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Strategic Product Line Design for Manufacturers in Competitive Sharing Markets

Yu Zhang [1], Jing Li [1,2] and Siyu Liu [3,*]

[1] School of Management, Fudan University, Shanghai 200433, China; zhangyuyu@fudan.edu.cn (Y.Z.); lijing1127@shupl.edu.cn (J.L.)
[2] School of Economics and Management, Shanghai University of Political Science and Law, Shanghai 200433, China
[3] School of Economics and Management, Shanghai Open University, Shanghai 200433, China
* Correspondence: liusiyu@sou.edu.cn

Abstract

In the fiercely competitive sharing market, manufacturers have launched product sharing/leasing services through business-to-customer (B2C) and peer-to-peer (P2P) platforms. To reduce the channel conflicts caused by product sharing, manufacturers expand product lines by renting products of different quality on their B2C platform. In this paper, we investigate the product lines in a vertically differentiated duopoly. We examine competing manufacturers' three product line strategies: the no-product line strategy, the high-end product line strategy, and the low-end product line strategy. We characterize the equilibrium outcomes under these strategies and investigate the manufacturers' preferences regarding these strategies. Our findings reveal a unique equilibrium: the high-quality manufacturer prefers offering a high-end product line, while the low-quality manufacturer opts for a low-end product line. This configuration leverages each firm's comparative advantage, mitigates channel conflict, reduces cannibalization, and supports effective market segmentation. The equilibrium leads to a Pareto improvement and enhances operational efficiency for both firms. These results suggest that aligning product line design with intrinsic product quality can balance profitability and market efficiency in shared markets.

Keywords: sharing economy; product lines; vertical differentiation; multi-product competition

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Academic Editors: Jose M. Cruz and Dong Li

Received: 1 July 2025
Revised: 20 August 2025
Accepted: 11 September 2025
Published: 12 December 2025

Citation: Zhang, Y.; Li, J.; Liu, S. Strategic Product Line Design for Manufacturers in Competitive Sharing Markets. *Sustainability* **2025**, *17*, 11143. https://doi.org/10.3390/su172411143

Correction Statement: This article has been republished with a minor change. The change does not affect the scientific content of the article and further details are available within the backmatter of the website version of this article.

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1. Introduction

The rise of the sharing economy has transformed traditional consumption and production models, creating both opportunities and tensions for manufacturers. Consumers increasingly value access over ownership, fostering the growth of product-sharing platforms that support flexible, and affordable consumption experiences. According to industry estimates, sharing-based models have eroded 10–30% of revenues in many traditional sectors over the past decade (Schroder [1]), forcing manufacturers to adapt.

In response, many manufacturers have entered the sharing economy by offering product-leasing services through business-to-customer (B2C) platforms or enabling consumer-to-consumer rentals via peer-to-peer (P2P) platforms. This dual-channel presence can improve product utilization and extend product lifecycles. However, it also introduces challenges such as market cannibalization, price competition, and channel conflicts. To mitigate these issues, manufacturers increasingly adopt vertical product differentiation—offering different quality levels across different channels.

For example, in the mobility sector, BMW's DriveNow platform rents out lower-end models like the MINI Cooper, while Tesla has announced plans to lease premium autonomous vehicles such as the Model X. Similar patterns emerge in other industries: Shenyang Machine Tool Group leases high-end CNC equipment via iSESOL in China, and Apple has experimented with rental-based access models for its devices through the iPhone Upgrade Program. In the healthcare industry, a clear quality-based segmentation is also evident: leading manufacturers such as GE Healthcare, Philips, and Siemens Healthineers lease advanced MRI and CT scanners to large hospitals, whereas smaller domestic firms such as Mindray and SonoScape provide rentals of basic devices like ultrasound and patient monitors to community clinics. These cases highlight a common trend—manufacturers strategically differentiate rental offerings by product quality to segment markets and alleviate competitive frictions in shared markets.

A growing body of research has explored product sharing from various angles, including platform pricing (Cachon et al. [2]), consumer heterogeneity (Abhishek et al. [3]), and manufacturer-platform partnerships (Li et al. [4]). Yet most studies focus on monopolistic contexts or single-product settings. Less attention has been paid to how competing manufacturers strategically design product lines when facing quality-based competition in sharing markets. Moreover, the intersection of product differentiation and channel structure remains underexplored (Bellos et al. [5]). We hope to fill these gaps by answering the following research questions: (1) How does competition affect a manufacturer's product line strategy for product sharing? (2) How does the product line strategy affect the price, demand, and market size?

We develop a game-theoretic model of a vertically differentiated duopoly, where each manufacturer can offer different quality products for rental on its B2C platform, in addition to direct sales and P2P options. Consumers decide whether to rent or buy based on their usage value. We characterize three product line strategies: no-product line (i.e., the manufacturer does not rent products on the B2C sharing platform), high-end product line (i.e., the manufacturer rents high-end products on the B2C sharing platform), and low-end product line (i.e., the manufacturer rents low-end products on the B2C sharing platform). Through subgame perfect Nash equilibrium analysis, we identify the manufacturers' equilibrium choices and assess the impact on market outcomes.

Our results show that the high-quality manufacturer prefers offering high-end products for rental, while the low-quality manufacturer opts for low-end rentals—forming a unique equilibrium that leads to a Pareto improvement. This equilibrium expands quality differentiation, mitigates cannibalization, and enables effective price discrimination without altering retail prices or market size. In contrast, strategies that fail to widen quality gaps intensify price competition and reduce retail demand. Managerially, aligning rental offerings with product positioning helps manufacturers coordinate channels, segment markets more effectively, and enhance overall performance in competitive sharing environments.

The rest of our paper is organized as follows. Section 2 summarizes the relevant literature. The main model is introduced in Section 3. Section 4 studies competing manufacturers' product line strategies. In Section 5, we discuss the impact of product line strategies on manufacturers' equilibrium prices and market sizes. Section 6 concludes the paper.

2. Related Literature

In this section, we review the related literature on product sharing, product lines, and multi-product competition to place our analysis in context.

2.1. Product Sharing

A stream of research has focused on operational aspects of sharing platforms, including vehicle routing (He et al. [6]; Kabra et al. [7]), staffing (Gurvich et al. [8]), pricing (Bai et al. [9]; Chen & Hu [10]; Hu & Zhou [11]; Kamble [12]; Taylor [13]), and risk management (Hong et al. [14]; Weber [15]; Liu et al. [16]). For instance, Mao et al. [17] further highlight the impact of operational performance on platform revenue.

Another stream of literature has investigated strategic partnerships between manufacturers and sharing platforms. On the supply side, Yu et al. [18] and Tian et al. [19] demonstrate that manufacturers might shift from traditional selling to leasing when per-use profit or marginal cost justifies the transition. Bellos et al. [5] emphasize how low-end, fuel-efficient car-sharing options can improve sustainability outcomes while maximizing returns. From the demand perspective, Abhishek et al. [3] and Li et al. [4] examine how usage heterogeneity and perceived value influence a manufacturer's decision to collaborate with P2P or B2C platforms. These studies complement earlier work on pricing effects and channel coordination challenges (Jiang & Tian [20]; Tian & Jiang [21]). Zhang et al. [22] further explore the optimal sharing model for a monopolist manufacturer, establishing an important benchmark for single-firm decisions.

Recent studies directly informing our work on quality differentiation and platform competition include Zhang et al. [23], who examine the impact of quality differentiation on a sharing manufacturer's product line strategy in a monopoly setting. Guan et al. [24] find that in a vertically differentiated duopoly, a manufacturer that establishes its own platform always benefits, while its rival may benefit only if quality differentiation is sufficient and production costs are not insignificant. Similarly, Zhang et al. [25] show that duopoly outcomes depend on the quality gap, with P2P generating scale effects and B2C enabling price discrimination.

However, these studies typically consider either monopoly/competition settings or quality differentiation/product lines in isolation, without addressing differentiated product lines in a competitive environment. Moreover, our work considers manufacturers' strategies of concurrently selling and adjusting product lines across multiple sharing channels (B2C and P2P). Our research addresses this gap by examining this complex interaction in a duopoly setting, demonstrating product line strategies for sharing manufacturers that incorporate rental channels within a competitive context.

2.2. Product Lines

Our work is also related to the literature on product line design, especially under quality differentiation (e.g., Mendelson and Parlaktürk [26]); Shugan et al. [27]). Foundational works by Mussa and Rosen [28] and Moorthy [29] analyze vertical differentiation and intra-line cannibalization in monopolistic settings. Desai et al. [30] and Heese and Swaminathan [31] point out that the lower the quality differentiation within the product line, the more intense the cannibalism. Desai [32] considers two dimensions of quality differentiation and level difference (i.e., taste preference), and studies how and when cannibalism affects product line design.

Recent research explores how product line strategy responds to demand uncertainty (Xu and Dukes [33]), communication and search costs (Villas-Boas [34]; Kuksov and Villas-Boas [35]), or endogenous quality choices (Joshi et al. [36]). Notably, Ha et al. [37] suggest that firms may prefer to allocate high-end products to direct sales channels while reserving low-end versions for secondary or less controlled channels—paralleling what we observe in B2C rental practices.

However, this body of work largely overlooks sharing platforms. The most relevant study is Zhang et al. [23], who explored the impact of quality differentiation on a

monopolist's product line design. We extend this inquiry to a competitive environment. Our contribution lies in integrating product line strategy, dual-channel sharing, and competition, illustrating how competitive factors influence firms' product line strategies for leasing channels.

2.3. Multi-Product Competition

There is also a rich literature on competition among multi-product firms, primarily in pricing (Federgruen and Hu [38]; Soon et al. [39]) and quantity decisions (Kluberg and Perakis [40]). Farahat and Perakis [41] establish equilibrium conditions in Bertrand competition, while Doraszelski and Draganska [42] and Chakraborty et al. [43] explore how firms adjust product portfolios in response to seasonal, financial, or cost-related factors.

Our research complements this stream by explicitly integrating sharing platforms into the multi-product competition framework. Unlike prior studies, we model access-based consumption, dual-channel strategies, and quality-differentiated product lines, demonstrating the optimal product line strategy for multi-product competition that considers rental platforms.

2.4. Contribution of Our Work

Our study provides a unified framework for analyzing quality-based competition in sharing markets, thereby contributing to three streams: product sharing, product line strategy, and multi-product competition. Unlike previous research focused on monopoly or single-product contexts—and even compared to recent studies exploring P2P/B2C mechanisms—we explicitly consider duopolistic competition where manufacturers design product lines spanning direct sales, B2C rental, and P2P sharing channels.

Crucially, we emphasize the strategic role of vertical differentiation in reducing cannibalization, maintaining pricing power, and enhancing market segmentation. This enables manufacturers to manage cross-channel self-competition and optimize profitability. Furthermore, our model integrates platform-mediated access into multi-product competition, offering a comprehensive perspective on how sharing platforms reshape product line strategies. By linking quality-differentiated product lines with dual-channel sharing considerations, our study addresses a gap in the recent literature and provides actionable insights for firms navigating contemporary sharing markets.

3. Model

There are two competing manufacturers $i = \{H, L\}$ in the market, which sell the retail product q_i to consumers directly and provide the product sharing service to consumers through their own P2P sharing platforms (e.g., Daimler, the parent company of Mercedes-Benz, operates car-sharing services through its P2P platform Croove). The two manufacturers are vertical differences in the quality of retail products, where $q_H > q_L > 0$. The quality differentiation between retail products is defined as $\Delta q = q_H - q_L$. Manufacturer i may expand its product line by building the B2C sharing platform to provide the rental product q_{si} ($q_i \neq q_{si}$) (the B2C sharing platform enables rental-based consumption and can help improve product utilization).

Consumers decide whether to buy products, rent products from P2P platforms, or rent products from B2C platforms based on their utility. Without loss of generality, we assume that the market size is 1 and each consumer use at most one unit of the product. On the one hand, Consumers' usage valuation of quality is heterogeneous, captured by θ, which is the willingness to pay for quality and independent and distributed uniformly within $[0, 1]$. A consumer of type θ obtains usage value $v + \theta q_i$ (or $v + \theta q_{si}$) when using a product of quality q_i (or q_{si}), where v is the constant ($v > 0$) and represents the basic utility

brought by the product. We assume that v is large enough, which means that all consumers will use the product. On the other hand, consumers will not use the product during the entire use time. Referring to Benjaafar et al. [44], we assume that consumer's usage level is ρ, which indicates the proportion of time they plan to use the product, $\rho \in (0,1)$. This means that consumers who have purchased the product (called the owner) have $1-\rho$ percentage of the time to rent it out through the P2P platform. The renter rents the owner's product from the P2P platform of manufacturer i at the market-clearing price p_{ri} per usage level (Jiang and Tian [18]), and uses it with ρ percentage of the time. Manufacturer i will charge a commission fee ηp_{ri} per usage level, where the exogenous $\eta \in [0,1)$ is called the commission rate (Abhishek et al. [3]). The marginal cost of manufacturer i's retail product and rental product (on the B2C platform) are c_i and c_{si}. We let $q_s = |q_i - q_{si}|$ and $c_s = |c_i - c_{si}|$ denote the quality differentiation and cost difference between retail and rental products, respectively (We consider the quality differentiation of heterogeneity (i.e., the quality differentiation of high-end product lines is q_s1, and that of low-end product lines is q_s2), and show that the equilibrium is consistent with the conclusion of the main model).

