologies, researchers have increasingly analyzed the impact of online channels on offline channels through spillover effects [19]. Kim and Lee investigate consumer purchase intention differences between online and offline channels using empirical methods, finding that consistent price promotions across the two channels induce significant spillover effects [20]. Zhang et al. analyze the pricing and greening strategies for players in a green dual-channel supply chain under the assumption of a consistent pricing strategy, using the Stackelberg model to evaluate cases where cross-channel return services are either available or unavailable [21]. By constructing a model with two manufacturers and a single e-tailer, Alaei et al. investigate the factors influencing manufacturers' decisions to incorporate a marketplace or reseller channel alongside their web-store channels to grow market share. Their study evaluates three e-channel frameworks and highlights the circumstances that favor each channel choice [22]. Timoumi et al. review 50 empirical studies published over the past 20 years, focusing on how omnichannel retail marketing strategies create cross-channel effects within retailers, shaping consumer behavior and influencing the overall performance of retail firms [23]. Liu and Hill investigate how TV advertising affects the effectiveness of search advertising in real time, focusing on moment marketing—a new strategy designed to synchronize online advertising with relevant offline events as they occur [24]. Dong et al. analyze the cross-channel spillover effects on competing manufacturers' pricing and quality decisions, exploring how these firms strategically modify their product strategies in response to the initial impact of such spillovers [25]. Zhou et al. considers manufacturers' online direct sales and offline channel, in which offline channel services have a service spillover (positive) effect on online channels, and studied when two channels use differentiated and non-differentiated pricing scenarios, how does service spillover affect the pricing and profits of supply chain members, and how to coordinate retailers' service efforts through contracts, but they do not study channel structure selection [26]. Different from previous literature, our work focuses on analyzing the effect of a retailer's service spillover on the manufacturer's channel structure decisions.

Our research distinguishes itself from existing relevant studies in three key aspects. First, we analyze the channel structure selection problem, which involves a manufacturer deciding between three possible configurations: the single-channel structure, the direct-channel structure, and the dual-channel structure. Second, we analyze how the optimal decisions of the manufacturer and the service-providing retailer are affected by the retailer's service spillover effect under three different channel structure. Third, we investigate the service providing motivation of the service-providing retailer under the condition of the manufacturer's optimal sales channel structure.

3 Model framework

We consider a supply chain consisting of a manufacturer (m) and a service-providing retailer (r). We use the pronoun "he" to represent the manufacturer, "she" to represent the service-providing retailer. To examine the influence of the service spillover effect on the manufacturer's channel selection, three analytical models are developed and presented in Figure 1.

(1) *The single channel structure*: the manufacturer sells his products solely through a service-providing retailer, as depicted in Figure 1(a).

(2) *The direct channel structure*: the manufacturer sells his products not only through a service-providing retailer, but also through a direct sales channel, although the direct channel will enjoy the spillover effect from the service-providing retailer leading to more intense channel competitions and conflicts, as depicted in Figure 1(b).

(3) *The dual channel structure*: the manufacturer sales his products through two heterogeneous retailers with one retailer (retailer 1 in Figure 1(c)) providing service and the other retailer (retailer 2 in Figure 1(c)) enjoying the free spillover effect, although the latter may cause some serious double marginal effect, as depicted in Figure 1(c).

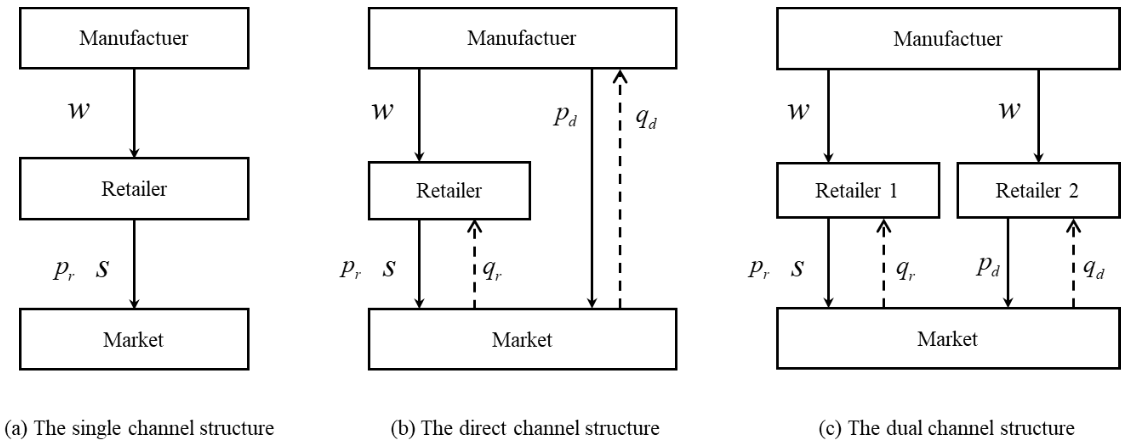

Figure 1: Illustration of the three different channel structures

We assume there is a representative consumer in the market with a quadratic utility function which is given by $U(q_r,q_d)=(1+s+\gamma\beta s)q_r+(1+\beta s+\gamma s)q_d-(q_r^2+2\gamma q_r q_d+q_d^2)/2$. Similar quadratic utility function have been widely used in previous research [27, 28]. By maximizing the consumer surplus $CS(q_r,q_d)=U(q_r,q_d)-(p_r q_r+p_d q_d)$, there is a unique optimal choice for a representative consumer, which are the demand functions:

$$q_r=\frac{1}{1+\gamma}-\frac{p_r}{1-\gamma^2}+\frac{\gamma p_d}{1-\gamma^2}+s \tag{1}$$

$$q_d=\frac{1}{1+\gamma}-\frac{p_\mathrm{d}}{1-\gamma^2}+\frac{\gamma p_r}{1-\gamma^2}+\beta s \tag{2}$$

A summary of the notation used is presented in Table 1.

Table 1: Description of parameters and symbols

Parameter	Description
w	Wholesale price
p_r	Market price charged by service-providing retailer
p_d	Market price charged by manufacturer at direct channel
s	The service level provided by the service-providing retailer
q_r	Demand of the service-providing retailer
q_d	Demand of direct channel
β	The spillover effect of service into a direct channel
γ	Competition intensity between channels
k	Service cost coefficient
π_m	Profit of the manufacturer
π_r	Profit of the service-providing retailer

For the remainder of the study, we incorporate superscripts on the optimums: S, D, T to denote the single channel, the manufacturer's direct channel, and the manufacturer's dual channel, respectively.

4 Analysis

We dedicate this section to examining and defining the equilibrium outcomes under the three distinct sales channel models: S, D, and T.Then, we derive the impact of exogenous parameters considered in the supply chain i.e. service cost efficiency k, competition intensity γ and service spillover coefficient β on the equilibrium outcomes to derive insights from these effects.

4.1 The Single Channel Structure (S)

This model assumes that the manufacturer sells products solely through a retailer offering value-added services, as depicted in Figure 1(a). The sequence of events unfolds as follows: First, the service-providing retailer sets the service level s. Second, after observing the level of service, the manufacturer announces the wholesale price w. Third, the retailer places an order to the manufacturer and determines the market prices p_r. Finally, products are sold to consumers. Note that, when the manufacturer opts to distribute solely via the service-providing retailer, the price in the direct channel is such that there are no sales through the direct channel [12, 28]. Thus, the demand function can be achieved by setting $q_d = 0$ which gives $p_d = 1-\gamma+\gamma p_r + s\beta\left(1-\gamma^2\right)$. Substituting this result in Equation (1) yields the demand function $q_r = 1 - p_r + \beta\gamma s + s$. The profit functions of the manufacturer and the service-providing retailer are $\pi_\mathrm{m} = wq_r$ and $\pi_r = \left(p_r - w\right)q_r - ks^2/2$, respectively. Through backward induction, we derive Proposition 1 as follows.

Proposition 1: In the single channel model, where the manufacturer sales products solely through a service-providing retailer, the decision equilibriums of supply chain members will be: $s^S = \dfrac{\beta\gamma+1}{8k-\beta^2\gamma^2-2\beta\gamma-1}$, $w^S = \dfrac{4k}{8k-\beta^2\gamma^2-2\beta\gamma-1}$, $p_r^S = \dfrac{6k}{8k-\beta^2\gamma^2-2\beta\gamma-1}$.

Correspondingly, the equilibrium profits of the supply chain members π_r^S and π_m^S can be obtained by substituting the decision equilibriums in proposition 1 into the profit functions. Proposition 1 outlines the optimal strategies for both the manufacturer and the service-providing retailer under the single-channel structure selected by the manufacturer. When the service cost coefficient $k \to +\infty$, the retailer has no incentive to provide service ($s^S \to 0$), and optimal wholesale price w^S, market price p_r^S and member's profits (π_r^S, π_m^S) will approach 1/2, 3/4, 1/16 and 1/8, respectively.

By analyzing the effect of exogenous parameters i.e. service cost efficiency k, competition intensity γ and service spillover coefficient β on the equilibriums, we obtain the following proposition 2.

Proposition 2: In the single channel model, the effect of service cost efficiency k, competition intensity γ and service spillover coefficient β on the equilibriums will be:

(1) $\frac{\partial s^S}{\partial \beta} > 0$, $\frac{\partial w^S}{\partial \beta} > 0$, $\frac{\partial p_r^S}{\partial \beta} > 0$, $\frac{\partial \pi_r^S}{\partial \beta} > 0$, $\frac{\partial \pi_m^S}{\partial \beta} < 0$;

(2) $\frac{\partial s^S}{\partial \gamma} > 0$, $\frac{\partial w^S}{\partial \gamma} > 0$, $\frac{\partial p_r^S}{\partial \gamma} > 0$, $\frac{\partial \pi_r^S}{\partial \gamma} > 0$, $\frac{\partial \pi_m^S}{\partial \gamma} < 0$;

(3) $\frac{\partial s^S}{\partial k} < 0$, $\frac{\partial w^S}{\partial k} < 0$, $\frac{\partial p_r^S}{\partial k} < 0$, $\frac{\partial \pi_r^S}{\partial k} < 0$, $\frac{\partial \pi_m^S}{\partial k} > 0$.

