The underexplored impacts of online consumer reviews: Pricing and new product design strategies in the O2O supply chain

Li, Y., Xiong, Y., Mariuzzo, F. & Xia, S.

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Abstract

In recent years, online consumer reviews have become popular in platform sellers to increase product sales, and the literature has widely recognized those reviews' positive impacts. Nevertheless, this paper identifies online consumer reviews' negative impacts on the intra-brand competition (multi-product), and aims to study such effect on wholesale prices and product design strategies of players in the FMCG (Fast Moving Consumer Goods) O2O (online to offline) supply chain. We model the decentralized O2O supply chain facing intra-brand competition that consists of a platform seller (follower) and a manufacturer (leader) when the new product entries. We find that the intra-brand competition driven by the reviews' increased-sales effect on the incumbent product causes the conflict. The platform seller prefers to limit such an effect if the new product's consumer valuation is not sufficiently high, but the manufacturer benefits from it. Manufacturers can reduce the product line's wholesale prices or lower down the new product quality to pre- empt the platform seller from limiting RE-I to coordinate the channel. This study contributes to O2O supply chain management literature by examining the possible negative impacts of online consumer reviews. Also, this study presents a new perspective to combine consumer reviews, pricing and product design strategies to coordinate the O2O channel.

Keywords: Cannibalization; Consumer reviews;, Product design; FMCG O2O supply Chain management; Vertical relationship

1 Introduction

The E-commerce giants Amazon, Alibaba Group, and JD.com have realized the importance of building an ecosystem of retail partners and consumers and had their local stores to start their O2O(online to offline) strategies in the post-COVID-19. Most FMCG (Fast Moving Consumer Goods) retailers have intensified their O2O services through self- run platforms, such as WeChat mini-programs or closer cooperation with Vanguard, JD.com, RT-mart, Wal-Mart and Dmall etc. Far more consumers are adjusting their daily routines and shopping online now as compared to the pre- COVID era. In the second quarter of 2020, 30% of Chinese urban families purchased FMCG through O2O platforms.[1]

This change requires FMCG companies to renew their channel-management approaches, including how they assort, price and promote their products. For example, many winning FMCG companies such as Three Squirrels and Conagra Foods have been renovating in their sub-category by deploying consumer-back analytics, imbuing them with more relevance to meet consumer needs, although they have a success of their incumbent products. One of the fasting growth instant-noodle brand RamenTalk founded in 2016 from China achieved 250 million yuan (30 million dollars) in 2019. Its essential successful strategies are to compress the time of launching the new product within two months from identifying the consumers' preference, pre-test, package design and production to the market and apply Word-of-mouth (WOM) to facilitate the products' sales.[2] Intuitively, Word-of-mouth increases the products' sales, but intensifies the intra-brand competition between the new product and the incumbent product. As the rapid development of a new product is a crucial strategy for success in the FMCG industry, marketers should pay more attention to this loss caused by such intra-brand competition when new product entries. Therefore it is critical to figure out whether Word-of-mouth brings a positive or negative effect on the manufacturers' and the platform sellers' profits and how to manage these effects in the FMCG O2O supply chain.

Consumers' evaluations of such experience products tend to be idiosyncratic, so the popularity of a product or other users' experience become more important for consumers as indicated by the volume of consumer reviews and detailed experience description from users' reviews. An increasingly dominant market strategy for retailers to boost new product sales is to make online consumer reviews available on their websites (Chevalier and Mayzlin, 2006; Pradeep et al., 2010). To have a sales-increased effect, sellers on Amazon or JD.com send an email or leave a message on the order webpage to ask reviews that increase the number of online reviews (volume and valence) (FloydRyan et al., 2014; You and VadakkepattAmit, 2015). They guide the content of reviews and respond reviews to improve the rating and win back consumers' trust. In a recent paper, Dost et al. (2019) prove that WOM has a positive effect on the sales of FMCG.

While considering the effect of consumer reviews on the product line with different margins, marketers need careful consideration of the information-driven cannibalization problem. When a product line extension is implemented from one sub-category to another sub-category, there is an internal competition of a part of the former's sales being squeezed by the latter or reversely. When the new product enters the market, the marketer often ignores that the incumbent product's demand-generating information helps it squeeze the market share of the new product with a higher margin. It decreases the profit from the new product. Most FMCG companies sell millions of packs of food every year. Even a small part of consumers switch to the incumbent product from the new product with a higher margin, the accumulation of such switching loss costs hundreds of thousands of dollars a year. This is because such cannibalization happens very

often in FMCG industry due to the fast new product development strategy. One of the approaches to control such information-driven cannibalization is to limit the reviews' (R) increased-sales effect (E) on the incumbent (I) product (RE-I hereafter).[3] Part of consumers would stop switching from the later to the former. Most literature on online reviews emphasizes its positive impact, but this paper extends the study on its negative aspect driving the intra-brand competition. We first ask whether platform sellers should differentiate consumer reviews' management for their product portfolio to soften such cannibalization.

Manufacturers often free ride retailers' marketing effort facilitating sales to enjoy the benefits. However, they also incentivize retailers' provision of demand-generating services by providing the compensation, when the retailers' income from the increased sales of marketing effort cannot offset its provision cost. For example, auto manufacturers sometimes compensate car dealerships for consumer test drives (Kuksov and Liao, 2018). We have the similar logic to study the conflict between the manufacturers and their platform sellers (one acquires the benefit, but the other gets the hurt), but this paper explores whether the increased-sales effect of consumer reviews leads to the conflict from the information-driven cannibalization aspect, rather than the cost offset mechanism. Then, we ask how manufacturers compensate their sellers by controlling the product line's wholesale prices to affect platform sellers' strategy on managing consumer reviews.

An interesting finding from the recent paper (Godes, 2017) shows that WOM's expansion may decrease the optimal product quality. He suggests the firm's product policy may require reconsideration with the implications of the growth of social interactions. The relation between the new product design and social communication is bidirectional. We aim to extend the analysis to study how manufacturers' new product design affects the platform sellers' consumer reviews strategy to solve the conflict problem and improve the FMCG O2O supply chain.

As the fast launching of the new product to meet consumers' new preference and the application of WOM attracting consumers are important strategies for the success, FMCG O2O chain members need to balance the product line's sales (the new product and the incumbent product) rather than the sales of a single product and consider the competition from other brands affecting these sales. They should also consider the interaction between the platform sellers' consumer reviews strategy for the product line and the manufacturers' possible strategy on the wholesale prices or the new product design. In this work, we model FMCG O2O decentralized chain with a Stackelberg sequential game where the manufacturer acts as leader and platform seller as a follower. By considering the information-driven cannibalization from the incumbent product against the new product, the platform sellers decide whether limit consumer reviews'

increased-sales effect on the incumbent product (RE-I) that soften the intra-brand competition. First our analysis examines how RE-I causes the conflict between the manufacturer and his platform seller in the O2O FMCG supply chain. One of the results is that the FMCG manufacturer always benefits from RE-I. The platform seller, on the other hand, only benefits from RE-I under certain conditions. Then we show the conditions where the manufacturer can distort wholesale prices of the whole product line or lower down the new product quality to direct the platform seller towards RE-I to coordinate the channel.

This study has two important theoretical contributions. First, this study extends the previous literature on consumer reviews by considering consumer reviews' impacts on the sales and the intra-brand competition for the product line. Past research usually focuses on the increased-sales effect of consumer reviews but does not consider its effect on intensifying the intra-brand competition that harms the profit. The previous literature does not reflect the business practices as most FMCG firms apply the fast new product development strategy for success and it causes the severe intra-brand competition between the new product and the incumbent product. Second, the past O2O supply chain management literature has considered the conflict conditions where the market return cannot offset a high marketing investment but unfortunately ignores that the intra-brand competition intensified by sellers' online reviews strategy causes the conflict. Further, we contribute to this literature by presenting a new method to coordinate the channel. In particular, manufacturers can increase their profits through adopting new product design strategy to influence the platform sellers' online reviews strategy.

We yield several important practical implications for the coordination of the decentralized FMCG O2O supply chain, when the manufacturers launch the new product and distribute products through the platform sellers. When consumers' valuation for the new product is higher enough, the reviews' increased-sales effect on the incumbent product causes the conflict. Based on that, we provide new insights for the manufacturers' strategies to coordinate the channel. (i) When consumers' valuation for the new product is relatively high (higher enough), the manufacturers should compensate the platform sellers by reducing the product line's wholesale prices and the platform sellers apply the same consumer reviews strategy for the product line. (ii) When consumers' valuation is relatively low (higher enough), the manufacturers should lower down the new product quality to stimulate the same consumer reviews strategy for the product line from the platform sellers.

The paper is organized as follows. Section 2 reviews the related literature. Section 3 outlines the model and introduces the benchmark model. Section 4 models the impact of RE-I on the cannibalization of new products, in which we discuss the interaction between the manufacturer and the platform seller through their control on the product quality, pricing and the strategy on managing consumer reviews. Possible extensions of the model are presented in Section 5. Finally, the study concludes in Section 6 with a summary of the main findings. The corresponding proofs are in the appendix.