Manufacturer i has three product line strategies, and the model structure is presented in Figure 1. If manufacturer i adopts the no-product line strategy, he will produce retail product q_i at retail price p_i (Figure 1a). If manufacturer i adopts the high-end product line strategy, he will produce rental products of quality $q_i + q_s$ at the marginal cost $c_i + c_s$ by B2C platform (Figure 1b). If manufacturer i adopts the low-end product line strategy, he will produce rental products of quality $q_i - q_s$ at marginal cost $c_i - c_s$ by B2C platform (Figure 1c). The renter rents the rental product on the B2C platform of manufacturer i at rental price r_{si} per usage level, which is decided by manufacturer. Assuming $\Delta q > 2q_s$ and $c_H - c_L > 2c_s$, then even if manufacturer L introduces high-quality products to the rental channel, it is still not dominant. For the convenience of analysis, we assume that the construction cost of the B2C platform is zero.

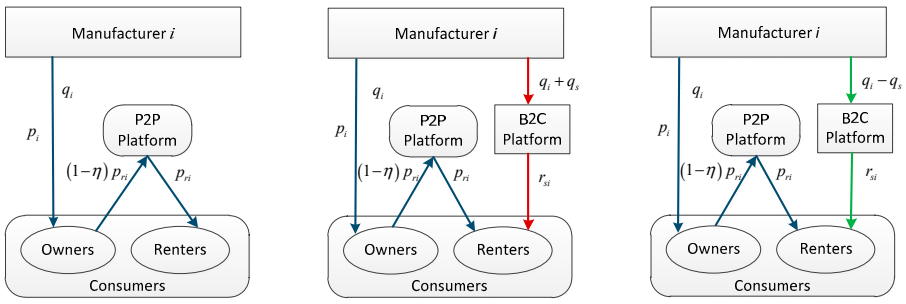


Figure 1. Model structure.

The sequence of the game is as follows. In stage 1, both manufacturers simultaneously decide their product line strategies (i.e., no-product line strategy (N), high-end product line strategy (S^+)), or low-end product line strategy (S^-). In Stage 2, the manufacturers determine their retail price p_i. If manufacturer i chooses a high-end product line strategy or a low-end product line strategy, he also determines the rental price r_{si} of rental products. In Stage 3, consumers choose a manufacturer and make purchase and/or share/lease decisions. We use $Z = z_L z_H$ to represent the product line strategy combination of competing manufacturers when the low-quality manufacturer (L) adopts strategy z_L and the high-quality manufacturer (H) adopts strategy z_H, where $z_i = \{N, S^+, S^-\}$. It follows that there are 9 possible strategy subgames, $Z = \{NN, NS^+, S^+N, S^+S^+, NS^-, S^-N, S^-S^-, S^+S^-, S^-S^+\}$. Table 1 details the notation and Figure 2 depicts the timing of events.

Table 1. Summary of notation.

Symbol	Definition
$i = \{H, L\}$	Types of two competing manufacturers
p_i	The retail price of the manufacturer i's retail products
r_{si}	The sharing price of the manufacturer i's rental products (per usage level)
q_i	The quality of the manufacturer i's retail products
q_{si}	The quality of the manufacturer i's rental products
c_i	The marginal cost of the manufacturer i's retail products
c_{si}	The marginal cost of the manufacturer i's rental products
Δq	The quality differentiation between retail products, where $\Delta q = q_H - q_L$
q_s	The quality differentiation between retail and rental products, where $q_s = \lvert q_i - q_{si} \rvert$
c_s	The cost difference between retail and rental products, where $c_s = \lvert c_i - c_{si} \rvert$
p_{ri}	The sharing price paid by the renter on manufacturer's P2P sharing platform
η	The commission rate of the P2P sharing platform
$\theta \sim U[0, 1]$	Consumers' willingness to pay for quality
ρ	Consumers' usage level

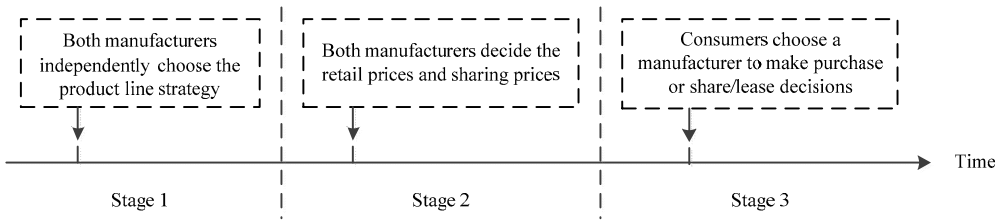


Figure 2. Timing of events.

4. Analysis

In this section, we first analyze consumers' purchase or share/lease decisions. Then, we present the subgame Nash equilibrium analysis. To ensure the existence of the equilibrium outcomes, $(c_H - c_L)/\Delta q < c_s/q_s$ and $q_s > 3c_s/2$ is required.

4.1. Consumer Decisions

When manufacturer i adopts the no-product line strategy (N), he will produce retail products with quality q_i at marginal cost c_i and sell them to consumers at the retail price p_i. The consumer either buys the retail product or rents the owner's rental product on the P2P platform at the sharing price p_{ri} per usage level, because the owner will rent it out with a probability of $1 - \rho$. For the consumer, the utility as an owner and the utility as a renter are as follows: The utility of a consumer buying (being an owner) or renting (being a renter) the product of manufacturer i is as follows:

$$U_{oi}^N = v + \rho\theta q_i + (1 - \rho)(1 - \eta)p_{ri} - p_i \tag{1}$$

$$U_{ri}^N = v + \rho(\theta q_i - p_{ri}) \tag{2}$$

When manufacturer i adopts a high-end product line strategy (S^+), he will produce rental products with quality $q_{si} = q_i + q_s$ at marginal cost $c_{si} = c_i + c_s$ and rent them to consumers at the rental price r_{si} per usage level. Consumers either buy retail products or rent products on P2P platforms or rent high-quality products from manufacturers on B2C

platforms. For consumers, the utility of the owner and the P2P platform's renter is shown in Equations (1) and (2), while the utility of the renter renting the products on the B2C platform of manufacturer i is as follows:

$$U_{si}^{S^+} = v + \rho[\theta(q_i + q_s) - r_{si}] \tag{3}$$

When manufacturer i adopts a low-end product line strategy (S^-), he will produce rental products with quality $q_{si} = q_i - q_s$ at marginal cost $c_{si} = c_i - c_s$ and rent them to consumers at the rental price r_{si} per usage level. Consumers either buy retail products or rent products on P2P platforms or rent low-quality products from manufacturers on B2C platforms. For consumers, the utility of the owner and the P2P platform's renter is shown in Equations (1) and (2), while the utility of the renter renting the products on the B2C platform of manufacturer i is as follows:

$$U_{si}^{S^-} = v + \rho[\theta(q_i - q_s) - r_{si}] \tag{4}$$

4.2. Subgame Equilibrium Analysis

In this section, the above nine subgames are divided into four cases: (1) benchmark—both manufacturers adopt the no-product line strategy; (2) at least one manufacturer adopts the high-end product line strategy; (3) at least one manufacturer adopts the low-end product line strategy; (4) one manufacturer adopts the high-end product line strategy and the other adopts the low-end product line strategy. We consider these cases sequentially.

4.2.1. Benchmark—Both Manufacturers Adopt the No-Product Line Strategy

We first consider the case where the manufacturers all adopt the no-product line strategy, i.e., the *NN* subgame. Under the *N* strategy, the manufacturer makes a profit by selling products and collecting the commission fee from his P2P platform. Each manufacturer's profit includes retail profit and rental profit on the P2P platform, and the profit function is:

$$\pi_i^N = (p_i - c_i)d_{bi} + \eta p_{ri}\rho d_{ri} \tag{5}$$

where d_{bi} represents the retail demand of manufacturer i and d_{ri} represents the size of renters from the P2P platform of manufacturer i.

Referring to Xue et al., the market-clearing price p_{ri} of the P2P platform is the sharing price in the equilibrium state of supply and demand, then we obtain the equation $(1-\rho)d_{bi} = \rho d_{ri}$. And referring to Jiang and Tian [18], P2P sharing will exist when the owner's utility is equal to the renter's utility, then equation $p_{ri} = (p_i - c_i)/e$ will hold, where $e = \rho + (1-\eta)(1-\rho)$. These two equations guarantee the existence of P2P sharing and the balance between supply and demand. The following lemma describes the equilibrium outcomes.

Lemma 1. *When both manufacturers adopt the no-product line strategy, the equilibrium prices in the NN subgame are* $p_H^{NN} = e(2\Delta q + 2c_H + c_L)/3$ *and* $p_L^{NN} = e(\Delta q + c_H + 2c_L)/3$, *and the equilibrium demands in the NN subgame are* $d_{bH}^{NN} = \rho(2\Delta q - c_H + c_L)/(3\Delta q)$ *and* $d_{bL}^{NN} = \rho(\Delta q + c_H - c_L)/(3\Delta q)$.

After simplifying the profit function (5), the manufacturer's profit function can be expressed as $\pi_i^N = (p_i/e - c_i)d_{bi}$. To ensure the uniqueness of the equilibrium price, $p_i^{NN}/e \geq c_i$ is required, i.e., $\Delta q \geq (c_H - c_L)/2$. The equilibrium profits of the two manufacturers are $\pi_H^{NN} = \rho(2\Delta q - c_H + c_L)^2/(9\Delta q)$ and $\pi_L^{NN} = \rho(\Delta q + c_H - c_L)^2/(9\Delta q)$, respectively.

Note that manufacturer L and manufacturer H have nine product line strategy combinations, and the set of product line strategy combinations is represented by

$Z = \{NN, NS^+, S^+N, S^+S^+, NS^-, S^-N, S^-S^-, S^+S^-, S^-S^+\}$. We analyze the consumer's decision and the manufacturer's pricing decision in each subgame. For each subgame, we start from analyzing the consumer's decision, derive the demand for each manufacturer, and then substitute the demand into the profit function of the two manufacturers to obtain the optimal prices.

Proof of Lemma 1. *NN* **subgame:** In this subgame, both manufacturers offer the no-product line strategy, the manufacturer i's profit is given by $\pi_i^N = (p_i - c_i)d_{bi} + \eta p_{ri}\rho d_{ri}$. The utility of the owner is $U_{oi}^N = v + \rho\theta q_i + (1-\rho)(1-\eta)p_{ri} - p_i$. If $U_{oH}^N \geq U_{oL}^N$, or the equivalent, if $\theta \geq \theta^{NN} = (p_H - p_L)/(\rho\Delta q)$, consumers will buy manufacturer H's retail products, otherwise they will buy manufacturer L's retail products. The retail demand of the two manufacturers is $d_{bH}^{NN} = 1 - \theta^{NN}$ and $d_{bL}^{NN} = \theta^{NN}$, and the profit is $\pi_H^{NN} = (p_H - c_H)\left(1 - \theta^{NN}\right)$ and $\pi_L^{NN} = (p_L - c_L)\theta^{NN}$. From the first order conditions (FOC), by solving $\partial\pi_i^{NN}/\partial p_i = 0$, we obtain the equilibrium prices $p_H^{NN} = e(2\Delta q + 2c_H + c_L)/3$ and $p_L^{NN} = e(\Delta q + c_H + 2c_L)/3$, where $e = \rho + (1-\eta)(1-\rho)$. The manufacturers' equilibrium profits are $\pi_H^{NN} = \rho(2\Delta q - c_H + c_L)^2/(9\Delta q)$ and $\pi_L^{NN} = \rho(\Delta q + c_H - c_L)^2/(9\Delta q)$, and in order to guarantee $p_H^{NN}/e \geq c_H$, $\Delta q \geq (c_H - c_L)/2$ need to be satisfied, which guarantees the uniqueness of the equilibrium price. □

4.2.2. At Least One Manufacturer Adopts the S^+ Strategy

We now analyze the case where at least one manufacturer adopts the high-end product line strategy, which results in three combinations of strategies, i.e., NS^+, S^+N and S^+S^+ subgames. If the manufacturer adopts the S^+ strategy, he will maximize profits by setting the retail price for the retail product, taking the commission fee from his P2P platform and setting the rental price for the rental product of the B2C platform. The profit function is as follows:

$$\pi_i^{S^+} = (p_i - c_i)d_{bi} + \eta p_{ri}\rho d_{ri} + (r_{si} - c_i - c_s)\rho d_{si} \tag{6}$$

where d_{si} is the size of renters on manufacturer i's B2C platform. The equilibrium price and demand for NS^+, S^+N and S^+S^+ subgames are presented in the following lemma.