Proposition 2(1) represents that when the retailer's service spillover effect increases, consumers will be more sensitive to services, which encourages the retailer improves a higher level of service to effectively drive demand growth. Then the retailer can increase the market price of products to make a higher profit. In anticipation of higher margins for the retailer, the manufacturer will also increase the wholesale price of products. Therefore, the growth in the service spillover effect coefficient results in enhanced profitability for both the retailer and the manufacturer.

Proposition 2(2) indicates that, due to the manufacturer's incentive to open an additional channel, the equilibrium outcomes remain influenced by the intensity of competition in the single-channel scenario. As the degree of competition intensity increases, consumers become increasingly responsive to the quality of service provided by the retailer. As the retailer raises the service level, consumer demand grows, encouraging the retailer to implement a higher pricing strategy for the product. In anticipation of higher demand for the retailer, the manufacturer will raise the wholesale price to secure a larger share of the profits. Therefore, as the intensity of competition increases, both the retailer and the manufacturer can achieve higher profits.

Proposition 2(3) shows that when the service cost coefficient increases, the retailer has to suffer a higher cost to provide the same level of service. This will discourage the retailer to increase her service level, which will reduce the consumers' utility and demand of products. Observing this phenomenon, the retailer will decrease the market price to stimulate the demand of the product. Similarly, the manufacturer appropriately reduces the wholesale price of the product to stabilize the retailer's order volume. On the whole, an increase in the service cost coefficient reduces service efficiency, thereby negatively impacting the profits of supply chain members.

4.2 The Direct Channel Structure (D)

In this model, the manufacturer sells his products not only through a service-providing retailer, but also through his own direct channel. he sequence of events is structured as follows: First, the service-providing retailer establishes the service level s. Second, after observing the service level, the manufacturer announces the wholesale price w. Third, both the retailer and the manufacturer determine their market prices p_r and p_d simultaneously. Finally, products are sold to consumers. The profit functions of the manufacturer and the service-providing retailer are $\pi_{\mathrm{m}} = wq_r + p_d q_d$ and $\pi_r = (p_r - w)q_r - ks^2/2$, respectively. By backward induction, we obtain the following proposition 3.

Proposition 3: Under the direct channel model, in which the manufacturer distributes products via both a service-providing retailer and its own direct channel, the decision equilibriums of the supply chain members will be: $s^D = \frac{1-\gamma}{\gamma^2+8k-1}$, $w^D = \frac{8k-\gamma+\beta\gamma-\beta\gamma^2+\gamma^2}{2(\gamma^2+8k-1)}$, $p_r^D = \frac{12k-\gamma+\beta\gamma-4\gamma k-\beta\gamma^2+\gamma^2}{2(\gamma^2+8k-1)}$, $p_d^D = \frac{\beta+\gamma+8k-\beta\gamma-1}{2(\gamma^2+8k-1)}$.

Correspondingly, the equilibrium profits of the supply chain members π_r^D and π_m^D can be obtained by substituting the decision equilibriums in proposition 3. When the service cost coefficient $k \to +\infty$, the retailer has no incentive to provide service ($s^D \to 0$), the optimal wholesale price w^D, the market clear price (p_r^D, p_d^D) and the supply chain members' profits (π_r^D, π_m^D) will approach 1/2, $\frac{3-\gamma}{4}$, 1/2, $\frac{1-\gamma}{16(\gamma+1)}$ and $\frac{3+\gamma}{8(\gamma+1)}$, respectively.

Similarly, by analyzing the effect of exogenous parameters: the service cost efficiency k, the degree of channel competition intensity γ and the service spillover coefficient β on the equilibriums, we obtain the following proposition 4.

Proposition 4: In the manufacturer's direct channel model, the effect of the service cost efficiency k, the degree of channel competition intensity γ and the service spillover coefficient β on the equilibriums will be:

(1) $\frac{\partial s^D}{\partial \beta} = 0$, $\frac{\partial w^D}{\partial \beta} > 0$, $\frac{\partial p_r^D}{\partial \beta} > 0$, $\frac{\partial \pi_r^D}{\partial \beta} = 0$, $\frac{\partial \pi_m^D}{\partial \beta} > 0$,

(2) $\frac{\partial s^D}{\partial \gamma} < 0$, $\frac{\partial w^D}{\partial \gamma} < 0$, $\frac{\partial p_r^D}{\partial \gamma} < 0$, $\frac{\partial \pi_r^D}{\partial \gamma} < 0$, $\frac{\partial \pi_m^D}{\partial \gamma} < 0$,

(3) $\frac{\partial s^D}{\partial k} < 0$, $\frac{\partial w^D}{\partial k} < 0$, $\frac{\partial p_r^D}{\partial k} < 0$, $\frac{\partial \pi_r^D}{\partial k} < 0$, $\frac{\partial \pi_m^D}{\partial k} < 0$,

Proposition 4 shows that the service spillover coefficient β has a positive effect on the equilibrium outcomes, while the service cost efficiency k has a negative effect on the equilibriums. It's worth noting that, in this direct channel scenario, the service level s^D and the retailer's profit π_r^D are not affected by the service spillover coefficient β. The underlying reason is that a higher service spillover coefficient leads to an increase in consumers' marginal utility, thereby encouraging them to pay a premium for the products. When the retailer observes this phenomenon in the market, they will increase the product price. However, the manufacturer will also increase the wholesale price of the product accordingly and adjust the market price in the direct channel p_d^D ($\frac{\partial p_d^D}{\partial \beta} > 0$), which will keeps the retailer's product marginal revenue and the channel's product demand unchanged ($\frac{\partial q_r^D}{\partial \beta} = 0$). Thus, the retailer has no incentive to adjust her service level, and her profit is not affected by service spillover coefficient. As for the manufacturer, the product demand in the direct channel is positively affected by the retailer's service spillover. Therefore, the manufacturer can obtain a higher profit with the increase in service spillover coefficient.

Different from Proposition 2, the competition intensity between the channels γ has negative effect on the equilibrium. This can be explained by the fact that higher competition intensity γ prompts the retailer to cut service levels to reduce costs, while also reducing the market price to capture a larger share of consumer demand. As for the manufacturer, he will decrease the wholesale price to mitigate the decrease of the order quantity from the retailer. Therefore, as competition intensity increases, the profits of both the retailer and the manufacturer will decline.

4.3 The Dual Channel Structure (T)

In this scenario, the manufacturer sells his products through two heterogeneous retailers with one providing service (subscripted r) and the other enjoying the free-rider effect of service spillover (subscripted d). The event sequence is as follows: First, the service-providing retailer determines the service level s. Second, after observing the service level, the manufacturer announces the wholesale price w. Third, both the service-providing retailer and the retailer enjoying the spillover service determine their market prices p_r and p_d simultaneously. Finally, products are sold to consumers. The profit functions of the manufacturer, the service-providing retailer and the other retailer are $\pi_{\mathrm{m}} = wq_r + wq_d$, $\pi_r = (p_r - w)q_r - ks^2/2$ and $\pi_d = (p_d - w)q_d$. By backward induction, we obtain the following proposition 5.

Proposition 5: Under the dual-channel model, in which the manufacturer distributes products through two distinct and heterogeneous retailers, the decision equilibria of the supply chain participants are determined as follows:

$$s^T = \frac{(2\gamma^2 + 2\gamma - 4)(2\beta + \gamma - 3\beta\gamma - 6)}{8k(\gamma^2 - 4)^2 - (1-\gamma^2)(2\beta + \gamma - 3\beta\gamma - 6)^2},$$

$$w^T = \frac{(2-\gamma)\left((\gamma^2 - 1)(\beta - 1)(2\beta + \gamma - 3\beta\gamma - 6) - 4k(\gamma - 2)(\gamma + 2)^2\right)}{8k(\gamma^2 - 4)^2 - (1-\gamma^2)(2\beta + \gamma - 3\beta\gamma - 6)^2},$$

$$p_r^T = \frac{(2-\gamma)\left((\gamma^2 - 1)(\beta - 1)(2\beta + \gamma - 3\beta\gamma - 6) - 4k(2\gamma - 3)(\gamma + 2)^2\right)}{8k(\gamma^2 - 4)^2 - (1-\gamma^2)(2\beta + \gamma - 3\beta\gamma - 6)^2},$$

$$p_d^T = \frac{4k(\gamma + 2)^2(2\gamma^2 - 7\gamma + 6) + (\beta - 1)(-3\gamma^3 + 4\gamma^2 + 3\gamma - 4)(2\beta + \gamma - 3\beta\gamma - 6)}{8k(\gamma^2 - 4)^2 - (1-\gamma^2)(2\beta + \gamma - 3\beta\gamma - 6)^2}.$$

Correspondingly, the equilibrium profits of the supply chain members π_r^T, π_d^T and π_m^T can be obtained by substituting the decision equilibriums in proposition 5. Similarly, by analyzing the effect of exogenous parameters i.e. the service cost efficiency k, the degree of channel competition intensity γ and the service spillover coefficient β on the equilibriums, we obtain the following proposition 7-8.

Proposition 6: In the dual channel model, the effect of the service spillover coefficient β on the equilibriums will be:

(1) When $0<\gamma<2/3$, then $\frac{\partial s^T}{\partial \beta}>0$ and $\frac{\partial \pi_r^T}{\partial \beta}<0$; When $2/3<\gamma<1$, then $\frac{\partial s^T}{\partial \beta}<0$ and $\frac{\partial \pi_r^T}{\partial \beta}>0$;

(2) When $0<\gamma<2/3$ and $k^T<k<k_1^T$, (as shown in Figure 2 region A), then $\frac{\partial w^T}{\partial \beta}<0$ and $\frac{\partial \pi_m^T}{\partial \beta}<0$; When $0<\gamma<2/3$ and $k>k_1^T$, (as shown in Figure 2 region B), then $\frac{\partial w^T}{\partial \beta}>0$ and $\frac{\partial \pi_m^T}{\partial \beta}>0$; When $2/3<\gamma<1$, (as shown in Figure 2 region C), then $\frac{\partial w^T}{\partial \beta}>0$ and $\frac{\partial \pi_m^T}{\partial \beta}>0$.