2 Literature review

The research questions addressed in this paper relate mostly to the literature on online consumer reviews. As several studies have empirically shown that more favourable reviews or rating environment can directly improve sales ((Moe and Trusov, 2011; Mayzlin et al., 2014)), and the social welfare generated by review systems can improve consumer choice (e.g. (Duan et al., 2008)). In the extant literature, the impact of product reviews on sales is typically measured using numeric variables that represent the valence and volume of reviews ((FloydRyan et al., 2014; You and VadakkepattAmit, 2015)). By applying the economic and applied models, Kuksov and Xie (2010) suggest that firms can modify their strategies to improve average consumer rating and stimulate further consumption. Sun (2012) examines the informational role of product ratings' variance in affecting products' subsequent price, demand, and profit. Beyond investigating the profound effects of reviews on the demand side (sales), the availability of online reviews can also influence firm's other strategies such as the marketing communication strategies ((Chen and Xie, 2008)) and the return policy ((Sun et al., 2020; Sahoo et al., 2018)), and the competition between the retailer and the manufacturer. For example, Kwark et al. (Young et al., 2014) suggest that the various contents of consumers reviews have different effects on retailers and manufacturers. Most of them focus on the increased-sales impact of consumer reviews (positive effect). However, the increased-sales impact of consumer reviews on the incumbent product intensifies the intra-brand competition that decreases the new product sales with a higher margin (negative effect). We contribute the literature by concluding the comprehensive effect of consumer reviews on the manufacturers' and platform sellers' profit.

A consistent body of studies on product line extensions addresses cannibalization between low quality and high quality products (e.g. (Preyas, 2001; Yogesh et al., 2015; Sridhar Moorthy, 1984; Pedram and Balachander, 2014)). Considering such cannibalization, most of the literature study the factors affecting the product line design. For example, Villas-Boas (1998) explores the impact of channel structure on the product line's optimal design. He finds that a strategic manufacturer considering the retailers' strategic behaviour will intentionally reduce the product quality levels in a decentralized channel. Johnson and Myatt (2006) investigate the interaction between product design decisions, advertising and marketing activities for the multi-product firms. In recent literature, Godes (2017) discusses the impact of communication information on product design and suggests that the consumer reviews may reduce or increase the product quality. These literature concludes the effect of retailers' strategic behaviour such as the communication information on the product design. However, it is unclear about the reversed relation between them and how to manage them to improve the supply chain, so we fill this gap on studying how the new product design controlled by manufacturers influences the platform sellers' consumer reviews strategy for the product line to improve the channel.

The other stream of research related to our paper is O2O channel management. For example, Gao and Su (2017) apply a theoretical model to study the implications of BOPS (Buy-Online-and-Pickup-in-Store) on channel coordination. While considering channel conflicts and cannibalization between the franchisee and the brand owner, Choi et al. (2019) explore the focal points on the choice of franchising contract and the ordering time in the online-offline fashion franchising supply chains. However, our research focuses on how FMCG O2O chain members behave in a non-cooperative game in the context of product line extension. By extending the literature on the advertisement in the traditional supply chain (Huang et al., 2002; Karray and Zaccour, 2006), Li et al. (Xiang et al., 2019) analyze the cooperative advertising strategies in three models (integration, unilateral and bilateral advertise model). They find the optimal the share mechanisms of the advertisement expenditure in the O2O supply chain. Govindan and Malomfalean (2019) consider two types of demand under three mechanisms (revenue-sharing, buy-back, and quantity flexibility contracts) to coordinate the O2O supply chain. Most of them have examined the conflict conditions from the cost offset mechanism, we extend the study on whether the intra-brand competition intensified by online reviews causes the conflict. We also contribute the O2O literature by providing a new alternative strategy for the traditional compensation methods to coordinate the FMCG O2O supply chain, that is the adjustment of the new product design.

3 The model

Consider a market in which there are two differentiated FMCG substitute products produced by two manufacturers. Product *a* produced by manufacturer *A* is sold online directly to consumers; product *b* produced by manufacturer *B* is distributed through a platform seller. With consumer-back analytics, manufacturer *B* knows consumers' new preference and considers launching a new product to satisfy them, , into the market. He decides the quality of the new product and sets the new and the incumbent products' wholesale prices. In doing so, it has to internalize competition from its incumbent product and the competitor's product. The platform seller *B* chooses the selling prices and manage the consumer reviews for the product line. In Table 1 we introduce some useful notation for variables and parameters that the model relies upon.

alt-text: Table 1

Table 1

The table layout displayed in this section is not how it will appear in the final version. The representation below is solely purposed for providing corrections to the table. To preview the actual presentation of the table, please view the Proof.

Parameters and decision variables.

Symbols	Definitions
q_a, q_b $q_{b'}$	Quality for channel *A* 's product, channel *B* 's incumbent product, channel s new product
θ_a, θ_b, $\theta_{b'}$	Consumer willingness to pay for channel *A* 's product quality, channel incumbent product quality, channel *B* 's new product quality
$v_a, v_b, v_{b'}$	Incremental value of consumer reviews, with $i \in \{a, b, b'\}$
Tt	Consumer perceived differentiation between products
p_a, p_b $p_{b'}$	Price for channel *A* 's product, channel *B* 's product, channel *B* 's new product
w_b, $w_{b'}$	Wholesale price for channel *B* 's incumbent product, channel *B* 's new product
π_i	Firm *i* 's profit, with $i \in \{AM, BM, BS\}$, where *M* = manufacturer and *S* = the platform seller.

3.1 The platform seller's strategy on managing consumer reviews

This section introduces the positive or negative effect of consumer reviews and the platform seller's possible strategies on managing consumer reviews. Godes (2017) and Sun et al. (2020) model that the consumer reviews managed by sellers increase consumers' evaluation of the product, so we assume the reviews feedback positively on consumer utility, that is the increased-sales effect (positive impact). However, when new product entries, the reviews' increased- sales effect on the incumbent squeezes the new product demand (negative impact). One possible method to soften the cannibalization for the new product is to limit reviews' increased-sales effect on the incumbent product. For example, the online seller can control the number of reviews or the reviews' content through the E-mail reminders, management response or the guidance, to reduce the increased-sales effect of consumer reviews. Therefore, the platform seller *B* considers these two reversed effects of reviews and has two strategies on the management of consumers reviews: limit (*L*) the reviews' increased-sales effect on the incumbent product (RE-I) or not when the new product becomes available.

We assume v_i, $i \in \{a, b, b'\}$ to represent the increased-sales effect on consumer valuation of products via the provision of consumer reviews. Sun et al. (2020) assume that consumer reviews add high or low value to consumers and explain that the higher score or, the larger number of reviews bring a higher value of the online review. Similar to them, if the platform seller *B* limits the increased-sales effect of consumer reviews on product *b*, such effect on consumer valuation

of product b becomes smaller and thus we assume $v_b^L < \{v_{b'}, v_a\}$. Like Sun et al. (2020), we call v as the value of consumer reviews. To simplify the analysis of the model, we impose $v_b^L = 0$

3.2 Manufacturer's possible approaches on affecting the platform seller's reviews strategy

The manufacturer and his retailer pursue their interests and compete, so they often apply the strategy optimizing their profit that may cause the loss for others. This model will study two strategies taken by the manufacturer affecting the platform seller's action to solve the conflict. (i) As a supply chain leader, it is common for the manufacturer to direct platform seller's behaviour through the compensation mechanisms (Kuksov and Liao, 2018), when there is a conflict between them. we will model how the manufacturer adjusts the product line's wholesale prices to affect the platform seller's strategy on managing consumer reviews for the product line. (ii) FMCG manufacturers are keen to innovate the product. When he decides the new product design, he needs to consider how his decision lead the possible retailer's market behavior (Godes, 2017) and the effect on his profit. This model will analyze the effect of the manufacturer's new product quality decision on the platform seller's management strategy on consumer reviews. Similar to the product design literature (Preyas, 2001; Yogesh et al., 2015), we assume that consumers have marginal valuation (willingness to pay) θ for the quality of the product, which we denote by q.

A feature of our model is that, for channel A, production and distribution are centralized, whereas for channel B, they are decentralized. Having only one distribution vertically separated is an assumption that unquestionably does help in making the model tractable, and it also has the benefit of being realistic, as asymmetry in vertical channel structures is a marketing reality. For example, several FMCG manufacturers such as Conagra Foods opt for a separated structure, while Three Squirrels tend to integrate its channel to control the user experience.[4]

3.3 Benchmark model

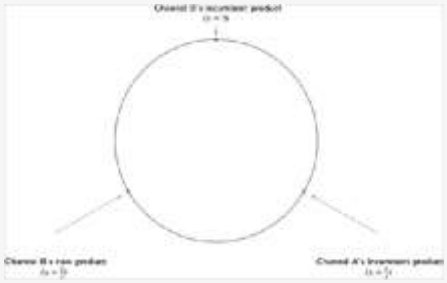
We first give the benchmark model where the platform seller chooses RE-I strategy. The next section will compare it with the scenario in which the reviews' increased-sales effect on the incumbent product (RE-I) is limited to examine RE-I's effect. Our analytical approach utilizes a Stackelberg sequential game. We consider three differentiated FMCG products and assume that the consumer reviews are available to all three products. Our model includes a manufacturer (BM) and the platform seller (BS–which together make channel B–and a manufacturer ($AM$the only agent of channel A. The manufacturer ( ) sells BMtwo differentiated products of the same brand through the platform seller ( ) to consumers BS The other manufacturer ( ) sells a different AM incumbent product directly to consumers online. We denote with the quality of channel B's incumbent product, the quality of the new product, and the quality of channel A's product. Like the production cost model for the quality applied in (Sridhar Moorthy, 1984; Preyas, 2001), we assume both manufacturers incur a strictly convex cost of producing quality, . $\frac{q_i^2}{2}$