Lemma 2. *When at least one manufacturer adopts the high-end product line strategy, Table 2 presents the equilibrium prices and demands in the NS^+, S^+N and S^+S^+ subgames.*

Table 2. Manufacturers' equilibrium prices and demands in NS^+, S^+N and S^+S^+ subgames.

	$Z = NS^+$	$Z = S^+N$	$Z = S^+S^+$
p_H^Z	$\frac{e(2\Delta q+2c_H+c_L)}{3}$	$\frac{e(2\Delta q+2c_H+c_L+c_s-2q_s)}{3}$	$\frac{e(2\Delta q+2c_H+c_L+c_s-2q_s)}{3}$
p_L^Z	$\frac{e(\Delta q+c_H+2c_L)}{3}$	$\frac{e(2\Delta q+2c_H+4c_L+c_s-2q_s)}{6}$	$\frac{e(2\Delta q+2c_H+4c_L+c_s-2q_s)}{6}$
r_H^Z	$\frac{2\Delta q+2c_H+c_L}{3} + \frac{c_s+q_s}{2}$	——	$\frac{4\Delta q+c_H-q_s+3c_{Hs}+2c_{Ls}}{6}$
r_L^Z	——	$\frac{\Delta q+c_H+2c_L+2c_s-q_s}{3}$	$\frac{\Delta q+c_H+2c_L+2c_s-q_s}{3}$
d_{bH}^Z	$\frac{\rho}{6} + \frac{\rho c_s}{2q_s} - \frac{\rho(c_H-c_L)}{3\Delta q}$	$\frac{2\rho}{3} - \frac{\rho(c_H-c_L-c_s)}{3(\Delta q-q_s)}$	$\frac{\rho}{6} + \frac{\rho c_s}{2q_s} - \frac{\rho(c_H-c_L)}{3\Delta q}$
d_{bL}^Z	$\frac{\rho(\Delta q+c_H-c_L)}{3\Delta q}$	$\frac{\rho c_s}{2q_s}$	$\frac{\rho c_s}{2q_s}$
d_{mH}^Z	$\frac{q_s-c_s}{2q_s}$	——	$\frac{q_s-c_s}{2q_s}$
d_{mL}^Z	——	$\frac{1}{3} + \frac{c_H-c_L-c_s}{3(\Delta q-q_s)} - \frac{c_s}{2q_s}$	$\frac{1}{3} + \frac{c_H-c_L-c_s}{3(\Delta q-q_s)} - \frac{c_s}{2q_s}$

As shown in Table 2, assuming that the low-quality manufacturer adopts the N or S^+ strategy and remains unchanged, it will only affect the high-quality manufacturer but not the competitor if the high-quality manufacturer adopts the S^+ strategy (i.e., a high-end product line strategy). Specifically, the high-quality manufacturer's retail price remains

unchanged and retail demand decreases, but the low-quality manufacturer's retail price and retail demand remain unchanged. This shows that when the high-quality manufacturer adopts the S^+ strategy, some of its consumers will switch from its retail channel to its rental channel. Assuming that the high-quality manufacturer adopts the N or S^+ strategy and remains unchanged, it will affect both manufacturers if the low-quality manufacturer adopts the S^+ strategy. Specifically, both manufacturer's retail prices decreases, and the low-quality manufacturer's retail demand decreases and the high-quality manufacturer's retail demand increases. This shows that when the low-quality manufacturer adopts the S^+ strategy, some of its consumers will switch from its retail channel to its competitor's retail channel.

Proof of Lemma 2. NS^+, S^+N **and** S^+S^+ **subgames:** In NS^+ subgame, manufacturer L offers the no-product line strategy and manufacturer H offers the S^+ strategy. We have $U_{oH}^{S^+} = v + \rho\theta q_H + (1-\rho)(1-\eta)p_{rH} - p_H$, $U_{rH}^{S^+} = v + \rho(\theta q_H - p_{rH})$, $U_{rL}^{N} = v + \rho(\theta q_L - p_{rL})$, $U_{sH}^{S^+} = v + \rho[\theta(q_H + q_s) - r_{sH}]$, and $U_{oL}^{N} = v + \rho\theta q_L + (1-\rho)(1-\eta)p_{rL} - p_L$. If $\theta \geq \theta_H^{NS^+}, = (r_{sH} - p_{rH})/q_s$ consumers will rent products of quality q_{sH} from the B2C platform of manufacturer H, if $\theta_{HL}^{NS^+} = (p_{rH} - p_{rL})/\Delta q < \theta \leq \theta_H^{NS^+}$, consumers will buy or rent products of quality q_H from the P2P platform of manufacturer H, otherwise, if $0 \leq \theta \leq \theta_{HL}^{NS^+} \theta \geq \theta_H^{NS^+} = (r_{sH} - p_{rH})/q_s$, consumers will buy or rent products of quality q_L from the P2P platform of manufacturer L. The retail demand and the size of renters on the B2C and P2P platform of manufacturer H are $d_{bH}^{NS^+} = \rho\left(\theta_H^{NS^+} - \theta_{HL}^{NS^+}\right)$, $d_{sH}^{NS^+} = 1 - \theta_H^{NS^+}$ and $d_{rH}^{NS^+} = (1-\rho)\left(\theta_H^{NS^+} - \theta_{HL}^{NS^+}\right)$, and the retail demand and the size of renters on the P2P platform of the manufacturer L is $d_{bL}^{NS^+} = \rho\theta_{HL}^{NS^+}$ and $d_{bL}^{NS^+} = (1-\rho)\theta_{HL}^{NS^+}$. Then The equilibrium profits of competing manufacturers are $\pi_H^{NS^+} = (p_H - c_H)d_{bH}^{NS^+} + \eta p_{rH}\rho d_{rH}^{NS^+} + (r_{sH} - c_H - c_s)\rho d_{sH}^{NS^+}$ and $\pi_L^{NS^+} = (p_L - c_L)d_{bL}^{NS^+} + \eta p_{rL}\rho d_{rL}^{NS^+}$. From the first order conditions (FOC), by solving $\partial\pi_i^{NS^+}/\partial p_i = 0$ and $\partial\pi_i^{NS^+}/\partial r_i = 0$, we obtain the manufacturers' equilibrium prices are $p_H^{NS^+} = e(2\Delta q + 2c_H + c_L)/3$, $p_L^{NS^+} = e(\Delta q + c_H + 2c_L)/3$, and $r_H^{NS^+} = (2\Delta q + c_H + 2c_L)/3 + (c_s + q_s)/2$. Then, the equilibrium profits of manufacturers are $\pi_H^{NS^+} = \rho(2\Delta q - c_H + c_L)^2/(9\Delta q) + \rho(q_s - c_s)^2/(4q_s)$ and $\pi_L^{NS^+} = \rho(\Delta q + c_H - c_L)^2/(9\Delta q)$.

In S^+N subgame, manufacturer H offers the no-product line strategy and manufacturer L offers the S^+ strategy. We have $U_{oH}^{N} = v + \rho\theta q_H + (1-\rho)(1-\eta)p_{rH} - p_H$, $U_{rH}^{N} = v + \rho(\theta q_H - p_{rH})$ and $U_{oL}^{S^+} = v + \rho\theta q_L + (1-\rho)(1-\eta)p_{rL} - p_L$,.$U_{rL}^{S^+} = v + \rho(\theta q_L - p_{rL})$, $U_{sL}^{S^+} = v + \rho[\theta(q_L + q_s) - r_{sL}]$. If $\theta \geq \theta_{HL}^{S^+N} = (p_{rH} - r_{sL})/(\Delta q - q_s)$, consumers will buy or rent products of quality q_H from the P2P platform of manufacturer H, if $\theta_L^{S^+N} = (r_{sL} - p_{rL})/q_s \leq \theta < \theta_{HL}^{S^+N}$, consumers will rent products of quality q_{sL} from the B2C platform of manufacturer L, otherwise, if $0 \leq \theta < \theta_L^{S^+N}$, consumers will buy or rent products of quality q_L from the P2P platform of manufacturer L. The retail demand and the size of renters on the P2P platform of manufacturer H are $d_{bH}^{S^+N} = \rho\left(1 - \theta_{HL}^{S^+N}\right)$ and $d_{rH}^{S^+N} = (1-\rho)\left(1 - \theta_{HL}^{S^+N}\right)$, and the retail demand and the size of renters on the P2P and B2C platform of the manufacturer L are $d_{bL}^{S^+N} = \rho\theta_L^{S^+N}$, $d_{bL}^{S^+N} = (1-\rho)\theta_L^{S^+N}$ and $d_{sL}^{S^+N} = \theta_{HL}^{S^+N} - \theta_L^{S^+N}$. Then the profits are $\pi_H^{S^+N} = (p_H - c_H)d_{bH}^{S^+N} + \eta p_{rH}\rho d_{rH}^{S^+N}$ and $\pi_L^{S^+N} = (p_L - c_L)d_{bL}^{S^+N} + \eta p_{rL}\rho d_{rL}^{S^+N} + (r_{sL} - c_L - c_s)\rho d_{sL}^{S^+N}$. From the first order conditions (FOC), by solving $\partial\pi_i^{S^+N}/\partial p_i = 0$ and $\partial\pi_i^{S^+N}/\partial r_i = 0$, we obtain the equilibrium prices are $p_H^{S^+N} = e(2\Delta q + 2c_H + c_L + c_s - 2q_s)/3$, $p_L^{S^+N} = e(2\Delta q + 2c_H + 4c_L + c_s - 2q_s)/6$, and $r_L^{S^+N} = (\Delta q + c_H + 2c_L + 2c_s - q_s)/3$. Then, the equilibrium profits of competing manufacturers are $\pi_L^{S^+N} = \rho{c_s}^2/(4q_s) + \rho(\Delta q + c_H - c_L - c_s - q_s)^2/(9(\Delta q - q_s))$ and $\pi_H^{S^+N} = \rho(2\Delta q - 2q_s - c_H + c_L + c_s)^2/(9(\Delta q - q_s))$.

In S^+S^+ subgame, both manufacturers offer the S^+ strategy. We have $U_{oH}^{S^+} = v + \rho\theta q_H + (1-\rho)(1-\eta)p_{rH} - p_H$, $U_{rH}^{S^+} = v + \rho(\theta q_H - p_{rH})$, $U_{rL}^{S^+} = v + \rho(\theta q_L - p_{rL})$, $U_{sH}^{S^+} = v + \rho[\theta(q_H + q_s) - r_{sH}]$, $U_{oL}^{S^+} = v + \rho\theta q_L + (1-\rho)(1-\eta)p_{rL} - p_L$ and $U_{sL}^{S^+} = v + \rho[\theta(q_L + q_s) - r_{sL}]$. If $\theta \geq \theta_H^{S^+S^+} = (r_{sH} - p_{rH})/q_s$, consumers will rent products of quality q_{sH} from the B2C platform of manufacturer H, if $\theta_{HL}^{S^+S^+} = (p_{rH} - r_{sL})/(\Delta q - q_s) \leq \theta < \theta_H^{S^+S^+}$, consumers will buy or rent products of quality q_H from the P2P platform of manufacturer H, if $\theta_L^{S^+S^+} = (r_{sL} - p_{rL})/q_s \leq \theta < \theta_{HL}^{S^+S^+}$, consumers will rent products of quality q_{sL} from the B2C platform of manufacturer L, otherwise, if $0 \leq \theta < \theta_L^{S^+S^+}$, consumers will buy or rent products of quality q_L from the P2P platform of manufacturer L. The retail demand and the size of renters on the P2P and B2C platform of the manufacturer H are $d_{bH}^{S^+S^+} = \rho\left(\theta_H^{S^+S^+} - \theta_{HL}^{S^+S^+}\right)$, $d_{rH}^{S^+S^+} = (1-\rho)\left(\theta_H^{S^+S^+} - \theta_{HL}^{S^+S^+}\right)$, and $d_{sH}^{S^+S^+} = 1 - \theta_H^{S^+S^+}$. The retail demand and the size of renters on the P2P and B2C platform of the manufacturer L are $d_{bL}^{S^+S^+} = \rho\theta_L^{S^+S^+}$, $d_{rL}^{S^+S^+} = (1-\rho)\theta_L^{S^+S^+}$, and $d_{sL}^{S^+S^+} = \theta_{HL}^{S^+S^+} - \theta_L^{S^+S^+}$. Then the competing manufacturers' profits are $\pi_H^{S^+S^+} = (p_H - c_H)d_{bH}^{S^+S^+} + \eta p_{rH}\rho d_{rH}^{S^+S^+} + (r_{sH} - c_H - c_s)\rho d_{sH}^{S^+S^+}$ and $\pi_L^{S^+S^+} = (p_L - c_L)d_{bL}^{S^+S^+} + \eta p_{rL}\rho d_{rL}^{S^+S^+} + (r_{sL} - c_L - c_s)\rho d_{sL}^{S^+S^+}$. From the first order conditions (FOC), by solving $\partial\pi_i^{S^+S^+}/\partial p_i = 0$ and $\partial\pi_i^{S^+S^+}/\partial r_i = 0$, we obtain equilibrium prices are $p_H^{S^+S^+} = e(2\Delta q + 2c_H + c_L + c_s - 2q_s)/3$, $p_L^{S^+S^+} = e(2\Delta q + 2c_H + 4c_L + c_s - 2q_s)/6$, $r_H^{S^+S^+} = (4\Delta q + c_H - q_s + 3c_{Hs} + 2c_{Ls})/6$ and $r_L^{S^+S^+} = (\Delta q + c_H + 2c_L + 2c_s - q_s)/3$. The profits are $\pi_H^{S^+S^+} = \rho(q_s - c_s)^2/(4q_s) + \rho(c_H - c_L - c_s)^2/(9(\Delta q - q_s)) + 4\rho(\Delta q - c_H + c_L - q_s + c_s)/9$ and $\pi_L^{S^+S^+} = \rho(\Delta q + c_H - c_L - c_s - q_s)^2/(9(\Delta q - q_s)) + \rho {c_s}^2/(4q_s)$. □