(3) When $0<\gamma<2/3$, if $\beta_1^T<\beta<1$ (as shown in Figure 3 region A), then $\frac{\partial p_r^T}{\partial \beta}<0$; if $0<\beta<\beta_1^T$ (as shown in Figure 3 region B), then $\frac{\partial p_r^T}{\partial \beta}<0$ in $\left(k^T,k_2^T\right)$ and $\frac{\partial p_r^T}{\partial \beta}>0$ in $\left(k_2^T,\infty\right)$; When $2/3<\gamma<1$ (as shown in Figure 3 region C), then $\frac{\partial p_r^T}{\partial \beta}>0$.

Where $k_1^T=\frac{(\gamma^2-1)(2\beta+\gamma-3\beta\gamma-6)^2}{(4\gamma-8)(\gamma+2)^2(\gamma-2\beta+3\beta\gamma+2)}$, $k_2^T=\frac{(\gamma^2-1)(2\beta+\gamma-3\beta\gamma-6)^2}{(4\gamma+8)(4\beta-36\gamma+4\beta\gamma-23\beta\gamma^2+12\beta\gamma^3+25\gamma^2-2\gamma^3+4)}$, $\beta_1^T=\frac{2\gamma^3-25\gamma^2+36\gamma-4}{12\gamma^3-23\gamma^2+4\gamma+4}$.

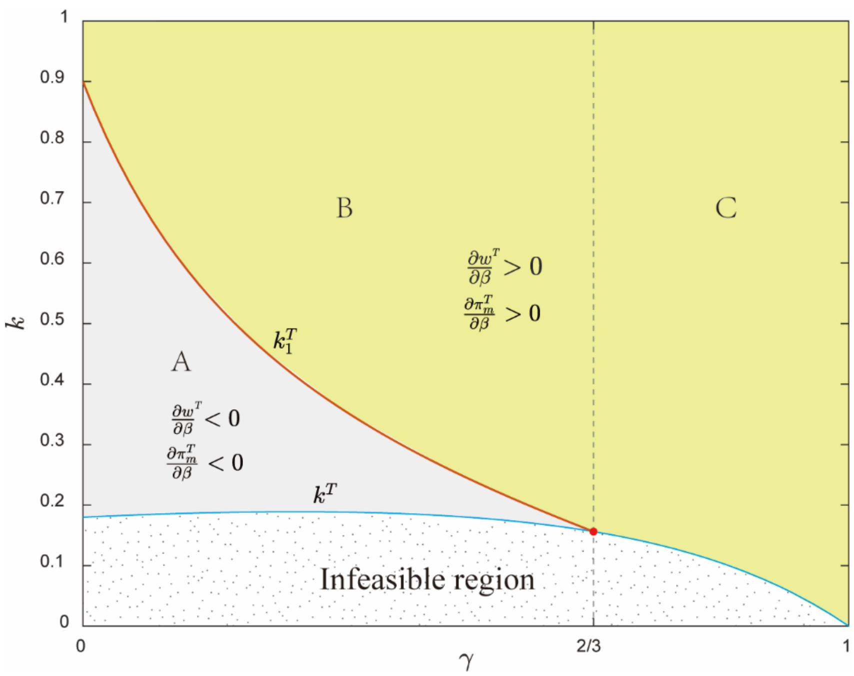

Figure 2: The effect of service spillover coefficient β on wholesale price and the manufacturer's profit

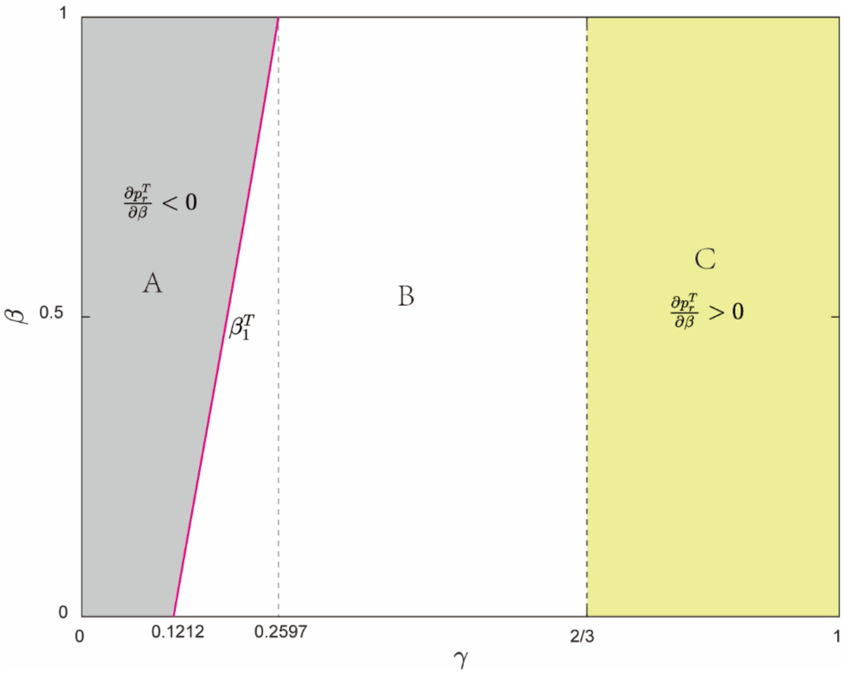

Figure 3: The effect of service spillover coefficient β on the market price in the retail channel

Proposition 6 represents the effect of service spillover coefficient β on the equilibrium outcomes in the dual channel with two heterogeneous retailers. Specifically, according to Proposition 6(1), when the competition intensity between channels is relatively small ($0<\gamma<2/3$), a higher service spillover coefficient contributes to an increase in the service level s^T, while exerting a negative effect on the profit of service-providing retaile π_r^T. When the competition intensity between channels is relatively large ($2/3<\gamma<1$), an increase in service spillover coefficient will have a negative effect on service level s^T, yet it enhances the profit of service-providing retailer π_r^T.

According to Proposition 6(2), under conditions of relatively small competition intensity between channels ($0<\gamma<2/3$), the influence of service spillover on the wholesale price and the manufacturer's profit depends on the value of the service cost coefficient k. If the service cost coefficient k is relatively small which means that the service efficiency of the service-providing retailer is high enough ($k^T < k < k_1^T$), then the service spillover will lower the wholesale price and the profit of the manufacturer, as shown in Figure 2 region A. However, if the service cost coefficient k is relatively large which means that the service efficiency of the service-providing retailer is relatively low ($k > k_1^T$), as shown in Figure 2 region B, or when the competition intensity between channels is relatively large ($2/3<\gamma<1$), as shown in Figure 2 region C, then the service spillover will increase the wholesale price and the profit of manufacturer.

Proposition 6(3) indicates that, when the competition intensity between channels is relatively small, as shown in Figure 3 region A, then an increase in the service spillover will decrease the market price in service-providing retailer channel p_r^T. When the competition intensity between channels is relatively high, as shown in Figure 3 region C, then an increase in the service spillover will increase the market price in service-providing retailer channel p_r^T. Additionally, when the competition intensity between channels is a medium level, as shown in Figure 3 region B, then the effect of service spillover on the market price in service-providing retailer channel depends on the service cost coefficient k. If the service cost coefficient k is relatively small which means that the service efficiency of the service-providing retailer is high enough ($k^T < k < k_2^T$), then the service spillover will decrease the market price in the service-providing retailer channel p_r^T. If the service cost coefficient k is relatively large which means that the service efficiency of the service-providing retailer is relatively low ($k > k_2^T$), then the service spillover will increase the market price in service-providing retailer channel.

Proposition 7: In the dual channel model, the effect of competition intensity between channels γ on the equilibriums will be:

(1) When $1/2 < \gamma < 1$ (as shown in Figure 4 region A), then $\frac{\partial s^T}{\partial \gamma} < 0$; when $0 < \gamma < 1/2$ and $0 < \beta < \beta_2^T$ (as shown in Figure 4 region B), then $\frac{\partial s^T}{\partial \gamma} < 0$; when $0 < \gamma < 1/2$ and $\beta_2^T < \beta < 1$ (as shown in Figure 4 region C), then $\frac{\partial s^T}{\partial \gamma} > 0$ in $\left(k^T, k_3^T\right)$, and $\frac{\partial s^T}{\partial \gamma} < 0$ in $\left(k_3^T, \infty\right)$.

(2) When $0 < \beta < \beta_3^T$ (as shown in Figure 5 region A), then $\frac{\partial w^T}{\partial \gamma} < 0$; when $\beta_3^T < \beta < 1$ (as shown in Figure 5 region B), then $\frac{\partial w^T}{\partial \gamma} < 0$ in $\left(k^T, k_4^T\right)$, and $\frac{\partial w^T}{\partial \gamma} > 0$ in $\left(k_4^T, \infty\right)$.

(3) When $0 < \beta < \beta_4^T$, then $\frac{\partial p_r^T}{\partial \gamma} < 0$, as is shown in Figure 6.

(4) When $1/2 < \gamma < 1$ (as shown in Figure 4 region A), then $\frac{\partial s^T}{\partial \gamma} < 0$, $\frac{\partial \pi_r^T}{\partial \gamma} < 0$; when $0 < \gamma < 1/2$ and $0 < \beta < \beta_2^T$ (as shown in Figure 4 region B), then $\frac{\partial s^T}{\partial \gamma} < 0$, $\frac{\partial \pi_r^T}{\partial \gamma} < 0$; when $0 < \gamma < 1/2$ and $\beta_2^T < \beta < 1$ (as shown in Figure 4 region C), then $\frac{\partial s^T}{\partial \gamma} > 0$ in $\left(k^T, k_3^T\right)$, $\frac{\partial s^T}{\partial \gamma} > 0$ in $\left(k^T, k_3^T\right)$, and $\frac{\partial \pi_r^T}{\partial \gamma} > 0$ in $\left(k^T, k_5^T\right)$, $\frac{\partial \pi_r^T}{\partial \gamma} < 0$ in $\left(k_5^T, \infty\right)$.

(5) There exists k_6^T. When $0 < \beta < \beta_2^T$ (as shown in Figure 4 region A and B), then $\frac{\partial \pi_m^T}{\partial \gamma} < 0$ in $\left(k^T, k_6^T\right)$, $\frac{\partial \pi_m^T}{\partial \gamma} > 0$ in $\left(k_6^T, \infty\right)$; when $\beta_2^T < \beta < 1$ (as shown in Figure 4 region C), then $\frac{\partial \pi_m^T}{\partial \gamma} > 0$.