We use a localized competition framework (á la Salop) to model the rivalry between the two manufacturers. Consumers are located uniformly on a circular market of unitary length (Salop (1979)). Each consumer buys at most one product. ~~Shulman et al. (ShulmanAnne and Savaskan, 2011)~~ ShulmanAnne and Savaskan (2011) develop the Salop model. They consider four horizontally differentiated products with locations and view the distance between products as the level of differentiation between them. We have the same logic and describe profit competition between three differentiated products, each exogenously located at equidistant intervals along the unit circle. More specifically, when manufacturer B with two products competes with manufacturer A with one product, the location of B's incumbent product is assumed to be at the zero point ( ) of the Salop circular market. The location of B's new product is assumed to be at the two-thirds point ( ), and the location of A's competing product is assumed to be at the one- third point ( ), as displayed in Fig. 1.[5] We relax the assumption of equidistant location in Section 5.1. Consumer willingness to pay for product quality are , for channel B's incumbent and new products, and for channel A's product. When channel B launches the new product, both channels apply consumer reviews to improve consumer valuation of the products $v_i,\ i = \{a, b, b'\}$. The magnitude of disutility that a consumer incurs from a mismatch between an ideal product and the product offered by the seller is represented by the mismatch cost t. It is often referred to in the literature as the degree of perceived differentiation between products ~~(e.g., Liu and Cui (2010), Shulman et al. (ShulmanAnne and Savaskan, 2011))~~(Liu and Cui, 2010; Shulman et al., 2011)). Given the three retail prices p_a and p_b, $p_{b'}$, the surplus of a consumer located at $0 \le x \le 1$ is given by [6]

$$\begin{aligned} V_a &= \theta_a q_a + v_a - p_a - t\left(\tfrac{1}{3} - x\right) \\ V_b &= \theta_a q_b + v_b - p_b - tx. \end{aligned} \tag{1a}$$

alt-text: Fig. 1

Fig. 1



Spatial circular market model of competition for the product entry.

Similarly, the surplus of a consumer located at $\frac{1}{3} < x \leq \frac{2}{3}$ is given by:

$$V_{ia} = \theta_a q_a + v_a - p_a - t\left(x - \frac{1}{3}\right)$$
$$V_{ib'} = \theta_{b'} q_{b'} + v_{b'} - p_{b'} - t\left(\frac{2}{3} - x\right). \quad (1b)$$

Finally, the surplus of a consumer located at $\frac{2}{3} < x \leq 1$ is given by:

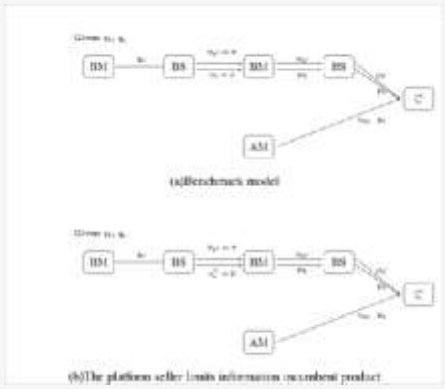
$$V_{ib} = \theta_b q_b + v_b - p_b - t(1 - x)$$
$$V_{ib'} = \theta_{b'} q_{b'} + v_{b'} - p_{b'} - t\left(x - \frac{2}{3}\right). \quad (1c)$$

To avoid cumbersome algebra, we impose symmetry in willingness to pay for product quality of the incumbent products, thus $\theta_a = \theta_b \equiv \theta$. This simplification implies that both manufacturer *b*'s incumbent product and manufacturer *a*'s product have initially the same competitive edge. We then assume that $q_{b'} > \theta$ which means consumers have higher valuation for the new product and motivates the manufacturer to develop the new product, i.e., they have a taste for novelty.

The sequential choices of the two manufacturers and the platform seller's decisions are displayed in Fig. 2. Panel (a) describes the benchmark model. The quality of the new product is chosen prior to entry into the market, taking the quality of the existing products as given, this because they are already in the market and the manufacturer cannot re-adjust the quality decided at the stage of entry (prior to our timeline). Stage two is the time the platform seller BS chooses whether limit RE-I.[7] Wholesale prices are set in stage three, and are denoted with w_b and $w_{b'}$. Finally, in stage four, the retail prices for all three products (p_b, $p_{b'}$, p_a) are decided based on the wholesale prices. We solve the game by backward induction to guarantee subgame perfection in a fully covered market.

alt-text: Fig. 2

Fig. 2



Channels A and B's decision tree when the manufacturer does not take actions.

We use Lemma 1 to have the value of the incumbent products' quality of brand *A* and *B*. Then we put these results into our solutions. Since both incumbent products have been in the market for some time, we assume that their qualities q_a and q_b are given before the manufacturer decides the new product quality and regards as exogenous variables. The following Lemma suggests that, given symmetry in consumer willingness to pay for quality, the two original products will have the same quality in equilibrium.

Lemma 1 *Under symmetry in willingness to pay for product quality ($\theta_a = \theta_b \equiv \theta$), asymmetry in vertical structure does not lead to asymmetry in quality, i.e. in equilibrium,* $q_a = q_b = \theta$.

These results are in line with the findings of Moorthy (Sridhar Moorthy, 1984) and Desai (Preyas, 2001). The efficient quality for consumers is the quality that maximizes the difference between a consumer's valuation and the firm's cost of quality. From Lemma 1 we know that $\theta_a q_a = \theta_b q_b = \theta^2 = u$. Similarly, for the new product the condition is $\theta_{b'} q_{b'} = \theta_{b'}^2 = u'$. Under this notation, u represents consumer valuation of the incumbent product quality, and u' is the corresponding for the new product. Consumer reviews positively affects consumer valuation. We assume that the effect of consumer reviews leads to a positive shift in consumer surplus. With this new notation, we formulate the demand function for each product:

$$\begin{aligned} D_a &= \frac{3u - 6p_a + 2t - 3u' + 3p_{b'} + 6v_a - 3v_{b'} - 3v_b + 3p_b}{6t} \\ D_b &= \frac{3u + 6v_b - 3v_{b'} - 3v_a - 6p_b + 3p_{b'} + 2t - 3u' + 3p_a}{6t} \\ D_{b'} &= \frac{-6u + 3p_a + 2t + 6u' - 3v_b + 6v_{b'} - 3v_a + 3p_b - 6p_{b'}}{6t}. \end{aligned} \tag{2}$$

To keep the model symmetric and tractable, we assume that both channels apply consumer reviews to increase consumer valuation of a product, and impose a symmetric change in consumer valuation of the three products, $v_a = v_b = v_{b'} = v > 0$. The assumption that the customer weighs the online reviews the same for products follows Kwark et al. (Young et al., 2014), in which the information precision of online reviews on products is assumed to be the same. This simplification does not affect the main results of the paper and will be relaxed when asymmetry between channels is fed into the analysis. To shield against negative demands, in equilibrium we enforce consumer valuation of the new product to be within the interval:

$$\max\left\{u - \frac{40t}{33}, 0\right\} < u' \leq u - \frac{22v}{7} + \frac{40t}{21}. \tag{3}$$

To ensure that the interval in Equation (3) is well behaved, we assume a sufficiently large degree of product differentiation $t > \frac{121}{120} v$ –a condition that is always satisfied in case of limiting RE-I. Indeed, the above inequality dictates that there is room for all three differentiated products in the market. Therefore, the results we draw upon in this paper are for markets in which differentiated products have sufficient competitive power to attract positive demands.

Provided the vertical structure that we have assumed the two manufacturers' and the platform seller's profit functions are expressed as:

$$\begin{aligned} \pi_{BM} &= \left(p_a - \frac{v_a^2}{2}\right) D_a \\ \pi_{BS} &= (p_b - w_b) D_b + (p_{b'} - w_{b'}) D_{b'} \\ \pi_{BM} &= \left(w_b - \frac{v_b^2}{2}\right) D_b + \left(w_{b'} - \frac{v_{b'}^2}{2}\right) D_{b'}. \end{aligned} \tag{4}$$

4 The platform seller's management strategy on consumer reviews

In this section, we first study the effect of consumer review on the platform seller's and the manufacturer's profit. We start by assuming that the manufacturer does not respond to the change in the reviews strategy by the platform seller, and later we allow the manufacturer can adjust his strategies to affect the platform seller's reviews strategy. The platform seller limit the reviews BS increased-sales effect on the incumbent product (RE-I) where the manufacturer does not take any action in the game with the platform seller. We compare the results of this strategy with the benchmark model depicted in Fig. 2 (a), where the platform seller does not limit the effect of reviews on the incumbent product. Then, we allow the manufacturer is strategic, where he takes into account how his decisions on wholesale prices or the new product quality affect the platform seller's action.