4.2.3. At Least One Manufacturer Adopts the S^- Strategy

We now analyze the case where at least one manufacturer adopts the low-end product line strategy, which results in three combinations of strategies, i.e., NS^-, S^-N and S^-S^- subgames. If the manufacturer adopts the S^- strategy, the profit function is as follows:

$$\pi_i^{S^-} = (p_i - c_i)d_{bi} + \eta p_{ri}\rho d_{ri} + (r_{si} - c_i + c_s)\rho d_{si} \tag{7}$$

The following lemma discusses the equilibrium prices and demands of these three subgames.

Lemma 3. *When at least one manufacturer adopts the low-end product line strategy, Table 3 presents the equilibrium prices in the NS^-, S^-N and S^-S^- subgames.*

Table 3. Manufacturers' equilibrium prices and demands in NS^-, S^-N and S^-S^- subgames.

	$Z = NS^-$	$Z = S^-N$	$Z = S^-S^-$
p_H^Z	$\frac{e(4\Delta q + 4c_H + 2c_L + c_s - q_s)}{6}$	$\frac{e(2\Delta q + 2c_H + c_L)}{3}$	$\frac{e(4\Delta q + 4c_H + 2c_L + c_s - q_s)}{6}$
p_L^Z	$\frac{e(\Delta q + c_H + 2c_L - c_s - q_s)}{3}$	$\frac{e(\Delta q + c_H + 2c_L)}{3}$	$\frac{e(\Delta q + c_H + 2c_L - c_s - q_s)}{3}$
r_H^Z	$\frac{2\Delta q + 2c_H + c_L - 2c_s - 2q_s}{3}$	——	$\frac{2\Delta q + 2c_H + c_L - 2c_s - 2q_s}{3}$
r_L^Z	——	$\frac{2\Delta q + 2c_H + 4c_L - 3c_s}{6}$	$\frac{2\Delta q + 2c_H + 4c_L - 5c_s - 2q_s}{6}$
d_{bH}^Z	$\frac{\rho(q_s - c_s)}{2q_s}$	$\frac{\rho(2\Delta q - c_H + c_L)}{3\Delta q}$	$\frac{\rho(q_s - c_s)}{2q_s}$
d_{bL}^Z	$\frac{\rho}{3} + \frac{\rho(c_H - c_L - c_s)}{3(\Delta q - q_s)}$	$\frac{\rho(\Delta q + c_H - c_L)}{3\Delta q} - \frac{\rho c_s}{2q_s}$	$\frac{\rho}{3} + \frac{\rho(c_H - c_L - c_s)}{3(\Delta q - q_s)} - \frac{\rho c_s}{2q_s}$
d_{mH}^Z	$\frac{1}{6} + \frac{c_s}{2q_s} - \frac{c_H - c_L - c_s}{3(\Delta q - q_s)}$	——	$\frac{1}{6} + \frac{c_s}{2q_s} - \frac{c_H - c_L - c_s}{3(\Delta q - q_s)}$
d_{mL}^Z	——	$\frac{c_s}{2q_s}$	$\frac{c_s}{2q_s}$

As shown in Table 3, assuming that the high-quality manufacturer adopts the N or S^- strategy and remains unchanged, it will only affect the low-quality manufacturer but

not the competitor if the low-quality manufacturer adopts the S^- strategy (a low-end product line strategy). Specifically, the low-quality manufacturer's retail price remains unchanged and retail demand decreases, but the high-quality manufacturer's retail price and retail demand remain unchanged. This shows that when the low-quality manufacturer adopts the S^- strategy, some of its consumers will switch from its retail channel to its rental channel. Assuming that the low-quality manufacturer adopts the N or S^- strategy and remains unchanged, it will affect both manufacturers if the high-quality manufacturer adopts the S^- strategy. Specifically, both manufacturer's retail prices decreases, and the high-quality manufacturer's retail demand decreases and the low-quality manufacturer's retail demand increases. This shows that when the high-quality manufacturer adopts the S^- strategy, some of its consumers will switch from its retail channel to its competitor's retail channel.

Proof of Lemma 3. NS^-, S^-N **and** S^-S^- **subgames:** In NS^- subgame, manufacturer L offers the no-product line strategy and manufacturers H offers the S^- strategy. We have $U_{oH}^{S^-} = v + \rho\theta q_H + (1-\rho)(1-\eta)p_{rH} - p_H$, $U_{oL}^{N} = v + \rho\theta q_L + (1-\rho)(1-\eta)p_{rL} - p_L$, $U_{rH}^{S^-} = v + \rho(\theta q_H - p_{rH})$, $U_{sH}^{S^-} = v + \rho[\theta(q_H - q_s) - r_{sH}]$ and $U_{rL}^{N} = v + \rho(\theta q_L - p_{rL})$. If $\theta \geq \theta_H^{NS^-} = (p_{rH} - r_{sH})/q_s$, consumers will buy or rent products of quality q_H from the P2P platform of manufacturer H, if $\theta_{HL}^{NS^-} = (r_{sH} - p_{rL})/(\Delta q - q_s) < \theta \leq \theta_H^{NS^-}$, consumers will rent products of quality q_{sH} from the B2C platform of manufacturer H, otherwise, if $0 \leq \theta \leq \theta_{HL}^{NS^-}$, consumers will buy or rent products of quality q_L from the P2P platform of manufacturer L. The retail demand and the size of renters on the P2P and B2C platform of the manufacturer H are $d_{bH}^{NS^-} = \rho\left(1 - \theta_H^{NS^-}\right)$, $d_{rH}^{NS^-} = (1-\rho)\left(1 - \theta_H^{NS^-}\right)$ and $d_{sH}^{NS^-} = \theta_H^{NS^-} - \theta_{HL}^{NS^-}$, and the retail demand and the size of renters on the P2P platform of the manufacturer L is $d_{bL}^{NS^-} = \rho\theta_{HL}^{NS^-}$ and $d_{bL}^{NS^-} = (1-\rho)\theta_{HL}^{NS^-}$. The competing manufacturers 's equilibrium profits are $\pi_H^{NS^-} = (p_H - c_H)d_{bH}^{NS^-} + \eta p_{rH}\rho d_{rH}^{NS^-} + (r_{sH} - c_H + c_s)\rho d_{sH}^{NS^-}$ and $\pi_L^{NS^-} = (p_L - c_L)d_{bL}^{NS^-} + \eta p_{rL}\rho d_{rL}^{NS^-}$. From the first order conditions (FOC), by solving $\partial\pi_i^{NS^-}/\partial p_i = 0$ and $\partial\pi_i^{NS^-}/\partial r_i = 0$, we obtain the equilibrium prices of competing manufacturers are $p_H^{NS^-} = e(4\Delta q + 4c_H + 2c_L + c_s - q_s)/6$, $p_L^{NS^-} = e(\Delta q + c_H + 2c_L - c_s - q_s)/3$ and $r_H^{NS^-} = (2\Delta q + 2c_H + c_L - 2c_s - 2q_s)/3$. Then, the manufacturers' equilibrium profits are $\pi_H^{NS^-} = \rho(q_s - c_s)^2/(4q_s) + \rho(c_H - c_L - c_s)^2/(9(\Delta q - q_s)) + 4\rho(\Delta q - c_H + c_L - q_s + c_s)/9$ and $\pi_L^{NS^-} = \rho(\Delta q + c_H - c_L - c_s - q_s)^2/(9(\Delta q - q_s))$.

In S^-N subgame, manufacturer H offers the no-product line strategy and manufacturer L offers the S^- strategy. We have $U_{oH}^{N} = v + \rho\theta q_H + (1-\rho)(1-\eta)p_{rH} - p_H$, $U_{rH}^{N} = v + \rho(\theta q_H - p_{rH})$, and $U_{oL}^{S^-} = v + \rho\theta q_L + (1-\rho)(1-\eta)p_{rL} - p_L$, $U_{rL}^{S^-} = v + \rho(\theta q_L - p_{rL})$, $U_{sL}^{S^-} = v + \rho[\theta(q_L - q_s) - r_{sL}]$. If $\theta \geq \theta_{HL}^{S^-N} = (p_{rH} - p_{rL})/\Delta q$, consumers will buy or rent products of quality q_H from the P2P platform of manufacturer H, if $\theta_L^{S^-N} = (p_{rL} - r_{sL})/q_s \leq \theta < \theta_{HL}^{S^-N}$, consumers will buy or rent products of quality q_L from the P2P platform of manufacturer L, otherwise, if $0 \leq \theta < \theta_L^{S^-N}$, consumers will rent products of quality q_{sL} from the B2C platform of manufacturer L. The retail demand and the size of renters on the P2P platform of manufacturer H are $d_{bH}^{S^-N} = \rho\left(1 - \theta_{HL}^{S^-N}\right)$ and $d_{rH}^{S^-N} = (1-\rho)\left(1 - \theta_{HL}^{S^-N}\right)$, and the retail demand and the size of renters on the P2P and B2C platform of manufacturer L are $d_{bL}^{S^-N} = \rho\left(\theta_{HL}^{S^-N} - \theta_L^{S^-N}\right)$, $d_{bL}^{S^+N} = (1-\rho)\left(\theta_{HL}^{S^-N} - \theta_L^{S^-N}\right)$ and $d_{sH}^{S^-N} = \theta_L^{S^-N}$. Then the manufacturers' profits are $\pi_H^{S^-N} = (p_H - c_H)d_{bH}^{S^-N} + \eta p_{rH}\rho d_{rH}^{S^-N}$ and $\pi_L^{S^-N} = (p_L - c_L)d_{bL}^{S^-N} + \eta p_{rL}\rho d_{rL}^{S^-N} + (r_{sL} - c_L + c_s)\rho d_{sL}^{S^-N}$. From the first order conditions (FOC), by solving $\partial\pi_i^{S^-N}/\partial p_i = 0$ and $\partial\pi_i^{S^-N}/\partial r_i = 0$, we obtain the equilibrium prices of the competing manufacturers are $p_H^{S^-N} = e(2\Delta q + 2c_H + c_L)/3$, $p_L^{S^-N} = e(\Delta q + c_H + 2c_L)/3$, and $r_L^{S^-N} = (2\Delta q + 2c_H + 4c_L - 3c_s)/6$. Then, the equilibrium profits of the competing

manufacturers are $\pi_H^{S^-N} = \rho(2\Delta q - c_H + c_L)^2/(9\Delta q)$ and $\pi_L^{S^-N} = (\Delta q + c_H - c_L)^2/(9\Delta q) + \rho {c_s}^2/(4q_s)$.