Where $\beta_2^T = \frac{6\gamma^3 - 7\gamma^2 + 12\gamma + 4}{2\gamma^3 - 21\gamma^2 + 4\gamma + 12}$, $\beta_3^T = \frac{2\gamma^3 + \gamma^2 + 16\gamma - 4}{-2\gamma^3 - 13\gamma^2 + 8\gamma + 4}$, β_4^T is the solution of the equation $\begin{pmatrix} +\beta\left(54\gamma^5 - 172\gamma^4 + 414\gamma^3 - 460\gamma^2 - 120\gamma + 176\right) \\ -\beta^2\left(17\gamma^5 - 166\gamma^4 + 245\gamma^3 + 62\gamma^2 - 148\gamma + 8\right) \\ +146\gamma^2 - 204\gamma - 189\gamma^3 + 110\gamma^4 - 9\gamma^5 + 56 \end{pmatrix} = 0$, $k_3^T = \frac{(\gamma-1)^2(2\beta+\gamma-3\beta\gamma-6)^2(4\beta-4\gamma+12\beta\gamma+3\beta\gamma^2-\gamma^2+4)}{8(\gamma-2)(\gamma+2)^2(16\beta+12\gamma-20\beta\gamma+4\beta\gamma^2-3\beta\gamma^3-12\gamma^2+\gamma^3-16)}$,

$$k_4^T = \frac{\left(\gamma^2-1\right)^2\left(1-\beta\right)\left(2\beta+\gamma-3\beta\gamma-6\right)^2}{2\left(\gamma-2\right)\left(\gamma+2\right)^2\left(16\gamma-4\beta-8\beta\gamma+13\beta\gamma^2+2\beta\gamma^3+\gamma^2+2\gamma^3-4\right)}, \quad k_5^T = \frac{\left(\gamma-1\right)^2\left(\gamma+1\right)\begin{pmatrix}9\beta^2\gamma^3+30\beta^2\gamma^2-12\beta^2\gamma-8\beta^2-6\beta\gamma^3\\ -4\beta\gamma^2+88\beta\gamma+16\beta+\gamma^3-2\gamma^2-28\gamma+24\end{pmatrix}}{8\left(\gamma+2\right)^3\left(2-\gamma^3+3\gamma^2-3\gamma\right)}$$

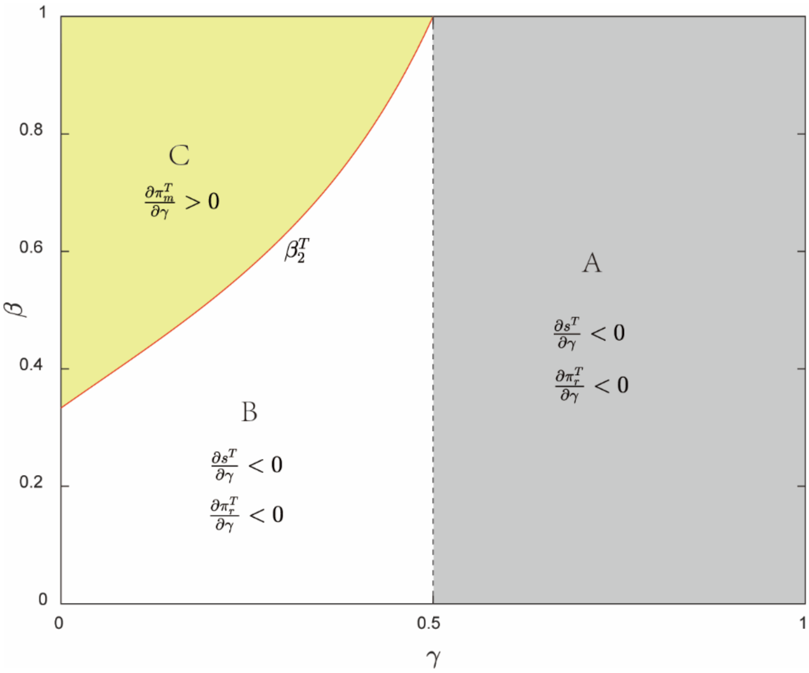

Figure 4: Effect of competition intensity between channels on service level and profits of the service-providing retailer and the manufacturer

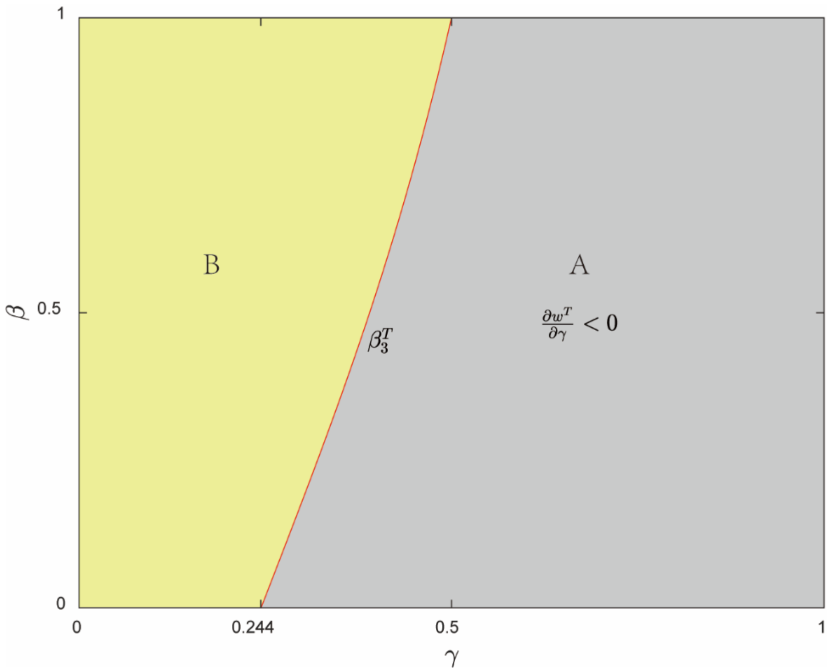

Figure 5: Effect of competition intensity between channels on wholesale price

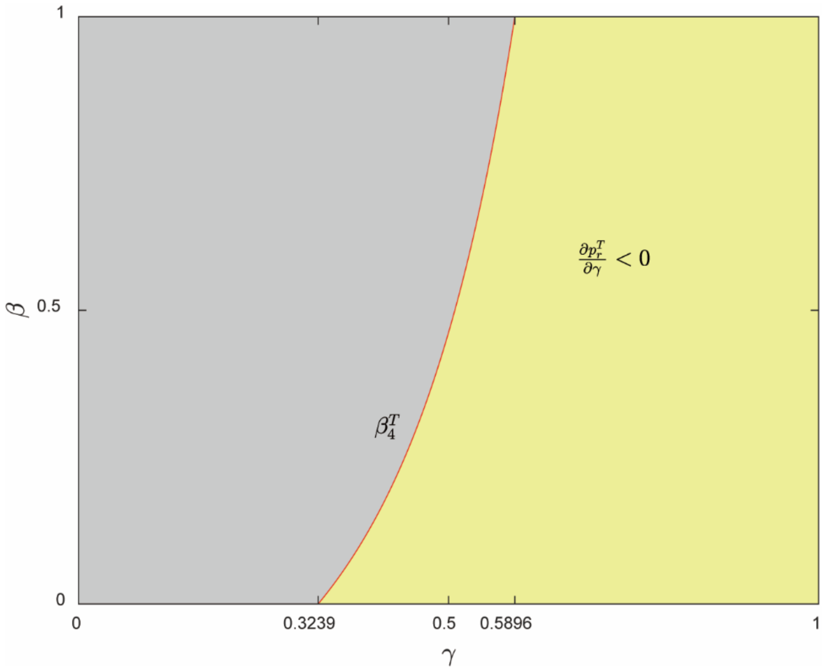

Figure 6: Effect of competition intensity between channels on the market price of the service-providing retailer

Proposition 7 represents the effect of competition intensity between channels on the equilibrium outcomes in the dual channel structure. When the degree of competition intensity between channels is large enough ($1/2<\gamma<1$), as is shown in Figure 4 region A, or when the degree of competition intensity between channels and the service spillover effect are relatively small ($0<\gamma<1/2$, $0<\beta<\beta_2^T$), as is shown in Figure 4 region B, then the service level and the profit of the service-providing retailer decrease with an increase in the degree of competition intensity. When the degree of competition intensity is relatively small ($0<\gamma<1/2$), but the degree of service spillover effect is relatively large ($\beta_2^T<\beta<1$), then an increase in the degree of competition intensity will increase the profit of the manufacturer, as shown in Figure 4 region C.

Proposition 7(2) demonstrates that, if the competition intensity reaches a sufficiently high level, further increases in competition intensity will result in a decrease in the wholesale price, as demonstrated in Region A of Figure 5. Additionally, when the degree of competition intensity is relatively small, the service spillover effect is higher than a threshold ($\beta_3^T<\beta<1$), and the service cost coefficient is relatively large ($k>k_4^T$), then the wholesale price increases with an increase in the channel competition.

Proposition 7(3) indicates that, under conditions of relatively high competition intensity, an increase in its degree reduces the market price in the service-providing channel, as depicted in Figure 6.

Proposition 8: In the dual channel model, the effect of service cost efficiency k on the equilibriums will be: $\frac{\partial s^T}{\partial k}<0$, $\frac{\partial w^T}{\partial k}<0$, $\frac{\partial p_r^T}{\partial k}<0$, $\frac{\partial \pi_r^T}{\partial k}<0$, $\frac{\partial \pi_m^T}{\partial k}<0$.

Similar to Proposition 2(3) and Proposition 4(3), Proposition 8 shows that the effect of service cost efficiency k has a negative effect on the equilibrium outcomes.

5 Comparison and channel selection

Having characterized the equilibriums associated with three different channel structures, we can now investigate the manufacturer's choice of the channel structure. The feasible region for the single channel model S is $k > k^S$, for the direct channel model D is $k > k^D$, and for the dual channel with two heterogeneous retailers T is $k > k^T$. Since $k^D < k^S$ and $k^D < k^T$, we will focus on the overlapping feasible regions $k > k^{TS} = \max\left(k^S, k^T\right)$ in this section. By comparing the equilibriums in three different channel structures, we obtain the following propositions.