4.1 The platform seller limits RE-I when manufacturer is not strategic

When the platform seller BS limits the increased-sales effect of reviews on the incumbent product (RE-I), this has a detrimental effect on consumer surplus, $v_b' = 0$. We work with the timing structure depicted in Fig. 2(b) and investigate the combinations of degree of product differentiation and consumer valuation of the new product quality (t, u') that guarantee RE-I as a subgame perfect equilibrium in the market. We highlight the loci (t, u') where there is conflict of interest between the platform seller and the manufacturer.[8]

Theorem 1 *Following the launch of the new product, a comparison between LRE-I and RE-I by the platform seller* BS *yields the following results:*

a) Manufacturer BM *always benefits from RE-I.*

b) The platform seller BS *benefits from RE-I only when consumer valuation of the new product is sufficiently small.*

Theorem 1 suggests that the manufacturer with multiple products, BM, benefits from RE-I after the new product enters the market, as long as each of the differentiated products has a competitive edge that guarantees an above-zero demand (captured by areas C_1 and C_{12} in Fig. 3(a)). By contrast, the platform seller only benefits from RE-I if the new product has a relatively weak competitive edge, that is, if consumer valuation to purchase the new product does not exceed that of the incumbent product (area) by much. Theorem 1 is the result of the following inequalities:

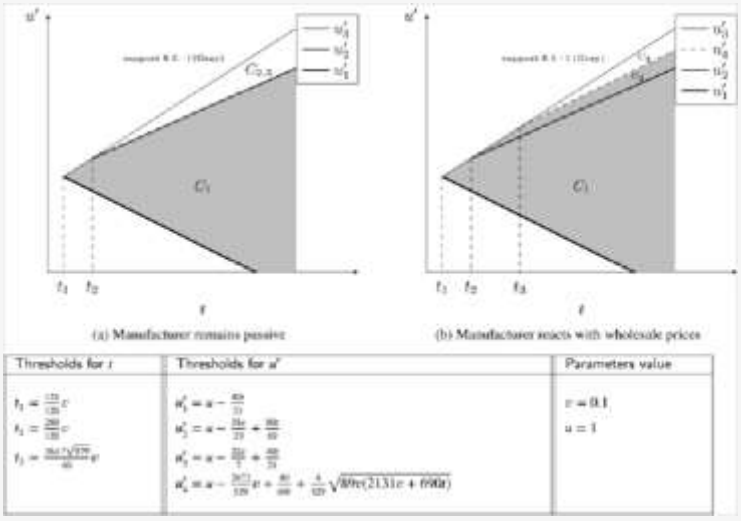
$$\pi_{BS}(v_0 = v_1^r) - \pi_{BS}(v_0^r = v_1^r) > 0 \text{ if } (t, u^r) \in C_{12} \text{ and } \pi_{BS}(v_0 = v_1^r - \pi_{BS}(v_0^r = 0) \leq 0 \text{ if } (t, u^r) \in \{C_{12}\}. \quad (5)$$

In this case, two factors influence the platform seller's profits. First, the increased demand of the incumbent product has an adverse effect on the new product's market share because of substitutability. Second, RE-I causes a drop in the price of the new product and this, together with the cannibalization of market shares, contributes to the platform seller's profit deflation. The reduction in the new product's price squeezes the platform seller's margin since the wholesale price remains unchanged. Interestingly, when competition is relaxed (higher degree of product differentiation *t*), the range of consumer valuation of the new product satisfying profitable RE-I widens, but so does the tendency of the platform seller not to prefer RE-I. Soft competition increases profitability and therefore can be used as a buffer against cannibalization. Hence, more intense competition is, the less room exists for RE-I at high values of consumer valuation of the new product. The reason for this result is that RE-I exacerbates cannibalization of the new product, and this is particularly severe when there is a high valuation of the new product. RE-I raises the profit of the existing product (positive effect) to the detriment of the profit of the new product (negative effect), but the negative effect only affects the platform seller.[9]

This section concludes the reviews' increased-sales effect on the incumbent product drives the cannibalization problem that causes the profit loss for the platform seller under certain conditions (See C_{12} in Fig. 3(a)). It also positively affects the manufacturer's profit (the conflict), so the platform seller chooses to limit such effect (LRE-I). In such a case, to gain higher profit in the presence of RE-I, the manufacturer has a strong motivation to guide RE-I from the platform seller. In the next section, we allow the manufacturer to adjust the wholesale prices or the new product quality, and use these as retaliation to the platform seller's LRE-I strategy to improve the profits. Again, we compare these new situations to the benchmark model.

alt-text: Fig. 3

Fig. 3



Optimal strategies for RE-PI.

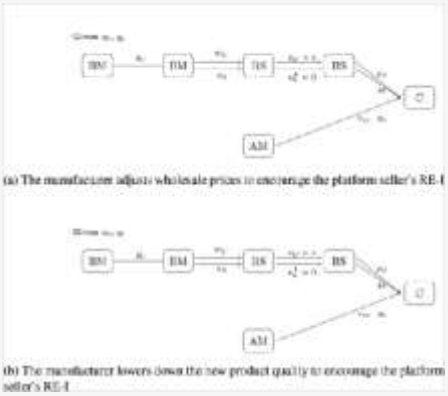
4.2 Strategic manufacturer adjusts wholesale prices to reverse the platform seller's LRE-I to RE-I

Manufacturers often compensate their retailers' loss when there is conflict (the inconsistent profit trend) to improve their profits. This section examines the situation where the manufacturer can influence the platform seller's consumer reviews strategy through more favourable wholesale prices to coordinate the channel when the platform seller chooses to limit RE-I, the decision tree of such adjustment is in Fig. 4(a). The platform seller does not limit RE-I if

$$\pi_{BS}(w_0, w_P | RE-I) - \pi_{BS}(w_0, w_P | LRE-I) = \frac{v[138w_P + 93v_0 - 186v - 186w_0 + 162u + 80t - 138w^r]}{432t} \geq 0. \quad (7)$$

alt-text: Fig. 4

Fig. 4



Channels A and B's decision tree when manufacturer is active.

We study the existence of a unique cut-off point on the range of wholesale prices $\hat{w}_{b'}$ and $\hat{w}_b$, that allows manufacturer B to influence the platform seller BS's decision of whether or not limit RE-I. The manufacturer's profit maximization problem is now constrained by the platform seller BS preferring RE-I to LRE-I:

$$\max_{\hat{w}_{b'},\hat{w}_b} \Pi_{BM}(\hat{w}_{b'},\hat{w}_b|PE-P) - \left(\hat{w}_{b'} - \frac{\alpha_2^2}{2}\right) D_{b'} + \left(\hat{w}_b - \frac{\alpha_2^2}{2}\right) D_b$$
$$\text{s.t.} \frac{\alpha_2^2(138+y+93v_b-186c-186v_b+162v+81v-138u')}{432} \geq 0. \tag{8}$$

We determine the equilibrium by solving manufacturer BM's trade-off between distorting the wholesale prices downward and inducing the platform seller to support RE-I. When choosing to reduce wholesale prices to prevent the platform seller from limiting RE-I, manufacturer BM must guarantee no harm to its profits. In other words, manufacturer BM's profits cannot be lower than when LRE-I is selected: $\pi_{BM}(\hat{w}_{b'},\hat{w}_b|v_b - v) \geq \pi_{BM}(w_{b'},w_b|v_b^L - 0)$.

Proposition 1 *With product differentiation and consumer valuation of the new product within a certain range ((t,u') in Fig. 3(b)), the manufacturer with multiple products can lower wholesale prices to restrain the platform seller from limiting the reviews' increased-sales effect on the incumbent.*

This proposition suggests that the manufacturer may cut the wholesale prices to induce the platform seller to choose RE-I, so their profits get the improvement. Wholesale prices thus serve not only to extract surplus from the platform seller, but also as means to control the platform seller's behavior toward RE-I. Fig. 5 illustrates the concept stated in Proposition 1. On the vertical axis, we have consumer valuation of the new product. The use of subscripts is consistent with those employed for the lines plotted in Fig. 3. On the horizontal axis, we have the change in profits, calculated from the benchmark situation of PE-P. The bottom panel studies the change in profits for a middle range of product differentiation, $t_2 \leq t < t_1$; a range for which in Fig. 3(b) we have seen there was no area C_3 where the manufacturer is unable to control the platform seller's behaviour via reduced wholesale prices. We note that for low values of consumer valuation of the new product, $u'_1 \leq u' < u'_2$ both the manufacturer and the platform seller gain from RE-I (where each term u' is shorter notation for $u'(t)$). On the other hand, for a higher range of consumer valuation $u'_2 \leq u' < u'_1$ the platform seller finds it not profitable to choose RE-I, as it would face negative profits (the dashed line would continue beyond zero). If the platform seller does not choose RE-I the change in profits for the manufacturer is zero (as the graph shows the difference in profits under RE-I and LRE-I). Here, the manufacturer has an incentive to give away part of its profits to direct the platform seller to choose RE-I and would be better off in that case. For this range of consumer valuation, both the manufacturer and the platform seller gain from RE-I. Similarly, the top panel studies the situation for larger values of product differentiation (softer competition), $t \geq t_3$. This range includes area C_3 in Fig. 3(b). For this new range of product differentiation we have an interesting range of consumer valuation, $u'_4(t) \leq u'(t) < u'_3(t)$, where the manufacturer finds it not optimal to incentivize RE-I and therefore the platform seller chooses LRE-I.

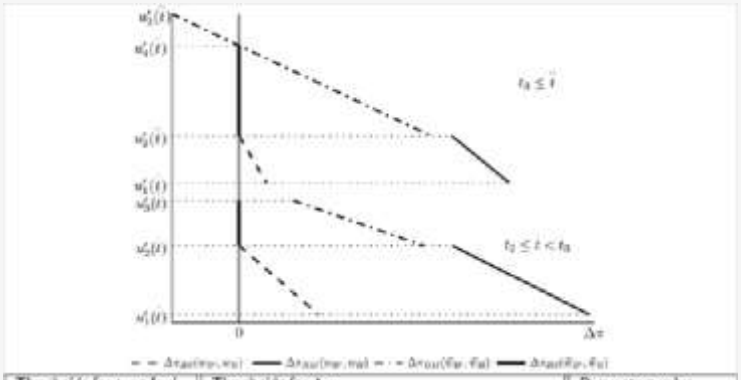
In the presence of RE-I, the cannibalization of the new product causes a loss to the platform seller, prompting it to select LRE-I. The manufacturer can counterbalance this loss by offering the platform seller more favourable wholesale prices, so as to change the platform seller's attitude towards RE-I. This strategy by the manufacturer only pays when the valuation of the new product (u) is not too large.