In S^-S^- subgame, both manufacturers offer the S^- strategy. We have $U_{oH}^{S^-} = v + \rho\theta q_H + (1-\rho)(1-\eta)p_{rH} - p_H$, $U_{rH}^{S^-} = v + \rho(\theta q_H - p_{rH})$, $U_{rL}^{S^-} = v + \rho(\theta q_L - p_{rL})$, $U_{sH}^{S^-} = v + \rho[\theta(q_H - q_s) - r_{sH}]$, $U_{oL}^{S^-} = v + \rho\theta q_L + (1-\rho)(1-\eta)p_{rL} - p_L$, $U_{sL}^{S^-} = v + \rho[\theta(q_L - q_s) - r_{sL}]$. If $\theta \geq \theta_H^{S^-S^-} = (p_{rH} - r_{sH})/q_s$, consumers will buy or rent products of quality q_H from the P2P platform of manufacturer H, if $\theta_{HL}^{S^-S^-} = (r_{sH} - p_{rL})/(\Delta q - q_s) \leq \theta < \theta_H^{S^-S^-}$, consumers will rent products of quality q_{sH} from the B2C platform of manufacturer H, if $\theta_L^{S^-S^-} = (p_{rL} - r_{sL})/q_s \leq \theta < \theta_{HL}^{S^-S^-}$, consumers will buy or rent products of quality q_L from the P2P platform of manufacturer L, otherwise, if $0 \leq \theta < \theta_L^{S^-S^-}$, consumers will rent products of quality q_{sL} from the B2C platform of manufacturer L. The retail demand and the size of renters on the P2P and B2C platform of the manufacturer H are $d_{bH}^{S^-S^-} = \rho\left(1 - \theta_H^{S^-S^-}\right)$, $d_{rH}^{S^-S^-} = (1-\rho)\left(1 - \theta_H^{S^-S^-}\right)$ and $d_{sH}^{S^-S^-} = \theta_H^{S^-S^-} - \theta_{HL}^{S^-S^-}$. The retail demand and the size of renters on the P2P and B2C platform of the manufacturer L are $d_{bL}^{S^-S^-} = \rho\left(\theta_{HL}^{S^-S^-} - \theta_L^{S^-S^-}\right)$, $d_{rL}^{S^-S^-} = (1-\rho)\left(\theta_{HL}^{S^-S^-} - \theta_L^{S^-S^-}\right)$ and $d_{sH}^{S^-S^-} = \theta_L^{S^-S^-}$. Then the equilibrium profits of the competing manufacturers are $\pi_H^{S^-S^-} = (p_H - c_H)d_{bH}^{S^-S^-} + \eta p_{rH}\rho d_{rH}^{S^-S^-} + (r_{sH} - c_H + c_s)\rho d_{sH}^{S^-S^-}$ and $\pi_L^{S^-S^-} = (p_L - c_L)d_{bL}^{S^-S^-} + \eta p_{rL}\rho d_{rL}^{S^-S^-} + (r_{sL} - c_L + c_s)\rho d_{sL}^{S^-S^-}$. From the first order conditions (FOC), by solving $\partial\pi_i^{S^-S^-}/\partial p_i = 0$ and $\partial\pi_i^{S^-S^-}/\partial r_i = 0$, we obtain the competing manufacturers' equilibrium prices are $p_H^{S^-S^-} = e(4\Delta q + 4c_H + 2c_L + c_s - q_s)/6$, $p_L^{S^-S^-} = e(\Delta q + c_H + 2c_L - c_s - q_s)/3$, $r_H^{S^-S^-} = (2\Delta q + 2c_H + c_L - 2c_s - 2q_s)/3$ and $r_L^{S^-S^-} = (2\Delta q + 2c_H + 4c_L - 5c_s - 2q_s)/6$. The competing manufacturers' equilibrium profits are $\pi_H^{S^-S^-} = \rho(q_s - c_s)^2/(4q_s) + \rho(c_H - c_L - c_s)^2/(9(\Delta q - q_s)) + 4\rho(\Delta q - c_H + c_L - q_s + c_s)/9$ and $\pi_L^{S^-S^-} = (\Delta q + c_H - c_L - c_s - q_s)^2/(9(\Delta q - q_s)) + \rho {c_s}^2/(4q_s)$. □

4.2.4. One Manufacturer Adopts the S^+ Strategy and the Other Adopts the S^- Strategy

We analyze the case where one manufacturer adopts the high-end product line strategy and the other manufacturer adopts the low-end product line strategy, i.e., S^-S^+ and S^+S^- subgames. We present the equilibrium outcomes in the following lemma.

Lemma 4. *When one manufacturer adopts the low-end product line strategy while the other manufacturer adopts the high-end product line strategy, Table 4 presents the equilibrium prices and demands in the $S^-S^+$and S^+S^- subgames.*

Table 4. Manufacturers' equilibrium prices and demands in S^-S^+ and S^+S^- subgames.

	$Z = NS^-$	$Z = S^-S^-$
p_H^Z	$\frac{e(2\Delta q + 2c_H + c_L)}{3}$	$\frac{e(4\Delta q + 4c_H + 2c_L + c_s - 5q_s)}{6}$
p_L^Z	$\frac{e(\Delta q + c_H + 2c_L)}{3}$	$\frac{e(2\Delta q + 2c_H + 4c_L - c_s - 4q_s)}{6}$
r_H^Z	$\frac{2\Delta q + 2c_H + c_L}{3} + \frac{c_s + q_s}{2}$	$\frac{2\Delta q + 2c_H + c_L - c_s - 4q_s}{3}$
r_L^Z	$\frac{2\Delta q + 2c_H + 4c_L - 3c_s}{6}$	$\frac{\Delta q + c_H + 2c_L + c_s - 2q_s}{3}$
d_{bH}^Z	$\frac{\rho}{6} + \frac{\rho c_s}{2q_s} - \frac{\rho(c_H - c_L)}{3\Delta q}$	$\frac{\rho(q_s - c_s)}{2q_s}$
d_{bL}^Z	$\frac{\rho(\Delta q + c_H - c_L)}{3\Delta q} - \frac{\rho c_s}{2q_s}$	$\frac{\rho c_s}{2q_s}$
d_{mH}^Z	$\frac{q_s - c_s}{2q_s}$	$\frac{1}{3} + \frac{c_H - c_L - 2c_s}{3(\Delta q - 2q_s)} - \frac{c_s}{2q_s}$
d_{mL}^Z	$\frac{c_s}{2q_s}$	$\frac{1}{6} + \frac{c_s}{2q_s} - \frac{c_H - c_L - 2c_s}{3(\Delta q - 2q_s)}$

Assuming that the competitor adopts any strategy and keeps the strategy unchanged, the effects of the manufacturer adopting the S^+/S^- strategy on the prices and demands of the two manufacturers are consistent with Lemma 1 and Lemma 2, and are not affected by the competitor's strategy.

Proof of Lemma 4. S^-S^+ **and** S^+S^- **subgames:** In S^-S^+ subgame, manufacturer L offers the S^- strategy and manufacturer H offers the S^+ strategy. We have $U_{oH}^{S^+} = v + \rho\theta q_H + (1-\rho)(1-\eta)p_{rH} - p_H$, $U_{rH}^{S^+} = v + \rho(\theta q_H - p_{rH})$, $U_{rL}^{S^-} = v + \rho(\theta q_L - p_{rL})$, $U_{sH}^{S^+} = v + \rho[\theta(q_H + q_s) - r_{sH}]$, $U_{oL}^{S^-} = v + \rho\theta q_L + (1-\rho)(1-\eta)p_{rL} - p_L$ and, $U_{sL}^{S^-} = v + \rho[\theta(q_L - q_s) - r_{sL}]$. If $\theta \geq \theta_H^{S^-S^+} = (r_{sH} - p_{rH})/q_s$, consumers will rent products of quality q_{sH} from the B2C platform of manufacturer H, if $\theta_{HL}^{S^-S^+} = (p_{rH} - p_{rL})/(\Delta q - q_s) \leq \theta < \theta_H^{S^-S^+}$, consumers will buy or rent products of quality q_H from the P2P platform of manufacturer H, if $\theta_L^{S^-S^+} = (p_{rL} - r_{sL})/q_s \leq \theta < \theta_{HL}^{S^-S^+}$, consumers will buy or rent products of quality q_L from the P2P platform of manufacturer L, otherwise, if $0 \leq \theta < \theta_L^{S^-S^+}$, consumers will rent products of quality q_{sL} from the B2C platform of manufacturer L. The retail demand and the size of renters on the B2C and P2P platform of the manufacturer H are $d_{bH}^{S^-S^+} = \rho\left(\theta_H^{S^-S^+} - \theta_{HL}^{S^-S^+}\right)$, $d_{sH}^{S^-S^+} = 1 - \theta_H^{S^-S^+}$ and $d_{rH}^{S^-S^+} = (1-\rho)\left(\theta_H^{S^-S^+} - \theta_{HL}^{S^-S^+}\right)$. The retail demand and the size of renters on the B2C and P2P platform of the manufacturer L are $d_{bL}^{S^-S^+} = \rho\left(\theta_{HL}^{S^-S^+} - \theta_L^{S^-S^+}\right)$, $d_{sH}^{S^-S^+} = \theta_L^{S^-S^+}$ and $d_{rL}^{S^-S^+} = (1-\rho)\left(\theta_{HL}^{S^-S^+} - \theta_L^{S^-S^+}\right)$. Then the competing manufacturers' equilibrium profits are $\pi_H^{S^-S^+} = (p_H - c_H)d_{bH}^{S^-S^+} + \eta p_{rH}\rho d_{rH}^{S^-S^+} + (r_{sH} - c_H - c_s)\rho d_{sH}^{S^-S^+}$ and $\pi_L^{S^-S^+} = (p_L - c_L)d_{bL}^{S^-S^+} + +\eta p_{rL}\rho d_{rL}^{S^-S^+} + (r_{sL} - c_L + c_s)\rho d_{sL}^{S^-S^+}$. From the first order conditions (FOC), by solving $\partial\pi_i^{S^-S^+}/\partial p_i = 0$ and $\partial\pi_i^{S^-S^+}/\partial r_i = 0$, we obtain the equilibrium prices are $p_H^{S^-S^+} = e(2\Delta q + 2c_H + c_L)/3$, $p_L^{S^-S^+} = e(\Delta q + c_H + 2c_L)/3$, $r_H^{S^-S^+} = (2\Delta q + 2c_H + c_L)/3$ and $+(c_s + q_s)/2$ $r_L^{S^-S^+} = (2\Delta q + 2c_H + 4c_L - 3c_s)/6$. The competing manufacturers' equilibrium profits are $\pi_H^{S^-S^+} = \rho(2\Delta q - c_H + c_L)^2/(9q_s) + \rho(q_s - c_s)^2/(4q_s)$ and $\pi_L^{S^-S^+} = (\Delta q + c_H - c_L)^2/(9\Delta q) + \rho {c_s}^2/(4q_s)$.

In S^+S^- subgame, manufacturer L offers the S^+ strategy and manufacturer H offers the S^- strategy. We have $U_{oH}^{S^-} = v + \rho\theta q_H + (1-\rho)(1-\eta)p_{rH} - p_H$, $U_{rH}^{S^-} = v + \rho(\theta q_H - p_{rH})$, $U_{sH}^{S^-} = v + \rho[\theta(q_H - q_s) - r_{sH}]$, $U_{oL}^{S^+} = v + \rho\theta q_L + (1-\rho)(1-\eta)p_{rL} - p_L$, and $U_{sL}^{S^+} = v + \rho[\theta(q_L + q_s) - r_{sL}]$, $U_{rL}^{S^+} = v + \rho(\theta q_L - p_{rL})$. If $\theta \geq \theta_H^{S^+S^-} = (p_{rH} - r_{sH})/q_s$, consumers will buy or rent products of quality q_H from the P2P platform of manufacturer H, if $\theta_{HL}^{S^+S^-} = (r_{sH} - r_{sL})/(\Delta q - 2q_s) \leq \theta < \theta_H^{S^+S^-}$, consumers will rent products of quality q_{sH} from the B2C platform of manufacturer H, if $\theta_L^{S^+S^-} = (r_{sL} - p_{rL})/q_s \leq \theta < \theta_{HL}^{S^+S^-}$, consumers will rent products of quality q_{sL} from the B2C platform of manufacturer L, otherwise, if $0 \leq \theta < \theta_L^{S^+S^-}$, consumers will buy or rent products of quality q_L from the P2P platform of manufacturer L. The retail demand and the size of renters on the P2P and B2C platform of the manufacturer H are $d_{bH}^{S^+S^-} = \rho\left(1 - \theta_H^{S^+S^-}\right)$, $d_{rH}^{S^+S^-} = (1-\rho)\left(1 - \theta_H^{S^+S^-}\right)$ and $d_{sH}^{S^+S^-} = \theta_H^{S^+S^-} - \theta_{HL}^{S^+S^-}$. The retail demand and the size of renters on the P2P and B2C platform of the manufacturer L are $d_{bL}^{S^+S^-} = \rho\theta_L^{S^+S^-}$, $d_{rL}^{S^+S^-} = (1-\rho)\theta_L^{S^+S^-}$ and $d_{sH}^{S^+S^-} = \theta_{HL}^{S^+S^-} - \theta_L^{S^+S^-}$. Then the profits are $\pi_H^{S^+S^-} = (p_H - c_H)d_{bH}^{S^+S^-} + \eta p_{rH}\rho d_{rH}^{S^+S^-} + (r_{sH} - c_H + c_s)\rho d_{sH}^{S^+S^-}$ and $\pi_L^{S^+S^-} = (p_L - c_L)d_{bL}^{S^+S^-} + \eta p_{rL}\rho d_{rL}^{S^+S^-} + (r_{sL} - c_L - c_s)\rho d_{sL}^{S^+S^-}$. From the first order conditions (FOC), by solving $\partial\pi_i^{S^+S^-}/\partial p_i = 0$ and $\partial\pi_i^{S^+S^-}/\partial r_i = 0$, we obtain the equilibrium prices are $p_H^{S^+S^-} = e(4\Delta q + 4c_H + 2c_L + c_s - 5q_s)/6$, $p_L^{S^+S^-} = e(2\Delta q + 2c_H + 4c_L - c_s - 4q_s)/6$, $r_H^{S^+S^-} = (2\Delta q + 2c_H + c_L - c_s - 4q_s)/3$ and $r_L^{S^+S^-} = (\Delta q + c_H + 2c_L + c_s - 2q_s)/3$. The manufacturers' equilibrium profits are $\pi_L^{S^+S^-} = (\Delta q + c_H - c_L - 2c_s - 2q_s)^2/(9(\Delta q - 2q_s)) + \rho {c_s}^2/(4q_s)$ and $\pi_H^{S^+S^-} = \rho(q_s - c_s)^2/(4q_s) + \rho(\Delta q + c_H - c_L - 2c_s - 2q_s)^2/(9(\Delta q - 2q_s)) + \rho q_s(\Delta q - 2c_H + 2c_L + 4c_k - 2q_s)/3$. □