Proposition 9: (1) $s^D < s^S$, $s^D < s^T$; (2) when $0 < \beta < \hat{\beta}_1$, then $s^S < s^T$, where $\hat{\beta}_1 = -\dfrac{\gamma^3 - 4\gamma^2 + 10\gamma - 4}{\gamma^4 - 2\gamma^3 + 2\gamma^2 - 2\gamma + 4}$.

Proposition 9 indicated that compared with the manufacturer's direct channel D, the service-providing retailer will improve the service level in single channel structure (S) and dual channel structure (T), which means that the existence of the manufacturer's second channel does not always spur the service providing-retailer to improve the service level. However, in the single channel structure and the dual channel structure, under which can motivate the service-providing retailer to improve a higher service level is determined by the degree of service spillover coefficient. Specially, when the coefficient of service spillover from the service-providing retailer into other channel is relatively low ($0 < \beta < \hat{\beta}_1$), then the service-providing retailer will set a higher service level in the dual channel structure. What's more, reducing the competition intensity between channels will make the service-providing retailer more inclined to set a higher service level in the dual channel structure ($\frac{\partial \hat{\beta}_1}{\partial \gamma} < 0$).

Proposition 10: (1) $w^D < w^S$; (2) when $0 < \beta < \hat{\beta}_2$, then $w^S < w^T$ in $\left(k^{TS}, \hat{k}_1\right)$, $w^S > w^T$ in $\left(\hat{k}_1, \infty\right)$, and when $\hat{\beta}_2 < \beta < 1$, then $w^S > w^T$; (3) when $0.2181 < \gamma < 1$, or $0 < \gamma < 0.2181$ and $\hat{\beta}_3 < \beta < 1$, then $w^D < w^T$ (as shown in Figure 7 region A and region B); when $0 < \gamma < 0.2181$ and $0 < \beta < \hat{\beta}_3$, then $w^D < w^T$ in $\left(k^{TS}, \hat{k}_2\right)$, $w^D > w^T$ in $\left(\hat{k}_2, \infty\right)$, (as shown in Figure 7 region C).

Where $\hat{\beta}_2 = \dfrac{-\gamma^5 + 3\gamma^4 - 12\gamma^3 + 9\gamma^2 + 4\gamma - 12 + \sqrt{1-\gamma^2}\left(\gamma^4 - 3\gamma^3 - 6\gamma^2 + 12\gamma + 8\right)}{\gamma^6 + \gamma^4 - 12\gamma^3 + 11\gamma^2 + 12\gamma - 4}$,

$$\hat{k}_1 = \frac{\left(\beta\gamma+1\right)^2\left(\beta-1\right)\left(-\gamma^3+2\gamma^2+\gamma-2\right)\left(2\beta+\gamma-3\beta\gamma-6\right)}{\left(4\gamma+8\right)\left(-\beta^2\gamma^5+2\beta^2\gamma^4+\beta^2\gamma^3-6\beta^2\gamma^2+3\beta^2\gamma-2\beta^2-2\beta\gamma^4+2\beta\gamma^3+4\beta\gamma^2-14\beta\gamma+4\beta-4\gamma^2+3\gamma-2\right)},$$

$$\hat{\beta}_3 = \frac{\left(\gamma-2\right)\sqrt{\gamma\left(\gamma^5-12\gamma^3-8\gamma^2+28\gamma+16\right)}-2\gamma+6\gamma^2+2\gamma^3-\gamma^4+4}{4-6\gamma^2-2\gamma},$$

$$\hat{k}_2 = \frac{\left(\gamma^2-1\right)\left(\beta-1\right)\left(9\beta^2\gamma^3-12\beta^2\gamma^2+4\beta^2\gamma+30\beta\gamma^2-32\beta\gamma+8\beta-\gamma^3+2\gamma^2+28\gamma-24\right)}{\left(8\gamma+16\right)\left(3\beta^2\gamma^2+\beta^2\gamma-2\beta^2-\beta\gamma^4+2\beta\gamma^3+6\beta\gamma^2-2\beta\gamma+4\beta-\gamma^3+\gamma^2+9\gamma-2\right)}.$$

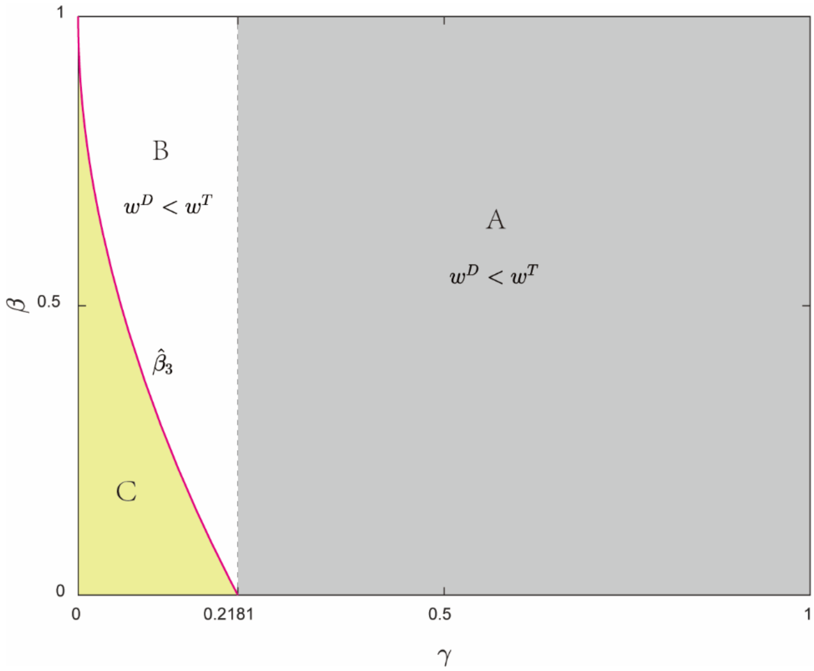

Figure 7: Impact of competition intensity and service spillover effect on the comparison of the wholesale price in three different channel structure

Proposition 10 illustrates the differences in wholesale prices among the three distinct channel structures. Proposition 10(1) represents that compared with the single channel structure S, the manufacturer will set a lower wholesale price in the manufacturer's direct channel structure D. According to Proposition 10(2), the differences in wholesale prices between the single-channel structure (S) and the dual-channel structure (T) are determined by the interplay of the service spillover effect and the service cost coefficient. When the service spillover coefficient is relatively small $0<\beta<\hat{\beta}_2$, the manufacturer will set a higher wholesale price in manufacturer's dual channel structure than in the single channel structure under the condition of high service efficiency ($k^{TS}<k<\hat{k}_1$), and will set a lower wholesale price in the single channel structure under the condition of low service efficiency ($k>\hat{k}_1$). Additionally, when the service spillover coefficient is relatively high ($\hat{\beta}_2<\beta<1$), the manufacturer is inclined to adopt a lower wholesale price in the dual-channel structure as opposed to the single-channel structure. Proposition 10(3) represents that how the supply chain exogenous parameters affect the comparison of wholesale price in the direct channel structure and the dual channel structure. When the degree of competition intensity or the service spillover effect is relatively large, as shown in Figure 7 region A and region B, the manufacturer is inclined to establish a higher wholesale price in the dual-channel structure compared to the direct-channel structure.

Proposition 11: (1) $p_r^D<p_r^S$; $p_r^D<p_r^T$; (2) when $0.7568<\gamma<1$, or $0<\gamma<0.7568$ and $\hat{\beta}_4<\beta<1$, then $p_r^S>p_r^T$ (as shown in Figure 8 region A and region B); when $0<\gamma<0.7568$ and $0<\beta<\hat{\beta}_4$, there exists an unique $\hat{k}_3$, then $p_r^S<p_r^T$ in $\left(k^{TS},\hat{k}_3\right)$, $p_r^S>p_r^T$ in $\left(\hat{k}_3,\infty\right)$, (as shown in Figure 8 region C).

Where $\hat{\beta}_4=\dfrac{-\gamma^5+3\gamma^4-12\gamma^3+9\gamma^2+4\gamma-12+\sqrt{1-\gamma^2}\left(\gamma^4-3\gamma^3-6\gamma^2+12\gamma+8\right)}{\gamma^6+\gamma^4-12\gamma^3+11\gamma^2+12\gamma-4}$.

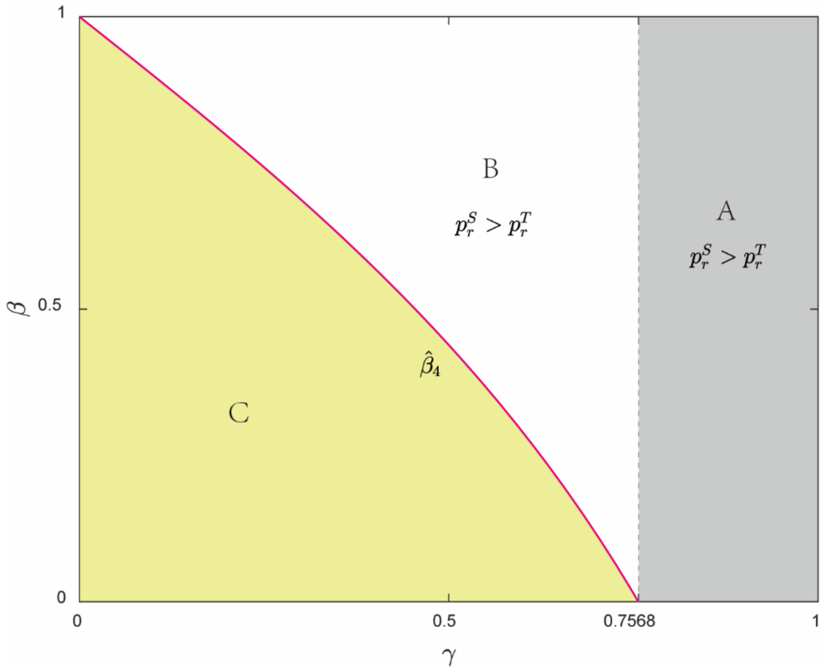

Figure 8: Impact of competition intensity and service spillover effect on the comparison of market price of service-providing retailer

Proposition 11 indicated that compared with the direct channel structure D, the service-providing retailer will set a higher market price in the single channel structure S and the dual channel structure T, which means that the manufacturer open direct stores can spur the service-providing retailer to decrease the market price. However, in the single channel structure and the manufacturer's dual channel structure, under which can motivate the service-providing retailer to set a higher market price depends on the competition intensity and the service spillover effect. Specially, when the degree of competition intensity between channels is relatively large, e.g. $0.7568 < \gamma < 1$, or when the degree of competition intensity is relatively small ($0 < \gamma < 0.7568$) but the degree of service spillover effect into the manufacturer's other channel is relatively large ($\hat{\beta}_4 < \beta < 1$), as shown in Figure 8 region A and region B, then the service-providing retailer will set a smaller market price in dual channel structure than in single channel structure. What's more, when the degree of completion intensity and the service spillover are relatively small, i.e. $0 < \gamma < 0.7568$ and $0 < \beta < \hat{\beta}_4$, then the service-providing retailer is also more inclined to set a larger market price in the single channel structure if she faces a relatively large service cost coefficient.