As can be seen in Fig. 5 when the valuation of the new product is within the ranges $u'_2(t) \leq u' < u'_3(t)$ or $u'_4(t) \leq u' < u'_4(t)$, the platform seller's profits in the presence of RE-I are lower than under LRE-I. However, the converse is not true for manufacturer B's profits, as it can extract more benefit from RE-I because of a larger demand and higher wholesale prices of the incumbent product. Because of the counterbalancing effect of wholesale prices, as u' increases in the presence of RE-I, manufacturer B's profits decrease more slowly than those of the platform seller. In addition, when the

differentiated products in the same market have their own competitive edges, the increased demand and wholesale prices of the incumbent product dominate manufacturer *B*'s profits in the presence of RE-I.

alt-text: Fig. 5

Fig. 5



Thresholds for t and u'	Thresholds for $\Delta\pi$	Parameters value
See Figure 3	$\pi_{BS}(w'_{b'}, w_b \mid v_b = v) - \pi_{BS}(w_{b'}, w_b \mid v_b^L = 0)$ $\pi_{BM}(w'_{b'}, w_b \mid v_b = v) - \pi_{BM}(w_{b'}, w_b \mid v_b^L = 0)$ $\pi_{BS}(\tilde{w}'_{b'}, \tilde{w}'_b \mid v_b = v) - \pi_{BS}(w_{b'}, w_b \mid v_b^L = 0)$ $\pi_{BM}(\tilde{w}'_{b'}, \tilde{w}'_b \mid v_b = v) - \pi_{BM}(w_{b'}, w_b \mid v_b^L = 0)$	$v = 0.1$ $u = 1$ $t = 0.3$ $\bar{t} = 1$

The effect of a reduction in wholesale prices on the platform seller's and manufacturer's profits.

Finally, attention should be paid to large consumer valuation of the new product (C_3 in Fig. 3(b)), $u'_4(\bar{t}) \le u'(\bar{t}) < u'_3(\bar{t})$. When u' rises to a sufficiently high level and t exceeds t_3, cannibalization becomes severe and the benefits of RE-I for channel *B* are dominated by the negative impact of cannibalization, in which case it is no longer optimal for the manufacturer to reduce the wholesale prices to direct the platform seller towards RE-I.

This section supports the manufacturer's compensation strategy by reducing the product line's wholesale prices to offset the platform seller's loss caused by the information-driven cannibalization, so the platform seller does not limit the increased-sales effect of reviews and both can gain the benefits.

4.3 Strategic manufacturer adjusts the new product quality to reverse the platform seller's LRE-I to RE-I

Manufacturers are keen to innovate the product to meet fragmented consumers and choose the new product quality. This section will discuss how the manufacturer controls the quality of the new product to affect the platform seller's consumer reviews strategy and improve their conditions. The platform seller chooses RE-I if the new product quality satisfies

$$\pi_{BS}(q_{b'} \mid RE-I) - \pi_{BS}(q_{b'} \mid LRE-I) = \frac{v_{b'}\left(69u - 138\theta_{b'}q_{b'} + 69q_{b'}^2 + 80t - 186v + 93v_b\right)}{1728t} \ge 0. \tag{9}$$

We first check the existence of a unique cut-off point of $q_{b'}$, that makes the platform seller BS decide to take RE-I or LRE-I strategy. The manufacturer's profit maximization problem is now constrained by the platform seller BS preferring RE-I to LRE-I:

$$\begin{aligned} &\max_{\tilde{w}'_{b'}} \Pi_{BM}(\tilde{w}'_{b'} \mid RE-I) = \left(w_{b'} - \frac{\tilde{w}'_{b'}}{2}\right) D_{b'} + \left(w_b - \frac{\tilde{w}'_b}{2}\right) D_b \\ &\text{s.t.} \frac{v_{b'}\left(69u - 138\theta_{b'}q_{b'} + 69q_{b'}^2 + 80t - 186v + 93v_b\right)}{1728t} \ge 0. \end{aligned} \tag{10}$$

We determine the equilibrium by solving manufacturer BM's trade-off between decreasing the quality of the new product and inducing the platform seller to support RE-I. When choosing to lower down the quality to encourage RE-I, manufacturer BM must guarantee no harm to its profits. In other words, manufacturer BM's profits must be higher than when LRE-I is selected: $\pi_{BM}(\tilde{q}'_{b'} \mid v_b - v) \ge \pi_{BM}(q_{b'} \mid v_b^L = 0)$.

Proposition 2 *With product differentiation and consumer valuation of the new product within a certain range, the manufacturer with multiple products choose a lower quality of the new product to restrain the platform seller from limiting the increased-sales effect of reviews on the incumbent product.*

Proposition 2 is driven by the following inequalities, where the new product quality is $\theta_{b'} < \frac{\sqrt{4761\theta_b^2 - 4761q_b^2 - 5520\theta + 6427v}}{69}$.

When $t > \frac{121v}{120}$ and $u_2' < u' < \min\left\{ u_3', u - \frac{40t}{11} - \frac{14v}{11} + \frac{\sqrt{[illegible]}}{253} \right\}$:

$$\pi_{MM}\left(\hat{q}_N \mid v_b = v\right) - \pi_{MM}\left(q_N \mid v_b = 0\right) > 0$$

$$\pi_{RR}\left(\hat{q}_N \mid v_b = v\right) - \pi_{RR}\left(q_N \mid v_b = 0,\right) \geq 0. \tag{11}$$

This proposition suggests the more innovation in a new product is not a good choice and causes the conflict between the manufacturer and the platform seller when consumers do not have a sufficiently high valuation of the new product. It makes the platform seller limit the increased-sales effect of reviews on the current product and the manufacturer cannot grab more surplus from the incumbent product. However, the reduction of the product quality by the manufacturer can coordinate the channel, as a means to control the platform seller's behaviour toward RE-I. This implicates that FMCG manufacturers should relatively reduce the quality investment of the new product to stimulate the sales-increased information from their platform sellers that increase their profits, when consumers' valuation of the new product is in the range above.

4.4 Manufacturer's optimal strategy on adjusting the quality or reduce wholesale prices

Propositions 1 and 2 are the results of the sequential choice of two alternative strategies that can affect the platform seller's attitude towards RE-I. We have studied the situation when the manufacturer can control wholesale prices. We have then consider that the manufacturer lowers down the quality of the new product. Now, we allow the manufacturer to adopt one of strategies.

Proposition 3 *When the platform seller differentiate the increased-sales effect of reviews for the product line that does harm the manufacturer's profit, the optimal strategy for the manufacturer to induce the platform seller's RE-I is:*

1) *The manufacturer does not lower down the quality of the new product and reduces the wholesale prices of the product line, in which case the platform seller selects RE-I if:* $u - 4t + \frac{713v}{225} + \sqrt{\frac{126736t^2}{4761} - \frac{166422288tv}{357075} + \frac{12030707772v^2}{53561250}} < u' < \min\{u_4', u_3'\}$
2) *The manufacturer lowers down the quality of the new product, in which case the platform seller chooses RE-I if* $u_2' < u' < \min\left\{ u_3', u - 4t + \frac{713v}{225} - \sqrt{\frac{126736t^2}{4761} - \frac{166422288tv}{357075} + \frac{12030707772v^2}{53561250}} \right\}$.

Proposition 3 gives conditions for *t* and u' where the manufacturer may either reduce wholesale prices and choose the higher quality design of the new product or lower down the quality of the new product. Then the platform seller chooses RE-I that improves their conditions. When u' is relatively high (sufficiently high), the manufacturer can decrease the wholesale prices to induce RE-I and set the higher quality of the new product, in others when consumers hav (relatively low e), the reduction u' of quality of the new product is preferred to wholesale prices to induce RE-I.

Now we explain the mechanism for which optimal strategy is. When the manufacturers choose a higher quality strategy, they needs to reduce the wholesale prices to motivate the platform sellers' RE-I strategy. On the one hand, they gain benefits from the higher quality design. On the other hand, they incur the additional cost for the compensation and the higher quality production cost. However manufacturers need not to reduce the wholesale prices and save some production cost in the lower quality strategy scenario. The higher valuation means consumers prefer to pay more for the same quality of the new product, compares with when they have low valuation. This higher quality strategy plays the dominant role (bring more income) when the market has high valuation for the new product and makes the manufacturers prefer higher quality strategy. When the valuation is relatively low, the higher quality strategy's income is not so high as in the scenario with higher consumers' valuation. Considering these savings and the market return of a higher quality investment is not so high, the manufacturers choose a lower quality strategy when consumers have a relatively valuation of the new product to coordinate the channel.

We have concluded the comprehensive effect of consumer reviews on the platform seller and his possible reviews strategy for the product line to pursue his optimal profit, causing the conflict with his manufacturer. By considering the manufacturer's leader role, we have presented two manufacturers' approaches to affect the platform seller's reviews strategy to coordinate the channel and show optimal situations for each strategy. Next, we will extend to study how the product differentiation change and the more intense competition from other brand affect the consumer reviews strategy.