4.3. Equilibrium Analysis

We now consider stage 1, where the manufacturer decides which product line strategy to adopt. The following proposition summarizes this conclusion.

Proposition 1. *The high-quality manufacturer adopts the high-end product line strategy, and the low-quality manufacturer adopts the low-end product line strategy, i.e., S^-S^+ is the unique equilibrium.*

Proof of Proposition 1. We analyze the competitive manufacturer's equilibrium strategy by comparing the equilibrium outcomes of each subgame. Note that $\Delta\pi_1 = \pi_H^{NN} - \pi_H^{NS^+} = \pi_H^{S^+N} - \pi_H^{S^+S^+} = \pi_H^{S^-N} - \pi_H^{S^-S^+} = -\rho(q_s - c_s)^2/(4q_s) < 0$, so that $\pi_H^{NN} < \pi_H^{NS^+}$, $\pi_H^{S^+N} < \pi_H^{S^+S^+}$, and $\pi_H^{S^-N} < \pi_H^{S^-S^+}$. Note that $\Delta\pi_2 = \pi_L^{NN} - \pi_L^{S^-N} = \pi_L^{NS^-} - \pi_L^{S^-S^-} = \pi_L^{NS^+} - \pi_L^{S^-S^+} = -\rho {c_s}^2/(4q_s) < 0$, so that $\pi_L^{NN} < \pi_L^{S^-N}$, $\pi_L^{NS^-} < \pi_L^{S^-S^-}$, and $\pi_L^{NS^+} < \pi_L^{S^-S^+}$. Then, subgames S^+S^+, S^-S^-, S^-S^+ and S^+S^- need to be compared. $\Delta\pi_3 = \pi_H^{S^+S^+} - \pi_H^{S^+S^-} = -\rho\Big(\Big(3(2q_s - c_s)^2 - 2(c_H - c_L)c_s\Big)\Delta q - \Big((c_H - c_L)^2 - 2(2q_s - c_s)^2\Big)q_s\Big)/(9(\Delta q - 2q_s)(\Delta q - q_s)) + 4\rho(q_s - c_s)\Delta q^2/(9(\Delta q - 2q_s)(\Delta q - q_s))$, we have $\partial\Delta\pi_3/\partial\Delta q > 0$ for any Δq, Because we assume $(c_H - c_L)/\Delta q < c_s/q_s$, then when $\Delta q = (c_H - c_L)q_s/c_s$, $\Delta\pi_3\Big|_{\Delta q = (c_H - c_L)q_s/c_s} = q_s(2q_s - c_s)^2(c_H - c_L - c_s)(c_H - c_L - 2c_s)/\left(9c_s^2(\Delta q - 2q_s)(\Delta q - q_s)\right) > 0$, so that $\Delta\pi_3 > 0$. Note that $\Delta\pi_4 = \pi_L^{S^-S^+} - \pi_L^{S^+S^+} = \rho((q_s + 2c_s)\Delta q - (q_s + c_s)^2 + 2(c_H - c_L)c_s)/(9(\Delta q - q_s))\rho((c_H - c_L)^2 q_s)/(9\Delta q(\Delta q - q_s))$, we have $\partial\Delta\pi_4/\partial\Delta q > 0$ for any Δq, so we have $\Delta\pi_4\Big|_{\Delta q = (c_H - c_L)q_s/c_s} = \rho q_s(q_s + c_s)^2(c_H - c_L)(c_H - c_L - c_s)/\left(9c_s^2\Delta q(\Delta q - q_s)\right) > 0$ when $\Delta q = (c_H - c_L)q_s/c_s$, so that $\Delta\pi_4 > 0$. Note that $\Delta\pi_5 = \pi_H^{S^-S^+} - \pi_H^{S^-S^-} = \rho\Big[4(q_s - c_s)\Delta q(\Delta q - q_s) + (c_H - c_L - c_s)c_s\Delta q + (c_H - c_L)c_s\Delta q - q_s(c_H - c_L)^2\Big]/(9\Delta q(\Delta q - q_s))$, because $(c_H - c_L)/\Delta q < c_s/q_s$, so that $\rho(c_H - c_L)c_s\Delta q - \rho q_s(c_H - c_L)^2 > 0$, then $\Delta\pi_5 = \pi_H^{S^-S^+} - \pi_H^{S^-S^-} > 0$. Therefore, S^-S^+ is the unique equilibrium. This completes the proof of Proposition 1. □

The high-quality (low-quality) product line strategy allows the high-quality (low-quality) manufacturer to extract the maximum surplus from their customers based on the customer's valuation and the price offered by the competitor, which expands the market size to the high (low) end and increases profit margins. Therefore, assuming that the competitor's strategy remains unchanged, the high-quality (low-quality) manufacturer will benefit (relative to the competitor) by switching from the no-product line strategy to the high-quality (low-quality) product line strategy. If the high-quality (low-quality) manufacturer adopts the high-quality (low-quality) product line strategy, for the low-quality (high-quality) manufacturer, adopting low-quality (high-quality) product line strategy will make it less attractive to high-end (higher-end) consumers, but adopting high-quality (low-quality) product lines will intensify competition and lose some consumer markets. Therefore, the high-quality manufacturer adopts the high-end product line strategy, and the low-quality manufacturer adopts the low-end product line strategy, which is the unique equilibrium.

4.4. Profit Implications

In this section, we compare the profit under the equilibrium strategy with the profit under *NN*, and analyze the profit implications of the product line strategy.

Proposition 2. *Compared with the scenario where both manufacturers adopt no-product line strategy* (i.e., *NN), the two manufacturers will gain more profit if the low-quality manufacturer*

adopts the S^- strategy and the high-quality manufacturer adopts the S^+ strategy (i.e., S^-S^+), i.e., $\pi_L^{NN} \leq \pi_L^{S^-S^+}$ *and* $\pi_H^{NN} \leq \pi_H^{S^-S^+}$.

Proof of Proposition 2. We compare the subgame NN and S^+S^-. Note that $\Delta\pi_6 = \pi_H^{S^-S^+} - \pi_H^{NN} = \rho(q_s - c_s)^2/(4q_s) > 0$ and $\Delta\pi_7 = \pi_L^{S^-S^+} - \pi_L^{NN} = \rho c_s^2/(4q_s) > 0$, so that $\pi_H^{NN} < \pi_H^{S^-S^+}$ and $\pi_L^{NN} < \pi_L^{S^-S^+}$. This completes the proof of Proposition 2. □

Compared with NN configuration, S^-S^+ configuration with competing manufacturers is a win-win situation (as shown in Figure 3). This is because when the low-quality manufacturer adopts the low-end product line strategy and the high-quality manufacturer adopts the high-end product line strategy, the quality differentiation in the product line expands. The two manufacturers use price discrimination to refine the consumer market. The consumers with low-value will switch from buying low-quality products to renting lower quality products and the consumers with high-value will switch from buying high-quality products to renting higher quality products. The two manufacturers maximize the consumers' surplus value. Therefore, if the low-quality manufacturer adopts the S^- strategy and the high-quality manufacturer adopts the S^+ strategy, the two manufacturers achieve a win-win situation. The equilibrium leads to a Pareto improvement. In Appendix A: Case Study, we demonstrated the practical validity of the conclusion through real cases.

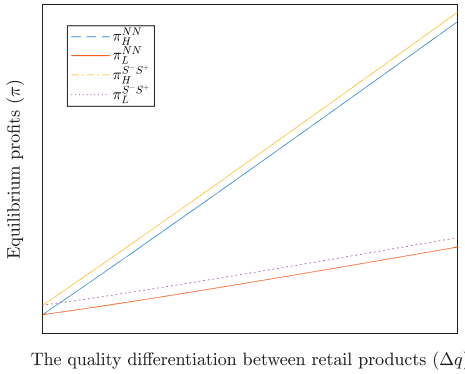


Figure 3. Profit comparison between S^-S^+ and NN.

5. The Impact of Product Line Strategy on Duopoly

In this section, we discuss the impact of manufacturers' product line strategy on their equilibrium prices, demands and market sizes.

5.1. The Impact on Equilibrium Prices

Proposition 3. *The equilibrium retail price of each subgame is compared as follows:*

(i) $p_H^{S^+S^-} < p_H^{S^+S^+} = p_H^{S^+N} < p_H^{NS^-} = p_H^{S^-S^-} < p_H^{NN} = p_H^{NS^+} = p_H^{S^-N} = p_H^{S^-S^+}$;

(ii) $p_L^{S^+S^-} < p_L^{S^+S^+} = p_L^{S^+N} < p_L^{NS^-} = p_L^{S^-S^-} < p_L^{NN} = p_L^{NS^+} = p_L^{S^-N} = p_L^{S^-S^+}$.

Proof of Proposition 3. We compare the prices of manufacturers in these subgames. Note that $p_H^{NN} = p_H^{NS^+} = p_H^{S^-N} = p_H^{S^-S^+} = e(2\Delta q + 2c_H + c_L)/3$, $p_H^{NS^-} = p_H^{S^-S^-} = e(4\Delta q + 4c_H + 2c_L + c_s - q_s)/6$ and $p_H^{S^+S^+} = p_H^{S^+N} = e(2\Delta q + 2c_H + c_L + c_s - 2q_s)/3$, we have $\Delta p_1 = p_H^{S^+S^+} - p_H^{S^+S^-} = e(q_s + c_s)/6 > 0$, $\Delta p_2 = p_H^{NS^-} - p_H^{S^+S^+} = e(q_s - c_s)/2 > 0$, and $\Delta p_3 = p_H^{NN} - p_H^{NS^-} = e(q_s + c_s)/6 > 0$. Then, $p_H^{S^+S^-} < p_H^{S^+S^+} = p_H^{S^+N} < p_H^{NS^-} = p_H^{S^-S^-} < p_H^{NN} = p_H^{NS^+} = p_H^{S^-N} = p_H^{S^-S^+}$. Note that $p_H^{NN} = p_H^{NS^+} = p_H^{S^-N}$, $= p_H^{S^-S^+} = e(\Delta q + c_H + 2c_L)/3$, $p_L^{NS^-} = p_L^{S^-S^-} = e(\Delta q + c_H + 2c_L - c_s - q_s)/3$ and $p_L^{S^+S^+} = p_L^{S^+N} = e(2\Delta q + 2c_H + 4c_L + c_s - 2q_s)/6$, we have $\Delta p_4 = p_L^{S^+S^+} - p_L^{S^+S^-} = e(q_s + c_s)/3 > 0$,

$\Delta p_5 = p_L^{NS^-} - p_L^{S^+S^+} = ec_s/2 > 0$ and $\Delta p_6 = p_L^{NN} - p_L^{NS^-} = e(q_s + c_s)/3 > 0$, Therefore, $p_L^{S^+S^-} < p_L^{S^+S^+} = p_L^{S^+N} < p_L^{NS^-} = p_L^{S^-S^-} < p_L^{NN} = p_L^{NS^+} = p_L^{S^-N} = p_L^{S^-S^+}$. This completes the proof of Proposition 3. □

Proposition 3 shows that if the high-quality manufacturer switches from the no-product line strategy to the high-end product line strategy and/or the low-quality manufacturer switches from the no-product line strategy to the low-end product line strategy, the retail prices of the two manufacturers will not change. If the high-quality manufacturer switches from the no-product line strategy to the low-end product line strategy and/or the low-quality manufacturer switches from the no-product line strategy to the high-end product line strategy, it will lower the retail prices of the two manufacturers. This is because the high-quality manufacturer offers the high-quality product line strategy and/or the low-quality manufacturer offers the low-quality product line strategy, quality differentiation within product lines expands. The manufacturer uses the price discrimination effect to attract consumers by setting a lower or higher rental price without reducing the retail price. However, the high-quality manufacturer provides the low-quality product line strategy and/or the low-quality manufacturer provides the high-quality product line strategy, quality differentiation within product line decreases, resulting in fierce price competition, and then the manufacturers have to choose to lower the retail prices to attract consumers.