Proposition 12: (1) There exist some β, so that when the competition intensity between channels γ is relatively large and the service cost coefficient k is relatively small, then the manufacturer will choose the single channel structure; (2) when the competition intensity between channels γ is medium and the service cost coefficient k is relatively small, then the manufacturer will choose the dual channel structure; (3) when the service cost coefficient is large enough, e.g. $k \to +\infty$, then the manufacturer will choose the direct channel structure.

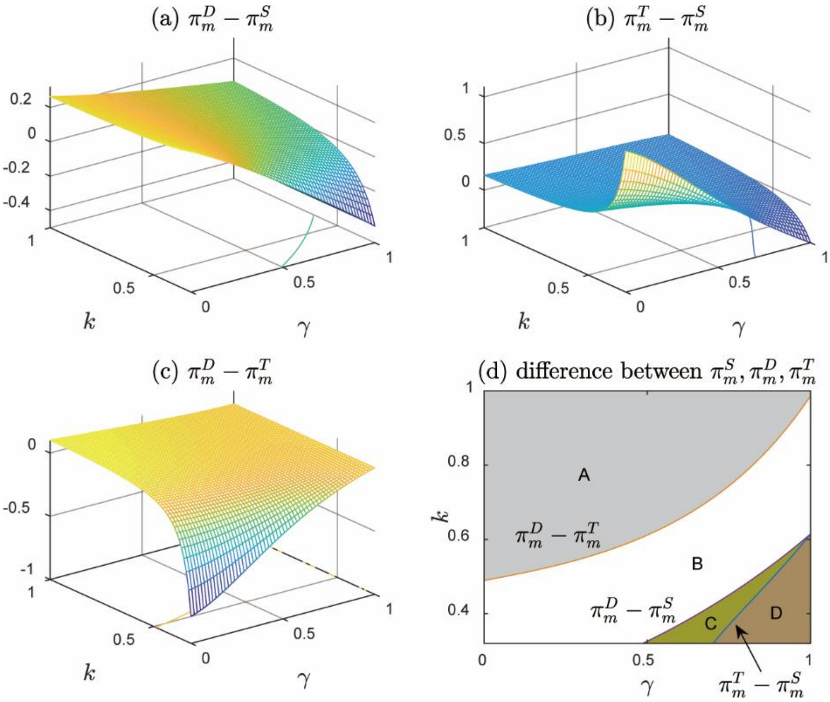

Figure 9: The comparison of manufacturer's profit in three channel structures with β=0.2

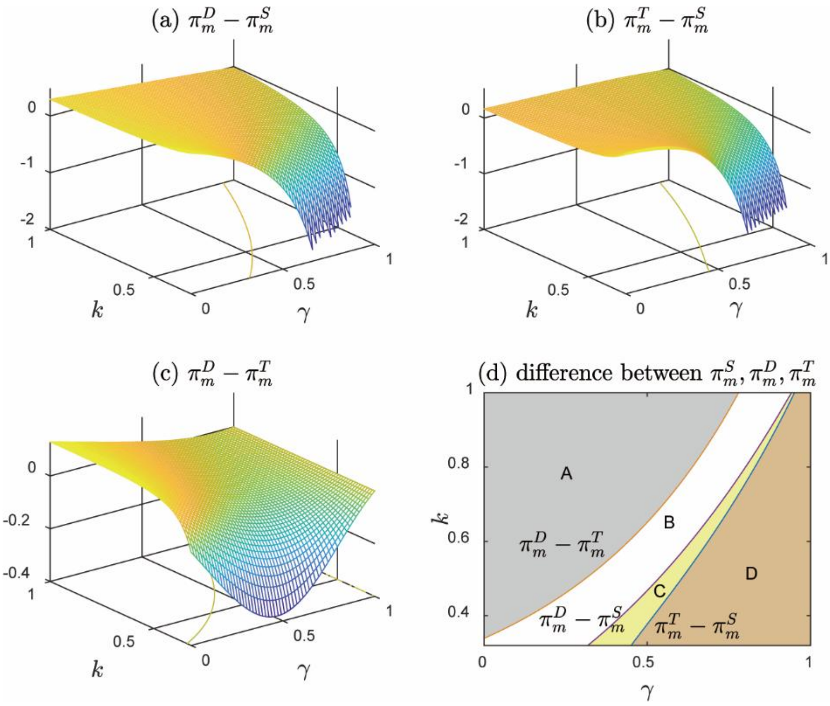

Figure 10: The comparison of manufacturer's profit between three channel structures with β=0.6

Proposition 12 compares the manufacturer's profit within the context of three distinct channel structures. Since solving for the comparison analytically is challenging, we derived the manufacturer's optimal channel selection based on certain values of service spillover effect β. We set β=0.2 and β=0.6 to represent a relatively low service spillover effect and a relatively high service spillover effect, respectively. When β=0.2, then $k^T = 0.245$,

$k^S = 0.18$, and $k > k^{TS} = 0.245$, and when β=0.6, then $k^T = 0.1891$, $k^S = 0.32$, and $k > k^{TS} = 0.32$. By comparing the manufacturer's profit in the single channel structure and the direct channel structure, we obtain that when the degree of competition intensity between channels is relatively large, then the manufacturer will make a higher profit in the single channel structure, as shown in Figure 9(a) and Figure 10(a). Similarly, when the service cost coefficient reaches a sufficiently high level, the manufacturer secures greater profit under the dual-channel structure relative to the single-channel structure, as shown in Figures 9(b) and 10(b). Additionally, the manufacturer realizes higher profit in the direct-channel structure compared to the dual-channel structure, as demonstrated in Figures 9(c) and 10(c). Therefore, Figure 9(d) and Figure 10(d) are obtained by rearranging the contour line with value zero in Figure 9(a-c) and Figure 10(a-c), respectively. As Figure 9(d) and Figure 10(d) shown, Firstly, when the service cost coefficient is large enough, e.g. $k \to +\infty$(region A in both Figure 9(d) and Figure 10(d)), then $\pi_m^D > \pi_m^S$, $\pi_m^T > \pi_m^S$, $\pi_m^T < \pi_m^D$, which means that the manufacturer will choose the direct channel structure. Secondly, when the degree of competition intensity between channels γ is medium and the service cost coefficient k is relatively small, then $\pi_m^T > \pi_m^S$, $\pi_m^T > \pi_m^D$, and $\pi_m^D > \pi_m^S$ in region B of both Figure 9(d) and Figure 10(d), $\pi_m^D < \pi_m^S$ in region C of both Figure 9(d) and Figure 10(d)), which means that the manufacturer will choose the dual channel structure. Thirdly, when the degree of competition intensity between channels γ is relatively large and the service cost coefficient k is relatively small (region D in both Figure 9(d) and Figure 10(d)), then $\pi_m^D < \pi_m^S$, $\pi_m^T < \pi_m^S$, $\pi_m^T > \pi_m^D$, which means that the manufacturer will choose single channel structure.

Proposition 13: (1) $\pi_r^D < \pi_r^S$; $\pi_r^D < \pi_r^T$; (2) $\pi_r^S < \pi_r^T$ in $\left(k^{TS}, \hat{k}_4\right)$, $\pi_r^S > \pi_r^T$ in $\left(\hat{k}_4, \infty\right)$, where $\hat{k}_4 = \dfrac{(1-\beta)\left(\gamma^3 - 4\gamma^2 + \gamma + 2\right)\left(7\gamma - 2\beta + 5\beta\gamma + 5\beta\gamma^2 - \gamma^2 + 10\right)}{8\gamma(\gamma+2)^2\left(\gamma^2 - 3\gamma + 4\right)}$.

Proposition 13 indicates that the service-providing retailer earns higher profits under the single-channel structure (S) and the dual-channel structure (T) than under the direct-channel structure (D). However, in the single channel structure and the dual channel structure, under which can the service-providing retailer make a higher profit depends on her service cost coefficient. Specially, when the service cost coefficient is relatively small ($k^{TS} < k < \hat{k}_4$), which means that the retailer's return on service investment is high enough, then the service-providing retailer will obtain a higher profit if the manufacturer chooses the dual channel. When the service cost coefficient is relatively large ($k > \hat{k}_4$), the service-providing retailer will achieve greater profitability in the single channel structure than in the dual channel structure.

6 Conclusions

In this research, we conduct an analytical investigation into the manufacturer's selection of channel structures—single-channel, direct-channel, or dual-channel—while incorporating the influence of the service spillover effect generated by the service-providing retailer. Accordingly, we focus on three channel structures: Structure S, characterized by a service-providing retailer and a manufacturer without alternative sales channels; Structure D, involving a service-providing retailer and a manufacturer utilizing a direct sales channel; and Structure T, which consists of a manufacturer and two distinct retailers, including one service-providing retailer and one non-service retailer. To understand the equilibrium outcomes with the impact of the service spillover effect, we formulate a three-stage Stackelberg game and assess three different channel structure alternatives. For each channel structure, we derive the equilibriums and the threshold conditions necessary for the channel's viability, along with the corresponding prices, service levels, and profits for each supply chain member. Then, we analyze the manufacturer's optimal channel structure selection among the single channel structure, the direct channel structure and the dual channel structure.