5 Extensions

5.1 The effect of the product differentiation change on RE-I strategy

We have so far assumed that the products are located at an equal distance from one another. We now turn our attention to the case where the new product is more similar to the incumbent product than the competing product. This refinement makes obsolete the assumption of equidistance between product locations. To be able to capture the closeness in substitutability we introduce a new parameter $1 < \delta < \frac{3}{2}$, which defines how much closer or farther away the new product is to the incumbent product produced by the same manufacturer (inter-product distance).[10]

We have hitherto assumed the three products located at zero, two-third and one-third point of the unit circle. Now, we allow for the location of the upgraded product be fluctuated between zero and two-thirds (that is that the new iteration can be located closer or further from *B*'s incumbent product). A larger value of the parameter δ means that the differentiation gap between product *b* and b' reduces. The surplus of the Salop circular road plotted in Fig. 1 modifies to:

for a consumer located at $\frac{1}{3} < x \leq \frac{2}{3}$, the surplus remains unvaried:

$$\begin{aligned} V_b &= u + v_b - p_b - tx \\ V_a &= u + v_a - p_a - t\left(\tfrac{1}{3} - x\right), \end{aligned} \tag{12a}$$

whereas for a consumer located at $\frac{1}{3} < x \leq \frac{2}{3}$ the surplus is:

$$\begin{aligned} V_a &= u + v_a - p_a - t\left(x - \tfrac{1}{3}\right) \\ V_{b'} &= u' + v_{b'} - p_{b'} - t\left(\tfrac{2}{3}\delta - x\right), \end{aligned} \tag{12b}$$

and similarly for a consumer located at $\frac{2}{3} < x \leq 1$ is:

$$\begin{aligned} V_{b'} &= u' + v_{b'} - p_{b'} - t\left(x - \tfrac{2}{3}\delta\right) \\ V_b &= u + v_b - p_b - t(1 - x). \end{aligned} \tag{12c}$$

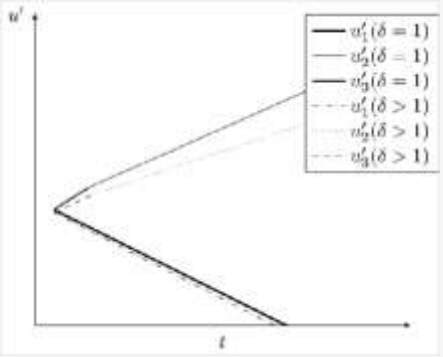
In the following proposition, we analyze the effect of product location on the retailer's review strategy.

Proposition 4 *A reduction in differentiation between the new and the incumbent product intensifies the cannibalization caused by RE-I and dampens the beneficial role of RE-I.*

Proposition 4 states that an increase in the similarity between new and incumbent products (rise in δ), narrows down the area where the platform seller benefits from RE-I (compare area encircled by a straight line with the area encircled by the dotted line in Fig. 6). In such case, the competition between the same brand products becomes intense, so the cannibalization problem caused by RE-I becomes more severe.

alt-text: Fig. 6

Fig. 6



Impact of closeness/remoteness of product differentiation on RE-I.

The section states that the change of differentiation between the products only affect the range of parameters and does not affect our findings. It supports the robustness of the product competition model in this paper by locating products at equidistant intervals along the unit circle.

5.2 Fierce competition from the opponent

So far, we have assumed that the two incumbent products controlled by the two manufacturers have the same competitive edge; that is, they are symmetric in quality valuation ($\theta_a q_a = \theta_b q_b = u$). Now, we remove symmetry and assume that product *a* has higher quality valuation than product *b*, $\theta_a q_a > \theta_b q_b$.

Proposition 5 *If the incumbent product of the single-product supply chain has significantly higher quality than that of the multi-product supply chain, then*

a) the platform seller BS *will not choose RE-I; no matter how high or low the quality evaluation of the new product is; and*

b) The manufacturer of product b' *never lower down the new product quality.*

This proposition suggests that when the competition from other brand is intense (consumers have sufficiently high valuation for product *a*), the platform sellers' optimal strategy is to limit RE-I, and the manufacturer launches the new product but does not adjust the quality or take any compensations. RE-I induces demand stealing, not only from manufacturer *A*'s incumbent product, but also from *B*'s own new product. When competition with product *a* is sufficiently high, the benefit of increased demand of *B*'s incumbent product that comes with RE-I is not sufficient to offset the loss caused by cannibalization on the new product margin. However, the benefit of increased demand of *B*'s new product with higher margin dominates the profit when the incumbent product of the single-product supply chain has significantly higher valuation by consumers than that of the multi-product supply chain.

This proposition strengthens the implication from our findings on balancing the positive or negative effect of consumer reviews. The reviews' increased-sales effect on the incumbent product (RE-I) becomes small, such as when the competition from another brand is highly intense. Still, it intensifies the competition to the new product. The negative effect of the information-driven cannibalization highly overrides the reviews' increased-sales effect. Therefore, both the manufacturer and the platform seller get hurt in the presence of RE-I.

6 Conclusions

It is widely agreed that apply online consumer reviews is the dominant market strategy to boost product sales. Interestingly, we have identified its negative effect on driving the intra-brand competition and how it leads the conflict between the platform seller and his manufacturer. We also have studied the possible compensation mechanism of the manufacturer through the balance of his product line's income and how his new product design affects the platform seller's consumer reviews strategy to coordinate the channel. We modelled a Stackelberg multi-stage non-cooperative sequential game, with particular focus on: (a) the increased-sales effect of consumer reviews on the product line controlled by the platform seller and (b) the wholesale prices and quality of a new product decided by the manufacturer. Our results add to the O2O supply chain literature and provide important insights for managerial decisions related to the compensation strategy and an alternative strategy affecting platform sellers' online reviews strategy to coordinate the FMCG O2O channel where the fast development of the new product and WOM are important for the success.

This study makes two significant theoretical implications. First, this paper sheds light on the cannibalization induced by the increased-sales effect of consumer reviews on the incumbent product. Our result brings new insights to the ever-growing literature on online reviews management and cannibalization. Specifically, it demonstrates that reviews' increased-sales effect on the incumbent product (RE-I) is not always beneficial for the platform sellers when consumers have sufficiently high valuation of the new product in the introduction of a new product to the market; this arguments that contradicts the assumed positive attitude that the platform sellers have on enabling the provision of consumer review. This is because RE-I produces cannibalization by increasing the platform sellers' profit of the incumbent product (positive effect) to the detriment of the profit of the new product (negative effect). Actually, RE-I damages the platform sellers and causes the conflict, because the manufacturers can at least partially pass on the harm to the platform sellers via higher wholesale prices to compete more benefits from the increased-sales effect of consumer reviews. Therefore, the platform sellers should limit RE-I when the negative effect of consumer reviews is dominant, even the manufacturers benefits from RE-I. Second, the past O2O supply chain literature has considered the conflict conditions where the market return cannot offset a high marketing investment but unfortunately ignores that the intra-brand competition intensified by sellers' online reviews strategy causes the conflict. We study this conflict and contribute to the literature in coordinating O2O supply chain by suggesting an alternative coordination strategy for the compensation mechanise, that is the reduction of the quality of the new product.

This study has important practical implications for the platform sellers and manufacturers in the decentralized FMCG O2O supply chain, where the manufacturers launch the new product and distribute products through the platform sellers. First, we have two suggestions for the platform sellers. (i) When consumers' valuation for the new product is not sufficiently high, the platform sellers apply the same consumer reviews strategy to the whole product line, bringing both optimal profits. (ii) when consumers' valuation for the new product is higher enough, the platform sellers should limit the reviews' increased-sales effect on the incumbent product to gain the optimal profit, but manufacturers does not. Second, we provide new insights for the manufacturers' strategies to coordinate the channel. (i) When consumers' valuation for the new product is relatively high (higher enough), the manufacturers should compensate the platform sellers by reducing the product line's wholesale prices and the platform sellers apply the same consumer reviews strategy for the product line. (ii) When consumers' valuation is relatively low (higher enough), the manufacturers should lower down the new product quality to stimulate the same consumer reviews strategy for the product line from the platform sellers.

Our findings point to several promising avenues for further research on managing consumer reviews in the FMCG O2O supply chain. It might be interesting, for example, to examine a similar case over two periods or to study the effects of other channel structure and competition on the optimal consumer reviews strategies. For instance, while in this paper we neglect another channel's response, this aspect could be addressed by modelling two channels' consumer reviews strategies for an incumbent and new product over two periods. Admittedly, any thorough analysis of these issues would be complicated. However, we hope that this paper has laid important groundwork for future research.

A Equilibrium outcomes

In this section, we derive the equilibrium outcomes of the benchmark model for the three-stage subgame: quality, wholesale prices and prices. In the paper we have assumed that a_H and a_M are fixed and showed in Lemma 1 that the

asymmetry in chain structure plays no role on the equilibrium qualities, as these are symmetric and their values are $\theta_a q_a = \theta_b q_b$, shortened to u.

The surplus for a consumer located at $x \leq \frac{1}{3}$ is given by:

$$V_A = u + v_b - p_b - tx$$

$$V_A = u + v_a - p_a - t\left(\frac{1}{3} - x\right).$$

The surplus for a consumer located at $\frac{1}{3} < x \leq \frac{2}{3}$ is given by:

$$V_A = u + v_a - p_a - t\left(x - \frac{1}{3}\right)$$

$$V_B = \theta_b q_b + v_b - p_{b'} - t\left(\frac{2}{3} - x\right),$$

and the surplus for a consumer located at $\frac{2}{3} < x \leq 1$ is expressed as:

$$V_B = \theta_b q_b + v_b - p_{b'} - t\left(x - \frac{2}{3}\right)$$

$$V_A = u + v_b - p_b - t(1 - x).$$

By setting $u + v_b - p_b - tx = u + v_a - p_a - t\left(\frac{1}{3} - x\right)$ and $\theta_{b'} q_{b'} + v_{b'} - p_{b'} - t\left(x - \frac{2}{3}\right) = u + v_b - p_b - t(1 - x)$, we get the demand for product *b*

$$D_b = \frac{3u + 6v_b - 3v_a - 6p_b + 3p_a + 2t - 3\theta_{b'} q_{b'} + 3p_{b'}}{6t}.$$