5.2. The Impact on Retail Demands

Proposition 4. *The equilibrium retail demand of each subgame is compared as follows:*

(i) $d_{bH}^{NN} = d_{bH}^{S^-N} > d_{bH}^{NS^-} = d_{bH}^{S^-S^-} = d_{bH}^{S^+S^-}, d_{bH}^{NN} > d_{bH}^{NS^+} = d_{bH}^{S^-S^+}, d_{bH}^{S^+N} > d_{bH}^{S^+S^+}$;

(ii) $d_{bL}^{NN} = d_{bL}^{NS^+} > d_{bL}^{S^+N} = d_{bL}^{S^+S^+} = d_{bL}^{S^+S^-}, d_{bL}^{NN} > d_{bL}^{S^-N} = d_{bL}^{S^-S^+}, d_{bL}^{NS^-} > d_{bL}^{S^-S^-}$.

Proof of Proposition 4. We compare the retail demand of manufacturers in these subgames. Note that $d_{bH}^{NS^-} = d_{bH}^{S^-S^-} = d_{bH}^{S^+S^-} = \rho(q_s - c_s)/(2q_s)$, $d_{bH}^{NS^+} = d_{bH}^{S^-S^+} = \rho/6 + \rho c_s/(2q_s) - \rho(c_H - c_L)/(3\Delta q)$ and $d_{bH}^{NN} = d_{bH}^{S^-N} = \rho(2\Delta q - c_H + c_L)/(3\Delta q)$, because $(c_H - c_L)/\Delta q < c_s/q_s$ Then, $d_{bH}^{NN} = d_{bH}^{S^-N} >$. $d_{bH}^{NS^-} = d_{bH}^{S^-S^-} = d_{bH}^{S^+S^-}$. Note that $\Delta d_{b2} = d_{bH}^{NN} - d_{bH}^{NS^+} = d_{bH}^{S^+N} - d_{bH}^{S^+S^+} = \rho(q_s - c_s)/(2q_s) > 0$. Then, $d_{bH}^{NN} > d_{bH}^{NS^+} = d_{bH}^{S^-S^+}$ and $d_{bH}^{S^+N} > d_{bH}^{S^+S^+}$. Note that $d_{bL}^{S^+N} = d_{bL}^{S^+S^+} = d_{bL}^{S^+S^-} = \rho c_s/(2q_s)$, $d_{bL}^{NN} = d_{bL}^{NS^+} = \rho(\Delta q + c_H - c_L)/(3\Delta q) d_{bL}^{S^-N} = d_{bL}^{S^-S^+} = \rho(\Delta q + c_H - c_L)/(3\Delta q) - \rho c_s/(2q_s)$ and $d_{bH}^{S^+N} > d_{bH}^{S^+S^+}$. Note that $\Delta d_{b3} = d_{bL}^{NN} - d_{bL}^{S^+N} = \rho(\Delta q + c_H - c_L)/(3\Delta q) - \rho c_s/(2q_s)$, because we have assumed $2q_s > 3c_s$, so that $\Delta d_3 = d_{bL}^{NN} - d_{bL}^{S^+N} > 0$. Then $d_{bL}^{NN} = d_{bL}^{NS^+} > d_{bL}^{S^+N} = d_{bL}^{S^+S^+} = d_{bL}^{S^+S^-}$. Note that $\Delta d_{b4} = d_{bL}^{NN} - d_{bL}^{S^-N} = d_{bL}^{NS^-} - d_{bL}^{S^-S^-} = \rho c_s/(2q_s) > 0$. Then $d_{bL}^{NN} > d_{bL}^{S^-N} = d_{bL}^{S^-S^+}$ and $d_{bL}^{NS^-} > d_{bL}^{S^-S^-}$. This completes the proof of Proposition 4. □

Proposition 4 shows that if the low-quality (or high-quality) manufacturer switches from the no-product line strategy to the low-end (or high-end) product line strategy, its retail demand will decrease but the competitor's retail demand will remain unchanged. This is because such a product line strategy expands the quality differentiation between channels and alleviates the cannibalization of the market. When the low-end (high-end) manufacturer rents low-quality (high-quality) products, some low-end (high-end) consumers who plan to buy the product will rent low-quality (high-quality) products, but the high-end (low-end) consumers are not affected. However, if the high-quality (low-quality) manufacturer switches from the no-product-line strategy to the low-end (high-end) product-line strategy, its retail demand will decrease but the retail demand of competitors will increase or decrease. This is because such a product line strategy intensifies cannibalization and leads to fierce price competition. When the low-end (high-end) manufacturer

rents high-quality (low-quality) products, some consumers in the middle segment will choose competitors' products, and the competitors' retail demand will be affected by its pricing decision.

5.3. The Impact on Market Sizes

The market size of manufacturer i includes the retail demand, the rental demand on its P2P platform, and the rental demand on its B2C platform, and is represented by $d_i = d_{bi} + d_{ri} + d_{mi}$. The following propositions compare the market sizes of the manufacturers.

Proposition 5. *The equilibrium market size of each subgame is compared as follows:*

(i) $d_H^{S^+S^-} > d_H^{S^+S^+} = d_H^{S^+N} = d_H^{NS^-} = d_H^{S^-S^-} > d_H^{NN} = d_H^{NS^+} = d_H^{S^-N} = d_H^{S^-S^+}$;

(ii) $d_L^{S^+S^-} < d_L^{S^+S^+} = d_L^{S^+N} = d_L^{NS^-} = d_L^{S^-S^-} < d_L^{NN} = d_L^{NS^+} = d_L^{S^-N} = d_L^{S^-S^+}$.

Proof of Proposition 5. We compare the market size of manufacturers in these subgames. Note that $d_H^{S^+S^+} = d_H^{S^+N} = d_H^{NS^-} = d_H^{S^-S^-} = (2\Delta q - 2q_s - c_H + c_L + c_s)/(3(\Delta q - q_s))$ and $d_H^{NN} = d_H^{NS^+} = d_H^{S^-N} = d_H^{S^-S^+} = (2\Delta q - c_H + c_L)/(3\Delta q)$. Note that $\Delta d_1 = d_H^{S^+S^+} - d_H^{S^+S^-} = (c_H - c_L - 2c_s)/(3(\Delta q - 2q_s)) - (c_H - c_L - c_s)/(3(\Delta q - q_s))$ and $\Delta d_2 = d_H^{NN} - d_H^{S^+S^+} =, (c_H - c_L - c_s)/(3(\Delta q - q_s)) - (c_H - c_L)/(3\Delta q)$ because $(c_H - c_L)/\Delta q < c_s/q_s$, so that $\Delta d_1 = d_H^{S^+S^+} - d_H^{S^+S^-} < 0$, $\Delta d_2 = d_H^{NN} - d_H^{S^+S^+} < 0$, that is $d_H^{NN} < d_H^{S^+S^+} < d_H^{S^+S^-}$. Then, $d_H^{S^+S^-} > d_H^{S^+S^+} = d_H^{S^+N} = d_H^{NS^-} = d_H^{S^-S^-} > d_H^{NN} = d_H^{NS^+} = d_H^{S^-N} = d_H^{S^-S^+}$. Note that $d_L^{S^+S^+} = d_L^{S^+N} = d_L^{NS^-} = d_L^{S^-S^-} = (\Delta q - q_s + c_H - c_L - c_s)/(3(\Delta q - q_s))$ and $d_L^{NN} = d_L^{NS^+} = d_L^{S^-N} = d_L^{S^-S^+} = (\Delta q + c_H - c_L)/(3\Delta q)$. Note that $\Delta d_3 = d_L^{S^+S^+} - d_L^{S^+S^-} = (c_H - c_L - 2c_s)/(3(\Delta q - 2q_s)) - (c_H - c_L - c_s)/(3(\Delta q - q_s))$ and $\Delta d_4 = d_L^{NN} - d_L^{S^+S^+} = (c_H - c_L)/(3\Delta q) - (c_H - c_L - c_s)/(3(\Delta q - q_s))$, because $(c_H - c_L)/\Delta q < c_s/q_s$, so that $\Delta d_3 = d_L^{S^+S^+} - d_L^{S^+S^-} > 0$ and $\Delta d_4 = d_L^{NN} - d_L^{S^+S^+} > 0$, that is $d_L^{NN} > d_L^{S^+S^+} > d_L^{S^+S^-}$. Then $d_L^{S^+S^-} < d_L^{S^+S^+} = d_L^{S^+N} = d_L^{NS^-} = d_L^{S^-S^-} < d_L^{NN} = d_L^{NS^+} = d_L^{S^-N} = d_L^{S^-S^+}$. This completes the proof of Proposition 5. □

Proposition 5 shows that the market size of the two manufacturers will remain unchanged if the high-quality manufacturer switches from the no-product line strategy to the high-end product line strategy and/or the low-quality manufacturer switches from the no-product line strategy to the low-end product line strategy. If the high-quality manufacturer switches from the no-product line strategy to the low-end product line strategy and/or the low-quality manufacturer switches from the no-product line strategy to the high-end product line strategy, the market size of the high-quality manufacturer increases and that of the low-quality manufacturer decreases. This is because if the high-quality manufacturer adopts the high-end product line strategy and/or the low-quality manufacturer adopts the low-quality product line strategy, the original consumers of the two manufacturers will only switch from their retail channel to their rental channel, but their respective market sizes remain the same. However, if the high-quality manufacturer adopts the low-end product line strategy and/or the low-quality manufacturer adopts the high-end product line strategy, quality differentiation within product lines decreases, and some consumers who used to choose the low-quality manufacturer will choose the high-quality manufacturer instead.

6. Sensitivity Analysis

While the preceding section shows that manufacturers' equilibrium strategies (S^-S^+) are robust to parameter changes and result in Pareto-improving (win-win) outcomes, this section investigates how key parameters—namely the quality differentiation between retail products (Δq) and the quality differentiation between retail and rental products

(q_s)—influence profitability under the equilibrium strategies. Let $\Delta\pi_H = \pi_H^{S^-S^+} - \pi_H^{NN}$ and $\Delta\pi_L = \pi_L^{S^-S^+} - \pi_L^{NN}$ denote the equilibrium profitability of the high-quality and low-quality manufacturers, respectively.

Based on the model assumptions, the baseline parameters are set as follows: $c_H = 0.45$, $c_L = 0.2$, $c_s = 0.2$, $\rho = 0.75$, $\Delta q = 1$, $q_s = 0.5$, $\eta = 0.3$.

6.1. Quality Differentiation Between Retail Products (Δq)

This subsection analyzes the impact of Δq on equilibrium profitability ($\Delta\pi_H, \Delta\pi_L$), holding other parameters constant. The results are illustrated in Figure 4.

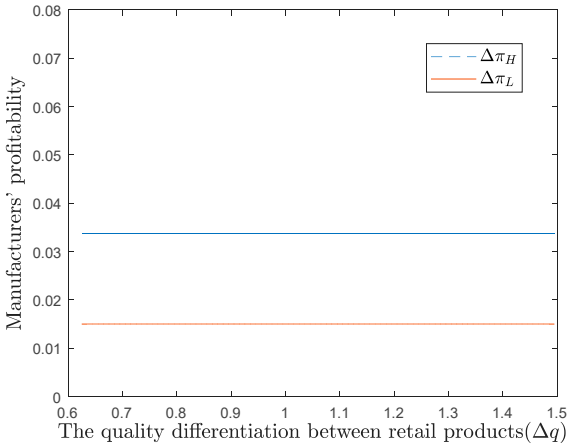


Figure 4. Effect of Δq on manufacturers' profitability.

As shown in Figure 4, manufacturers' profitability remain constant and strictly positive as Δq increases. This indicates that profitability under equilibrium strategies is unaffected by quality differentiation, and the equilibrium consistently yields a win-win outcome. Thus, competing manufacturers seeking higher profits should focus on adjusting other parameters rather than altering quality differentiation.