The analytical findings indicate that, within each channel structure, when the manufacturer aims at increasing his profit, he should opt for the single channel structure if the competition intensity and service efficiency are sufficiently high, adopt the direct channel structure if service efficiency is sufficiently low, and adopt the dual channel structure otherwise. The service-providing retailer's service cost coefficient, service spillover effect, and service level significantly influence the manufacturer's decision regarding channel structure selection. We also observe that in the direct channel consumer gains a lower price and service and the service-providing retailer gains a lower profit.

Potential extensions of this work in future research may include the following directions. It might be interesting to study the motivations of multiple retailers who should provide services. Moreover, future research should explore additional factors affecting the manufacturer's choice of channel structure, including channel convenience and consumer preferences.

Appendix A

Proof of Proposition 1. By backward induction, the second order condition of $\pi_r\left(p_r,s\right)$ is $\frac{\partial^2\pi_r}{\partial {p_r}^2}=-2<0$, which means that $\pi_r\left(p_r,s\right)$ is strictly concave in p_r. Then from $\frac{\partial\pi_r}{\partial p_r}=0$, we get $p_r\left(w,s\right)=\left(s+w+\beta\gamma s+1\right)/2$. By substituting $p_r\left(w,s\right)$ into $\pi_m\left(w\right)$, and we can obtain $\frac{\partial^2\pi_m}{\partial w^2}=-1<0$. From $\frac{\partial\pi_m}{\partial w}=0$, we get $w\left(s\right)=\left(s+\beta\gamma s+1\right)/2$. By substituting $w\left(s\right)$ into $\pi_r\left(s\right)$, and we can obtain $\frac{\partial^2\pi_r}{\partial s^2}=\left(\beta\gamma+1\right)^2/8-k$. We assume that $\left(\beta\gamma+1\right)^2/8-k<0$, so $\pi_r\left(s\right)$ is strictly concave in s. Then from $\frac{\partial\pi_r}{\partial s}=0$, we get $s^S=\frac{\beta\gamma+1}{8k-\beta^2\gamma^2-2\beta\gamma-1}$. By substituting s^S into $w\left(s\right)$ and $p_r\left(w,s\right)$, we obtain $w^S=\frac{4k}{8k-\beta^2\gamma^2-2\beta\gamma-1}$ and $p_r^S=\frac{6k}{8k-\beta^2\gamma^2-2\beta\gamma-1}$. □

Proof of Proposition 2. (1) $\frac{\partial s^S}{\partial\beta}=\frac{\gamma\left(\beta^2\gamma^2+2\beta\gamma+8k+1\right)}{\left(\beta^2\gamma^2+2\beta\gamma-8k+1\right)^2}>0$, $\frac{\partial w^S}{\partial\beta}=\frac{8\gamma k\left(\beta\gamma+1\right)}{\left(\beta^2\gamma^2+2\beta\gamma-8k+1\right)^2}>0$, $\frac{\partial p_r^S}{\partial\beta}=\frac{12\gamma k\left(\beta\gamma+1\right)}{\left(\beta^2\gamma^2+2\beta\gamma-8k+1\right)^2}>0$, $\frac{\partial\pi_r^S}{\partial\beta}=\frac{\gamma k\left(\beta\gamma+1\right)}{\left(\beta^2\gamma^2+2\beta\gamma-8k+1\right)^2}>0$, $\frac{\partial\pi_m^S}{\partial\beta}=\frac{32\gamma k^2\left(\beta\gamma+1\right)}{\left(8k-\beta^2\gamma^2-2\beta\gamma-1\right)^3}>0$.

(2) $\frac{\partial s^S}{\partial\gamma}=\frac{\beta\left(\beta^2\gamma^2+2\beta\gamma+8k+1\right)}{\left(\beta^2\gamma^2+2\beta\gamma-8k+1\right)^2}>0$, $\frac{\partial w^S}{\partial\gamma}=\frac{8\beta k\left(\beta\gamma+1\right)}{\left(\beta^2\gamma^2+2\beta\gamma-8k+1\right)^2}>0$, $\frac{\partial p_r^S}{\partial\gamma}=\frac{12\beta k\left(\beta\gamma+1\right)}{\left(\beta^2\gamma^2+2\beta\gamma-8k+1\right)^2}>0$, $\frac{\partial\pi_r^S}{\partial\gamma}=\frac{\beta k\left(\beta\gamma+1\right)}{\left(\beta^2\gamma^2+2\beta\gamma-8k+1\right)^2}>0$, $\frac{\partial\pi_m^S}{\partial\gamma}=\frac{32\beta k^2\left(\beta\gamma+1\right)}{\left(8k-\beta^2\gamma^2-2\beta\gamma-1\right)^3}>0$.

(3) $\frac{\partial s^S}{\partial k} = -\frac{8(\beta\gamma+1)}{(\beta^2\gamma^2+2\beta\gamma-8k+1)^2} < 0$, $\frac{\partial w^S}{\partial k} = -\frac{4(\beta\gamma+1)^2}{(\beta^2\gamma^2+2\beta\gamma-8k+1)^2} < 0$, $\frac{\partial p_r^S}{\partial k} = -\frac{6(\beta\gamma+1)^2}{(\beta^2\gamma^2+2\beta\gamma-8k+1)^2} < 0$, $\frac{\partial \pi_r^S}{\partial k} = -\frac{(\beta\gamma+1)^2}{2(\beta^2\gamma^2+2\beta\gamma-8k+1)^2} < 0$, $\frac{\partial \pi_m^S}{\partial k} = -\frac{16k(\beta\gamma+1)^2}{(8k-\beta^2\gamma^2-2\beta\gamma-1)^3} < 0$.

Proof of Proposition 3. Similar to the proof of Proposition 1, the proof of Proposition 2 is omitted here.

Proof of Proposition 4. Similar to the proof of Proposition 2, the proof of Proposition 4 is omitted here.

Proof of Proposition 5. Similar to the proof of Proposition 1, the proof of Proposition 5 is omitted here.

Proof of Proposition 6.

(1) $$\frac{\partial s^T}{\partial \beta} = -\frac{2(3\gamma^3+\gamma^2-8\gamma+4)\begin{pmatrix}128k-12\gamma-24\beta+40\beta\gamma+18\beta\gamma^2-12\beta^2\gamma-40\beta\gamma^3+6\beta\gamma^4-64\gamma^2k\\+8\gamma^4k+4\beta^2-35\gamma^2+12\gamma^3-\gamma^4+5\beta^2\gamma^2+12\beta^2\gamma^3-9\beta^2\gamma^4+36\end{pmatrix}}{\begin{pmatrix}24\beta+12\gamma+128k-40\beta\gamma-18\beta\gamma^2+12\beta^2\gamma+40\beta\gamma^3-6\beta\gamma^4-64\gamma^2k\\+8\gamma^4k-4\beta^2+35\gamma^2-12\gamma^3+\gamma^4-5\beta^2\gamma^2-12\beta^2\gamma^3+9\beta^2\gamma^4-36\end{pmatrix}^2}.$$

Since $k > k^T$, then we obtain $sign\left(\frac{\partial s^T}{\partial \beta}\right) = sign(-3\gamma^3-\gamma^2+8\gamma-4)$. Thus, we get when $0<\gamma<2/3$, then $\frac{\partial s^T}{\partial \beta} > 0$; when $2/3 \le \gamma < 1$, then $\frac{\partial s^T}{\partial \beta} \le 0$.

(2) $$\frac{\partial w^T}{\partial \beta} = -\frac{2(\gamma^4-5\gamma^2+4)\begin{pmatrix}40\beta\gamma-12\gamma-64k-24\beta+64\beta k-64\gamma k+18\beta\gamma^2-12\beta^2\gamma-40\beta\gamma^3\\+6\beta\gamma^4+16\gamma^3k+4\gamma^4k+4\beta^2-35\gamma^2+12\gamma^3-\gamma^4+5\beta^2\gamma^2\\+12\beta^2\gamma^3-9\beta^2\gamma^4-64\beta\gamma k-64\beta\gamma^2k+16\beta\gamma^3k+12\beta\gamma^4k+36\end{pmatrix}}{\begin{pmatrix}24\beta+12\gamma+128k-40\beta\gamma-18\beta\gamma^2+12\beta^2\gamma+40\beta\gamma^3-6\beta\gamma^4-64\gamma^2k\\+8\gamma^4k-4\beta^2+35\gamma^2-12\gamma^3+\gamma^4-5\beta^2\gamma^2-12\beta^2\gamma^3+9\beta^2\gamma^4-36\end{pmatrix}^2}$$, then

we obtain $sign\left(\frac{\partial w^T}{\partial \beta}\right) = sign(f_1)$, where $f_1 = g_1 k + g_0$.

$$g_1 = 64\gamma-64\beta+64\beta\gamma+64\beta\gamma^2-16\beta\gamma^3-12\beta\gamma^4-16\gamma^3-4\gamma^4+64,$$

$$g_0 = \begin{pmatrix}9\beta^2\gamma^4-12\beta^2\gamma^3-5\beta^2\gamma^2+12\beta^2\gamma-4\beta^2-6\beta\gamma^4+40\beta\gamma^3\\-18\beta\gamma^2-40\beta\gamma+24\beta+\gamma^4-12\gamma^3+35\gamma^2+12\gamma-36\end{pmatrix}.$$

It can be verified that $g_1 > 0$. What's more, when $0<\gamma<2/3$, $f_1(k=k^T)<0$; when $2/3 \le \gamma < 1$, $f_1(k=k^T) \ge 0$.

Thus, (i) when $0<\gamma<2/3$, there exists a unique k_1^T, so that when $k^T<k<k_1^T$, $f_1<0$, which means $\frac{\partial w^T}{\partial \beta}<0$; when $k \ge k_1^T$, $f_1>0$, which means $\frac{\partial w^T}{\partial \beta}>0$. k_1^T is the unique solution of the equation $f_1(k)=0$. (ii) When $2/3 \le \gamma < 1$, $f_1 \ge 0$, which means $\frac{\partial w^T}{\partial \beta}>0$.

(3) The rest of the proof is similar, then we omitted here. □

Proof of Proposition 7. Similar to the proof of Proposition 6, the proof of Proposition 7 is omitted here.