By setting $u + v_b - p_b - tx = u - p_a - t\left(\frac{1}{3} - x\right)$ and $u + v_a - p_a - t\left(x - \frac{1}{3}\right) = \theta_{b'} q_{b'} + v_a' - p_{b'} - t\left(\frac{2}{3} - x\right)$, we obtain the demand for product *A*,

$$D_a = \frac{3u - 6p_a + 2t - 3\theta_{b'} q_{b'} + 3p_{b'} + 6v_a - 3v_{b'} - 3p_b}{6t}.$$

Finally, by imposing $\theta_{b'} q_{b'} + v_{b'} - p_{b'} - t\left(\frac{2}{3} - x\right) = u + v_a - p_a - t\left(x - \frac{1}{3}\right)$ and $\theta_{b'} q_{b'} + v_{b'} - p_{b'} - t\left(x - \frac{2}{3}\right) = u + u_b - p_b - t(1 - x)$, we recover the demand for the new product,

$$D_{b'} = \frac{-6u + 3p_a + 2t + 6\theta_{b'} q_{b'} - 3v_b + 6v_{b'} - 3v_a + 3p_b - 6p_{b'}}{6t}.$$

Plugging D_a, D_b, $D_{b'}$ into $\pi_{AM} = p_a D_a - \frac{q_a^2}{2}$, $\pi_{BR} = (p_b - w_b) D_b + (p_{b'} - w_{b'}) D_{b'}$ and solving the first-order condition, yields to the subgame perfect equilibrium prices p_a, p_b, $p_{b'}$

$$p_a = \frac{u}{6} - \frac{v_b}{6} + \frac{v_a}{3} - \frac{v_{b'}}{6} + \frac{4t}{9} - \frac{\theta_{b'} q_{b'}}{6} + \frac{w_b}{6} + \frac{w_{b'}}{6}$$

$$p_b = \frac{u}{12} + \frac{5v_b}{12} - \frac{v_a}{3} - \frac{v_{b'}}{12} + \frac{5t}{9} - \frac{\theta_{b'} q_{b'}}{12} + \frac{7w_b}{12} + \frac{w_{b'}}{12}$$

$$p_{b'} = -\frac{5u}{12} - \frac{v_b}{12} - \frac{v_a}{3} + \frac{5v_{b'}}{12} + \frac{5t}{9} + \frac{5\theta_{b'} q_{b'}}{12} + \frac{w_b}{12} + \frac{7w_{b'}}{12}.$$

Subsequently, by substituting p_a, p_b, $p_{b'}$ into D_a, D_b, $D_{b'}$, and plugging these into $\pi_{BM} = \left(w_b - \frac{q_b^2}{2}\right) D_b + \left(w_{b'} - \frac{q_{b'}^2}{2}\right) D_{b'}$, after applying first order conditions (FOCs) to it with respect to w_b and $w_{b'}$, we obtain:

$$w_{b'} = \frac{3u'}{4} + \frac{5t}{6} - \frac{v_a}{2} + \frac{v_{b'}}{2} - \frac{u}{4}$$

$$w_b = \frac{5t}{6} + \frac{v_b}{2} - \frac{v_a}{2} + \frac{u}{2}.$$

Now, we explain how the manufacturer B decides the quality level of the new product. Moorthy (Sridhar Moorthy, 1984) and Desai (Preyas, 2001) describe that the efficient quality for consumers is the quality that maximizes the difference between a consumer's valuation and the firm's marginal cost of quality. In this paper, the difference between a consumer's valuation and the firm's marginal cost of quality is ($\theta_b q_{b'} - 1/2 q_{b'}^2$), so the optimal quality level is $q_{b'} = \theta_{b'}$.

It is also possible to retrieve the same results by substituting w_b, $w_{b'}$ and , D_a into D_b $D_{b'}$ $\pi_{BM} = \left(w_b - \frac{q_b^2}{2}\right) D_b + \left(w_{b'} - \frac{q_{b'}^2}{2}\right) D_{b'}$ and then taking the FOC with respect to $q_{b'}$ and we get $q_{b'} = \theta_{b'}$.

The equilibrium outcomes are based on $q_{b'} = \theta_{b'}$ and we denote with u' the interaction $\theta_{b'} q_{b'} = \theta_{b'}^2$:

$$p_a = \frac{v_a}{6} - \frac{v_{b'}}{12} - \frac{v_b}{12} + \frac{13t}{18} - \frac{u'}{24} + \frac{13u}{24}$$

$$p_b = \frac{25u}{48} + \frac{17v_b}{24} - \frac{v_{b'}}{24} - \frac{2v_a}{3} - \frac{u'}{48} + \frac{10t}{9}$$

$$p_{b'} = \frac{41u'}{48} - \frac{17u}{48} - \frac{v_b}{24} - \frac{2v_a}{3} + \frac{17v_{b'}}{24} + \frac{13t}{9}$$

$$w_{b'} = \frac{3u'}{4} + \frac{5t}{6} - \frac{v_a}{2} + \frac{v_{b'}}{2} - \frac{u}{4}$$

$$w_b = \frac{5t}{6} + \frac{v_b}{2} - \frac{v_a}{2} + \frac{u}{2}.$$

These solutions are for the benchmark scenario where the platform seller B selects RE-I strategy and channel A promotes its product a. To simplify the model, we assume that $\{v_a, v_{b'}, v_a\} = v$ in the benchmark scenario and the analysis that follows is based on this assumption. As we aim to study the effect of RE-I, we also need to get the solutions in the case where the platform seller chooses to limit RE-I. In such case, $\{v_{b'}, v_a\} > v_b^L$, and in addition we assume that $\{v_{b'}, v_a\} - v > v_b^L - 0$. Similar to the benchmark model, we can get the equilibrium outcomes when the platform seller B limits the promotion of information about product b by setting $v_b^L = 0$. To shield against nonnegative demands in equilibrium in the two instances when the platform seller B chooses $v_b = v$ or $v_b^L = 0$, we enforce the following inequality: u' must satisfy $\max\left\{v - \frac{40v}{33}, 0\right\} < u' \le v - \frac{32v}{7} + \frac{40t}{21}$. It is deliberately assumed that $t > \frac{121}{120} v$ to ensure that the interval of this equation is well behaved.

B Proofs

Proof of Lemma 1 We study the initial situation when the two manufacturers consider producing and selling their initial products, a and b. Prior to that decision, they select the quality of the product and face cost $\frac{q^2}{2}$ to produce quality q. The profit functions are given by:

$$\pi_{AM} = \left(p_a - \frac{q_a^2}{2}\right) D_a$$

$$\pi_{BR} = (p_b - w_b) D_b$$

$$\pi_{BM} = \left(w_b - \frac{q_b^2}{2}\right) D_b,$$

We obtain the demand for product a and product b from the surplus function under the demands:

$$D_a = \frac{t - \theta_a q_a + p_b + \theta_a q_a - p_a}{2t}, \tag{13}$$

$$D_b = \frac{\theta_b q_b - p_b + t - \theta_a q_a + p_a}{2t}, \tag{14}$$

We model the two manufacturers' (AM, BM) and the platform seller's (BS) decisions as a three-stage game. In stage 1, manufacturer A and manufacturer B respectively decide on the quality of products a and b. The wholesale price (w_b) for product b is set in stage 2 by manufacturer B. In stage 3, the platform seller B and manufacturer A decide the prices for the two products (p_a, p_b). The solution for the equilibrium quality is: $q_b = \theta_b$ and $q_a = \theta_a$, which implies that Lemma 1 is proven in the symmetric case $\theta_b = \theta_a$. For the optimal quality of products a and b we replace with $\theta_b, \theta_a = \theta$ and label with $u \equiv \theta^2$ the valuation for that quality.

Proof of Theorem 1a By setting $v_b = v$ in the benchmark model and $v_b^L = 0$ in the case of LRE-I, we can compare the two profits π_{BM} and π_{BM}^L. The difference in profit is $\pi_{BM}(v_b = v) - \pi_{BM}(v_b^L = 0) = \frac{v(-21u' + 40v + 33v + 21u)}{288t}$. We infer the indifference threshold $u'_{BM} = u - \frac{11v}{7} + \frac{40v}{21}$, below which the manufacturer benefits from RE-I. We have thatif $u' > u - \frac{11v}{7} + \frac{40v}{21}$, $\pi_{BM}(v_b = v) - \pi_{BM}(v_b^L = 0) < 0$ if $u' \le u - \frac{11v}{7} + \frac{40v}{21}$, $\pi_{BM}(v_b = v) - \pi_{BM}(v_b^L = 0) \ge 0$ u' and t must satisfy $\max\left\{u - \frac{40v}{33}, 0\right\} \le u' < u - \frac{22v}{7} + \frac{40v}{21}$ and $t > \frac{121}{120}v$.As $u - \frac{11v}{7} + \frac{40v}{21} > u - \frac{22v}{7} + \frac{40v}{21}$, when u' satisfies $\max\left\{u - \frac{40v}{33}, 0\right\} < u' \le u - \frac{22v}{7} + \frac{40v}{21}$ and $t > \frac{121}{120}v$, $\pi_{BM}(v_b = v) - \pi_{BM}(v_b^L = 0) > 0$.

Proof of Theorem 1b Similar to Theorem 1a, we compare the two cases π_{BR} and π_{BR}^L and get $\pi_{BR}(v_b = v) - \pi_{BR}(v_b^L = 0) = \frac{v(81v - 93v + 80v - 93u')}{720t}$. We infer the indifference threshold $u'_{BR} = u - \frac{31v}{23} + \frac{80v}{69}$, beyond which the platform seller does not benefit from RE-I.if $u' > u - \frac{31v}{23} + \frac{80v}{69}$, $\pi_{BR}(v_b = v) - \pi_{BR}(v_b^L = 0) < 0$ if $u' \le u - \frac{31v}{23} + \frac{80v}{69}$, $\pi_{BR}(v_b = v) - \pi_{BR}(v_b^L = 0) \ge 0$, By comparing $u - \frac{31v}{23} + \frac{80v}{69}$ with $\max\left\{u - \frac{40v}{33}, 0\right\}$ and $u - \frac{22v}{7} + \frac{40v}{21}$, we can get Theorem 1b.