6.2. Quality Differentiation Between Retail and Rental Products (q_s)

We next examine how q_s influence equilibrium profitability ($\Delta\pi_H, \Delta\pi_L$), with results presented in Figure 5.

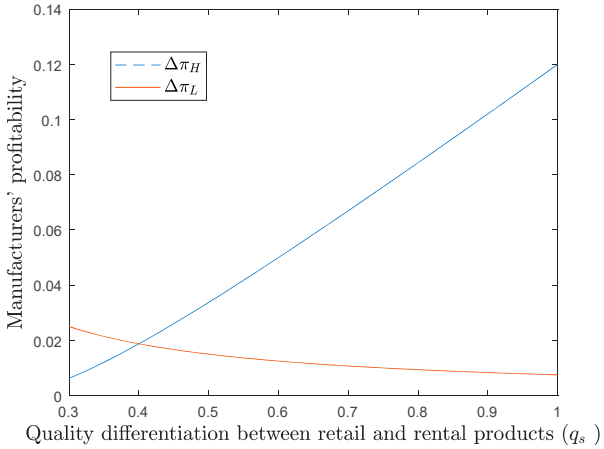


Figure 5. Effect of q_s on manufacturers' profitability.

As demonstrated in Figure 5, the profitability of high-quality manufacturers increases with the quality differentiation between retail and rental products (q_s), while low-quality

manufacturers experience a corresponding decrease—though both maintain positive profit margins. These findings reveal that while equilibrium strategy profitability remains sensitive to q_s, the directional effects are diametrically opposed between manufacturer tiers, yet the equilibrium consistently yields mutually beneficial outcomes.

The underlying economic mechanism operates through q_s's role in product line differentiation: (a) Increased q_s amplifies vertical differentiation in the product line; (b) This enhanced differentiation strengthens the competitive position of high-quality manufacturers. Simultaneously, it weakens the market position of low-quality competitors. Consequently, profit maximization strategies diverge: High-quality manufacturers benefit from maximizing q_s to reinforce their quality advantage; Low-quality manufacturers achieve optimal returns by minimizing q_s to reduce differentiation.

These results provide empirical support for the strategic importance of quality gap management in competitive product line design. The findings suggest that manufacturers can strategically manipulate quality differentiation (q_s) to optimize their profit positions within the market equilibrium, while maintaining the Pareto-efficient properties of the competitive landscape.

7. Extension: The Platform Construction Cost

In practice, establishing a rental platform incurs substantial fixed costs for manufacturers. To extend our baseline model, we incorporate platform construction costs into the analysis. We assume symmetric fixed costs F_H and F_L for both high- and low-quality manufacturers. Under this extension, manufacturer i's profit when adopting strategy $z_i = \{S^+, S^-\}$ becomes $\Pi_i^{z_i} = \pi_i^{z_i} - F_i$. The equilibrium outcomes under different cost regimes are characterized in Proposition 6.

Proposition 6.

(i) *When* $0 < F_H \leq \rho(q_s - c_s)^2/(4q_s)$ *and* $0 < F_L \leq \rho c_s^2/(4q_s)$, S^-S^+ *is the unique equilibrium;*

(ii) *When* $0 < F_H \leq \rho(q_s - c_s)^2/(4q_s)$ *and* $F_L > \rho c_s^2/(4q_s)$, NS^+ *is the unique equilibrium;*

(iii) *When* $F_H > \rho(q_s - c_s)^2/(4q_s)$ *and* $0 < F_L \leq \rho c_s^2/(4q_s)$, S^-N *is the unique equilibrium;*

(iv) *When* $F_H > \rho(q_s - c_s)^2/(4q_s)$ *and* $F_L > \rho c_s^2/(4q_s)$, NN *is the unique equilibrium.*

Proof of Proposition 6. We analyze the competitive manufacturer's equilibrium strategy. Note that $\Delta\Pi_1 = \Pi_H^{NN} - \Pi_H^{NS^+} = \Pi_H^{S^+N} - \Pi_H^{S^+S^+} = \Pi_H^{S^-N} - \Pi_H^{S^-S^+} = F_H - \rho(q_s - c_s)^2/(4q_s)$ and $\Delta\Pi_2 = \Pi_L^{NN} - \Pi_L^{S^-N} = \Pi_L^{NS^-} - \Pi_L^{S^-S^-} = \Pi_L^{NS^+} - \Pi_L^{S^-S^+} = F_L - \rho c_s{}^2/(4q_s)$. According to Proposition 1, if $0 < F_H \leq \rho(q_s - c_s)^2/(4q_s)$ and $0 < F_L \leq \rho c_s^2/(4q_s)$, S^-S^+ is the unique equilibrium. If $0 < F_H \leq \rho(q_s - c_s)^2/(4q_s)$ and $F_L > \rho c_s^2/(4q_s)$, subgames NS^+, NS^-, S^+S^+ and S^+S^- need to be compared. According to Proposition 1, we have $\pi_H^{NS^+} > \pi_H^{NS^-}$, $\pi_L^{NS^-} > \pi_L^{S^+S^-}$, and $\pi_L^{NS^+} > \pi_L^{S^+S^+}$. Then, NS^+ is the unique equilibrium. If $F_H > \rho(q_s - c_s)^2/(4q_s)$ *and* $0 < F_L \leq \rho c_s^2/(4q_s)$, subgames S^+N, S^-N, S^-S^- and S^+S^- need to be compared. According to Proposition 1, we have $\pi_H^{S^+N} > \pi_H^{S^+S^-}$, $\pi_H^{S^-N} > \pi_H^{S^-S^-}$, and $\pi_L^{S^-N} > \pi_L^{S^+N}$. Therefore, S^-N is the unique equilibrium. If $F_H > \rho(q_s - c_s)^2/(4q_s)$ *and* $F_L > \rho c_s^2/(4q_s)$, subgames S^+N, NS^-, NN and S^+S^- need to be compared. According to Proposition 1, we have $\pi_H^{S^+N} > \pi_H^{S^+S^-}$, $\pi_L^{NS^-} > \pi_L^{S^+S^-}$, and $\pi_L^{NN} > \pi_L^{S^+N}$. Therefore, NN is the unique equilibrium. This completes the proof of Proposition 6. □

Proposition 6 characterizes how platform construction costs shape manufacturers' equilibrium entry strategies. The results show that the cost thresholds $\rho c_s^2/(4q_s)$ and $\rho(q_s - c_s)^2/(4q_s)$—which depend on product quality and market competition—play a decisive role in manufacturers' platform participation.

In case (i), when the platform construction cost remains below both manufacturers' thresholds, both enter the market, replicating the equilibrium outcomes of the baseline model.

In case (ii), once the cost exceeds the threshold of the low-quality manufacturer ($F_L > \rho c_s^2/(4q_s)$) but remains below that of the high-quality manufacturer ($0 < F_H \leq \rho(q_s - c_s)^2/(4q_s)$), only the high-quality manufacturer sustains platform operation. The low-quality manufacturer exits due to its narrower profit margin in the rental market.

Conversely, in case (iii), should the cost exceed the high-quality manufacturer's threshold ($F_H > \rho(q_s - c_s)^2/(4q_s)$) while remaining affordable for the low-quality manufacturer ($0 < F_L \leq \rho c_s^2/(4q_s)$), the latter continues operating, whereas the high-quality manufacturer withdraws.

Finally, in case (iv), if the cost surpasses both manufacturers' thresholds, platform development becomes prohibitively expensive for both, resulting in market exit by all manufacturers.

8. Conclusions

In competitive markets, the design of product lines across retail and rental channels plays a critical role in enabling manufacturers—such as BMW and Daimler—to implement effective product-sharing strategies. This paper investigates a setting where vertically differentiated manufacturers not only sell directly to consumers but also operate peer-to-peer (P2P) platforms that facilitate consumer-to-consumer product sharing. To further engage in rental-based consumption, manufacturers build their own business-to-customer (B2C) platforms, offering products of varying quality levels to segment the rental market.

We develop a vertical duopoly model to examine three representative product line strategies: (1) No product line (no rental on B2C), (2) High-end product line (renting only high-quality products), and (3) Low-end product line (renting only low-quality products). Using a multi-stage non-cooperative game framework, we characterize the strategic decisions of competing manufacturers with quality asymmetry.

Our results reveal that a unique equilibrium emerges in which the high-quality manufacturer chooses the high-end product line strategy, while the low-quality manufacturer adopts the low-end product line strategy. This equilibrium not only reflects each firm's comparative advantage but also leads to a Pareto improvement, creating a win-win outcome for both manufacturers. The equilibrium mitigates channel conflict, enables effective market segmentation, and improves overall efficiency in the sharing ecosystem. Further analysis shows that product line strategies that expand vertical differentiation effectively reduce cannibalization and soften price competition, while sensitivity analysis confirms that these equilibrium outcomes remain robust across variations in key parameters. In contrast, strategies that compress quality differences intensify internal competition and erode market performance. Thus, aligning product line design with intrinsic product quality is a viable path to balancing efficiency and profitability.

Several extensions could further enrich this research. First, consumer-side transaction costs—such as search friction, trust, or inconvenience—may affect rental decisions, and incorporating them could provide a more realistic view of consumer behavior. Second, while we treat the P2P platform commission rate as exogenous, future work could endogenize it, allowing platforms to strategically set fees through manufacturer bargaining or platform competition, revealing how platform decisions influence product line strategies. Third, our model assumes static product quality; exploring dynamic quality adjustments would enable manufacturers to adapt retail and rental products over time in response to market signals, consumer preferences, or competition. Fourth, incorporating quantifiable sustainability metrics—such as product lifespan extension or carbon emission reduction—could evaluate how product line strategies support circular economy goals in sharing markets.

These extensions would advance the understanding of adaptive, platform-oriented, and sustainable product line strategies, offering both theoretical and managerial insights.

Author Contributions: Conceptualization and methodology and formal analysis and writing—original draft preparation, Y.Z.; writing—review and editing, Y.Z., J.L. and S.L.; supervision, J.L. and S.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research is supported in part by the National Natural Science Foundation of China Grant No. 72402041 and the China Postdoctoral Science Foundation Funded Project Grant No. 2024M750557 and No. 2025T180220, and the Shanghai Open University Center for Research on Digital Management and Service Innovation (yjzx2403).

Data Availability Statement: No new data were created or analyzed in this study.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Case Study

We demonstrate the practical validity of the theoretical framework using a real-world case involving Audi (a premium automaker) and SAIC Motor (a mass-market Chinese manufacturer). SAIC operates EVCARD, a B2C car-sharing platform offering models such as the Roewe i5, while Audi provides rentals of the A5 alongside retail sales of the A4L. Their optimal strategies are analyzed under four vehicle configurations, as summarized in Table A1.

Table A1. Relevant parameters of sharing market ($\times 10^5$).

Parameter	Value
Marginal cost (Roewe i5) c_{sL}	0.4
Marginal cost (Roewe RX5) c_L	0.8
Marginal cost (Audi A4L) c_H	2.2
Marginal cost (Audi A5) c_{sH}	2.4
Platform commission rate η	0.25
Consumer usage level ρ	0.625
Quality differentiation Δq	1–1.5

While q_s is theoretically bounded ($\Delta q > 2q_s$), we set $q_s = 0.2$ due to unobservable consumer preference factors.

Among nine possible subgame equilibria, four strategies (S^-S^+, S^-S^-, S^+S^-, S^+S^+) are viable after profit dominance elimination. Figure A1 compares Audi's and SAIC's profits under these strategies.

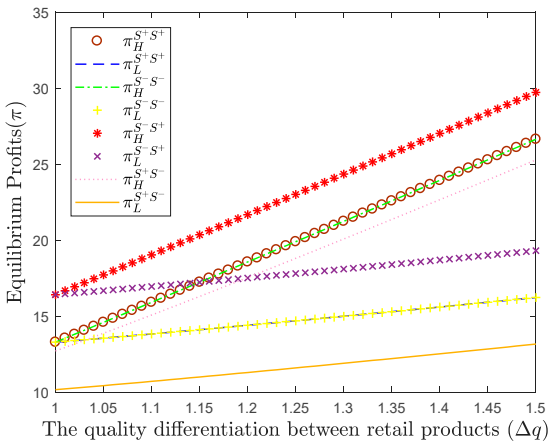


Figure A1. Firms' profits under different strategies.

The results confirm that: Audi (high-quality) achieves maximum profit under S^-S^+ (premium leasing); SAIC (low-quality) achieves maximum profit under S^-S^+ (basic leasing). This alignment with the theoretical equilibrium (S^-S^+) validates the model's applicability to real-world competitive sharing markets, showing that Pareto-improving outcomes can be achieved in practice.

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