Proof of Proposition 8. Similar to the proof of Proposition 6, the proof of Proposition 8 is omitted here.

Proof of Proposition 9.

(1) $s^D - s^S = \dfrac{\beta\gamma - \gamma + 8\gamma k - 2\beta\gamma^2 + \beta\gamma^3 + \gamma^2 + \beta^2\gamma^2 - \beta^2\gamma^3 + 8\beta\gamma k}{(\gamma^2 + 8k - 1)(\beta^2\gamma^2 + 2\beta\gamma - 8k + 1)}$. We get $sign(s^D - s^S) = sign(f_2)$, where $f_2 = -8\gamma k(\beta + 1) + \gamma(\beta\gamma + 1)(1-\beta)(1-\gamma)$. Since it can be verified that $f_2(k^T) < 0$, then $f_2 < 0$, which means $s^D < s^S$.

(2) $s^T - s^D = \dfrac{-\begin{bmatrix} k(8\gamma+16)(\gamma-1)(2\gamma - 4\beta + 6\beta\gamma + 2\gamma^2 - \gamma^3 + 4) \\ +(3\gamma-2)(\beta-1)(\gamma-1)^2(\gamma+1)(2\beta+\gamma-3\beta\gamma-6) \end{bmatrix}}{(\gamma^2+8k-1)\begin{pmatrix} 24\beta + 12\gamma + 128k - 40\beta\gamma - 18\beta\gamma^2 + 12\beta^2\gamma \\ +40\beta\gamma^3 - 6\beta\gamma^4 - 64\gamma^2 k + 8\gamma^4 k - 4\beta^2 + 35\gamma^2 \\ -12\gamma^3 + \gamma^4 - 5\beta^2\gamma^2 - 12\beta^2\gamma^3 + 9\beta^2\gamma^4 - 36 \end{pmatrix}}$. We get $sign(s^T - s^D) = sign(f_3)$, where $f_3 = \begin{bmatrix} -8k(\gamma^2+\gamma-2)(2\gamma - 4\beta + 6\beta\gamma + 2\gamma^2 - \gamma^3 + 4) \\ -(\beta-1)(\gamma-1)^2(3\gamma^2+\gamma-2)(2\beta+\gamma-3\beta\gamma-6) \end{bmatrix}$. Since it can be verified that $8(2-\gamma^2-\gamma)(2\gamma - 4\beta + 6\beta\gamma + 2\gamma^2 - \gamma^3 + 4) > 0$ and $f_3(k^T) > 0$, then $f_3 > 0$, which means $s^T > s^D$.

(3) $s^T - s^S = \dfrac{\begin{bmatrix} k(8\gamma+16)(4\beta + 10\gamma - 2\beta\gamma + 2\beta\gamma^2 - 2\beta\gamma^3 + \beta\gamma^4 - 4\gamma^2 + \gamma^3 - 4) \\ +(\beta\gamma+1)(\beta-1)(\gamma-1)(-\gamma^2+3\gamma+2)(2\beta+\gamma-3\beta\gamma-6) \end{bmatrix}}{(\beta^2\gamma^2 + 2\beta\gamma - 8k + 1)\begin{pmatrix} 24\beta + 12\gamma + 128k - 40\beta\gamma - 18\beta\gamma^2 + 12\beta^2\gamma \\ -64\gamma^2 k + 8\gamma^4 k - 4\beta^2 + 35\gamma^2 - 12\gamma^3 + 40\beta\gamma^3 \\ -6\beta\gamma^4 + \gamma^4 - 5\beta^2\gamma^2 - 12\beta^2\gamma^3 + 9\beta^2\gamma^4 - 36 \end{pmatrix}}$. We get $sign(s^T - s^S) = sign(f_4)$, where $f_4 = \begin{bmatrix} k(8\gamma+16)\begin{pmatrix} 2\beta\gamma - 10\gamma - 4\beta - 2\beta\gamma^2 \\ +2\beta\gamma^3 - \beta\gamma^4 + 4\gamma^2 - \gamma^3 + 4 \end{pmatrix} \\ +(\beta\gamma+1)(1-\beta)(1-\gamma)(2-\gamma^2+3\gamma)(6-2\beta-\gamma+3\beta\gamma) \end{bmatrix}$. Since it can be verified that $(\beta\gamma+1)(1-\beta)(1-\gamma)(2-\gamma^2+3\gamma)(6-2\beta-\gamma+3\beta\gamma) > 0$, and when $0 < \beta < \hat{\beta}_1$, then $\begin{pmatrix} 2\beta\gamma - 10\gamma - 4\beta - 2\beta\gamma^2 \\ +2\beta\gamma^3 - \beta\gamma^4 + 4\gamma^2 - \gamma^3 + 4 \end{pmatrix} > 0$, that is $f_4 > 0$, which means $s^T > s^S$, where $\hat{\beta}_1 = -\dfrac{\gamma^3 - 4\gamma^2 + 10\gamma - 4}{\gamma^4 - 2\gamma^3 + 2\gamma^2 - 2\gamma + 4}$.

Proof of Proposition 10. Similar to the proof of Proposition 9, the proof of Proposition 10 is omitted here.

Proof of Proposition 11. Similar to the proof of Proposition 9, the proof of Proposition 11 is omitted here.

Proof of Proposition 12. Since solving for the comparison analytically is challenging, we derived the manufacturer's optimal channel selection based on the whole parameter space.

Proof of Proposition 13.

(1) $\pi_r{}^D - \pi_r{}^S = \dfrac{k(2\beta\gamma - 2\gamma + 16\gamma k - 2\beta\gamma^2 + \gamma^2 + \gamma^3 + \beta^2\gamma^2 - \beta^2\gamma^3)}{2(\gamma+1)(\gamma^2+8k-1)(\beta^2\gamma^2 + 2\beta\gamma - 8k + 1)}$. We get $sign(\pi_r{}^D - \pi_r{}^S) = sign(f_5)$, where $f_5 = \beta^2\gamma^2 + 2\beta\gamma - 8k + 1$. It can be verified that when $k > k^S$, then $f_5 < 0$, which means $\pi_r{}^D < \pi_r{}^S$.

(2) $$\pi_r^{\ T}-\pi_r^{\ D}=\frac{k(1-\gamma)\begin{pmatrix}40\beta\gamma-28\gamma-24\beta+128\gamma k+18\beta\gamma^2-12\beta^2\gamma\\ -40\beta\gamma^3+6\beta\gamma^4+96\gamma^2k-8\gamma^4k+4\beta^2\\ -23\gamma^2+28\gamma^3+3\gamma^4+5\beta^2\gamma^2+12\beta^2\gamma^3-9\beta^2\gamma^4+20\end{pmatrix}}{2(\gamma+1)(\gamma^2+8k-1)\begin{pmatrix}24\beta+12\gamma+128k-40\beta\gamma-18\beta\gamma^2+12\beta^2\gamma\\ +40\beta\gamma^3-6\beta\gamma^4-64\gamma^2k+8\gamma^4k-4\beta^2+35\gamma^2\\ -12\gamma^3+\gamma^4-5\beta^2\gamma^2-12\beta^2\gamma^3+9\beta^2\gamma^4-36\end{pmatrix}}$$. We get $sign(\pi_r^{\ T}-\pi_r^{\ D})=sign(f_6)$, where $f_6=8\gamma k(\gamma+2)^2(4-\gamma)-(3\gamma-2)(\beta-1)(\gamma-1)(\gamma+1)(\gamma-2\beta+3\beta\gamma+10)$. It can be verified that when $k>k^T$, then $f_6>0$, which means $\pi_r^{\ T}>\pi_r^{\ D}$.

(3) $$\pi_r^{\ T}-\pi_r^{\ S}=\frac{k\begin{pmatrix}24\beta-24\gamma+16\beta\gamma+128\gamma k-58\beta\gamma^2+8\beta^2\gamma-2\beta\gamma^3+26\beta\gamma^4\\ -6\beta\gamma^5+32\gamma^2k-32\gamma^3k+8\gamma^4k+8\gamma^5k-4\beta^2+35\gamma^2-20\\ +19\gamma^3-11\gamma^4+\gamma^5+23\beta^2\gamma^2-17\beta^2\gamma^3-15\beta^2\gamma^4+5\beta^2\gamma^5\end{pmatrix}}{2(\gamma+1)(\beta^2\gamma^2+2\beta\gamma-8k+1)\begin{pmatrix}24\beta+12\gamma+128k-40\beta\gamma-18\beta\gamma^2+12\beta^2\gamma-4\beta^2\\ +40\beta\gamma^3-6\beta\gamma^4-64\gamma^2k+8\gamma^4k+35\gamma^2\\ -12\gamma^3+\gamma^4-5\beta^2\gamma^2-12\beta^2\gamma^3+9\beta^2\gamma^4-36\end{pmatrix}}$$. We get $sign(\pi_r^{\ T}-\pi_r^{\ S})=sign(f_7)$, where $f_7=(\beta-1)(\gamma-1)(-\gamma^2+3\gamma+2)(7\gamma-2\beta+5\beta\gamma+5\beta\gamma^2-\gamma^2+10)-8\gamma k(\gamma+2)^2(\gamma^2-3\gamma+4)$. It can be verified that when $k>k^T$, then $f_7>0$. Thus, when $k^{TS}<k<\hat{k}_4$, then $f_7>0$, that is $\pi_r^{\ T}>\pi_r^{\ S}$; when $k\geq\hat{k}_4$, then $f_7\leq 0$, that is $\pi_r^{\ T}\leq\pi_r^{\ S}$, where $\hat{k}_4=\frac{(1-\beta)(\gamma^3-4\gamma^2+\gamma+2)(7\gamma-2\beta+5\beta\gamma+5\beta\gamma^2-\gamma^2+10)}{8\gamma(\gamma+2)^2(\gamma^2-3\gamma+4)}$.

Acknowledgments

This work is jointly supported by the Guangdong Provincial Philosophy and Social Sciences Planning Project (Grant No. GD26CYJ09); the 2024 Young Innovative Talent Program of the Guangdong Provincial Department of Education (Grant No. 2024WQNCX086); and the 2026 Youth Project of the Dongguan Philosophy and Social Sciences Planning Program (Grant No. 2026QN15).

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