Lemma 2 *After plugging the demands* D_a, D_b, $D_{b'}$ *into* $\pi_{AM} = \left(p_a - \frac{q_a^2}{2}\right) D_a$, *and* $\pi_{BR} = (p_b - w_b) D_b + (p_{b'} - w_{b'}) D_{b'}$, *we solve the first-order conditions for* p_a, p_b, $p_{b'}$, $p_a, p_b, p_{b'}$ *and derive the subgame optimal demands given* $w_b, w_{b'}$. *We keep* v_b *in these solutions, so that we can easily compare* $\pi_{BR}(w_{b'}, w_b)$ *with* $\pi_{BR}^L(w_{b'}, w_b)$:

$$
\begin{aligned}
p_a &= \frac{t}{4} + \frac{5v_b}{12} - \frac{5v_{b'}}{12} + \frac{5u'}{9} - \frac{u'}{12} + \frac{5w_b}{12} + \frac{w_{b'}}{12} \\
p_{b'} &= -\frac{v}{4} - \frac{v_b}{12} + \frac{v}{12} + \frac{5t}{9} + \frac{5u'}{12} + \frac{w_b}{12} + \frac{5w_{b'}}{12} \\
D_a &= \frac{27u + 33v_b - 33v - 21u' - 33w_b + 21v + 21w_{b'}}{72t} \\
D_{b'} &= \frac{-27v - 21v_b + 21v + 33u' - 33w_{b'} + 21v + 21w_b}{72t}.
\end{aligned}
$$

Comparing *with* *where* *, we demonstrate that the platform seller does not limit RE-I* $\pi_{BR}(w_{b'}, w_b)$ $\pi_{BR}^L(w_{b'}, w_b)$ $v_b^L = 0$ $\hat{w}_{b'}$ $\hat{w}_b$ $\pi_{BR}(\hat{w}_{b'}, \hat{w}_b) - \pi_{BR}^L(w_{b'}, w_b)$ *conditional on the manufacturer charging wholesale prices* *and* *, so.* =

$$\frac{v(138w_{b'} + 93v_b - 186v - 186w_b + 162u + 80t - 138u')}{432t} \ge 0.$$

Proof of Proposition 1We add the constraint $\frac{v(138w_{b'} + 93v_b - 186v - 186w_b + 162u + 80t - 138u')}{432t} > 0$ into $\pi_{BR} = \left(w_b - \frac{q_b^2}{2}\right) D_b + \left(w_{b'} - \frac{q_{b'}^2}{2}\right) D_{b'}$. The Lagrangian for the manufacturer's problem is

$$\max\Pi(\hat{w}_{b'}, \hat{w}_b, \lambda) = \left(\hat{w}_b - \frac{q_b^2}{2}\right) D_b + \left(\hat{w}_{b'} - \frac{q_{b'}^2}{2}\right) D_{b'} + \lambda\left\{138w_{b'} + 93v_b - 186v - 186w_b + 162u + 80t - 138u'\right\},$$

and the Kühn-Tucker conditions for optimality are:

$$\frac{\partial\Pi(\hat{w}_{b'}, \hat{w}_b, \lambda)}{\partial\hat{w}_{b'}} = \frac{33u' + 20t - 27u + 21\hat{w}_b - 33\hat{w}_{b'} - 21v_b + 21v}{72t} - \frac{11\left(\hat{w}_{b'} - \frac{q_{b'}^2}{2}\right)}{24t} + \frac{7\hat{w}_b - \frac{q_b^2}{2}}{24t} + 138\lambda$$

$$\frac{\partial\Pi(\hat{w}_{b'}, \hat{w}_b, \lambda)}{\partial\hat{w}_b} = -\frac{21u' - 20t - 27u + 33\hat{w}_b - 21\hat{w}_{b'} - 33v_b + 33v}{72t} + \frac{7\left(\hat{w}_{b'} - \frac{q_{b'}^2}{2}\right)}{24t} - \frac{11\hat{w}_b - \frac{q_b^2}{2}}{24t} - 186\lambda$$

$$\frac{\partial\Pi(\hat{w}_{b'}, \hat{w}_b, \lambda)}{\partial\lambda} = 138w_{b'} + 93v_b - 186v - 186w_b + 162u + 80t - 138u'.$$

Because $\hat{w}_{b'} > 0$ and $\hat{w}_b > 0$, we have:

$$
\begin{aligned}
\hat{w}_b &= \frac{545t}{534} + \frac{421v}{712} - \frac{115u'}{356} + \frac{v_b}{2} - \frac{333v}{356} + \frac{11q_{b'}^2}{712} \\
\hat{w}_{b'} &= \frac{425t}{534} - \frac{203v}{712} + \frac{201u'}{356} + \frac{158q_{b'}^2}{713} - \frac{31v}{356}.
\end{aligned}
$$

In addition, we have the equilibrium solution $q_{b'} = \theta_{b'}$. To make sure that the manufacturer is willing to reduce the wholesale prices to induce the platform seller not to limit RE-I it must be that his profit in the case of RE-I is not less

$$\pi_{BM}(\hat{w}_{b'}, \hat{w}_b | v_b = v) \ge \pi_{BM}(w_{b'}, w_b | v_b^L = 0$$

than in the case of LRE-I:). Comparing $\pi_{MM}(\hat{w}_{y'}, \hat{w}_{v_b} | v_b = v)$ with , we get

$$= \frac{4761u'^2 - 6u'(1840t + 1587u - 4812v) + 4(69u + 80t)^2 - 36v(203v + 807u + 1400t)}{-307584t}.$$

The solutions of u' from the above equation are

$$\hat{u}_1' = u - \frac{2672v}{529} + \frac{80t}{69} + \frac{4\sqrt{89v(2131v + 690t)}}{529}.$$

and

$$\hat{u}_2' = u - \frac{2672v}{529} + \frac{80t}{69} - \frac{4\sqrt{89v(2131v + 690t)}}{529}.$$

So if $\hat{u}_1' \geq u' > \hat{u}_2'$,

$$\pi_{BM}\left(\hat{w}_{b'}, \hat{w}_b \middle| v_b = v\right) \geq \pi_{BM}\left(w_{b'}, w_b \middle| v_b^L = 0\right)$$

If the inequalities $t > \frac{289}{120}v$ and $u - \frac{22v}{7} + \frac{40t}{21} \geq u' > u - \frac{31v}{23} + \frac{80t}{69}$ hold, the platform seller can limit RE-I when his profit gets hurt by PE-P, i.e. when $\pi_{BR}\left(\hat{w}_{b'}, \hat{w}_b \middle| v_b = v\right) - \pi_{BR}\left(w_{b'}, w_b \middle| v_b^L = 0\right) < 0$.By comparing $\hat{u}_1'$ and $\hat{u}_2'$, with $u - \frac{22v}{7} + \frac{40t}{21}$ and $u - \frac{31v}{23} + \frac{80t}{69}$, we have that if $t > \frac{289v}{120}$ and $u - \frac{31v}{23} + \frac{80t}{69} < u' \leq \min\left\{u - \frac{22v}{7} + \frac{40t}{21}, \hat{u}_1'\right\}$, the manufacturer can reduce the wholesale prices to $\hat{w}_{b'}, \hat{w}_b$ so as to induce the platform seller not to limit RE-I: $\pi_{BM}\left(\hat{w}_{b'}, \hat{w}_b \middle| v_b = v\right) \geq \pi_{BM}\left(w_{b'}, w_b \middle| v_b^L = 0\right)$ and promise in return $\pi_{BR}\left(\hat{w}_{b'}, \hat{w}_b \middle| v_b = v\right) \geq \pi_{BR}\left(w_{b'}, w_b \middle| v_b^L = 0\right)$. Proposition 1 is proven.

Proof of Proposition 2 We add the constraint $\frac{v_{b}\left(69u - 138\theta_{b'}q_{b'} + 69q_{b'}^2 + 80t - 186v + 93v_c\right)}{1728t} > 0$ into $\pi_{BM} = \left(w_b - \frac{q_b^2}{2}\right)D_b + \left(w_{b'} - \frac{q_{b'}^2}{2}\right)D_{b'}$. The Lagrangian for the manufacturer's problem is $\max \Pi\left(\hat{q}_{b'}, \lambda\right) = \left(w_b - \frac{q_b^2}{2}\right)D_b + \left(w_{b'} - \frac{q_{b'}^2}{2}\right)D_{b'} + \lambda\left(69u - 138\theta_{b'}q_{b'} + 69q_{b'}^2 + 80t - 186v + 93v_c\right)$.From the Equilibrium outcomes, we have w_b, $w_{b'}$, D_b and $D_{b'}$. Similar to Proof of Proposition 1, we can obtain:

$$q_{b'} = \theta_{b'} - \frac{\sqrt{4761\theta_{b'}^2 - 4761q_b^2 - 5520t + 6471v}}{69}.$$

By comparing $\pi_{BM}\left(v_b = v, \widehat{q_{b'}}\right)$ (the scenario with the limitation of new product quality and RE-I) with $\pi_{BM}\left(v_b^L = 0, q_{b'}\right)$ (the scenario of no limitation on quality decision and LRE-I) we get:

$$\Delta\pi_{BM}^{II} = \pi_{BM}\left(v_b = v, \widehat{q_{b'}}\right) - \pi_{BM}\left(v_b^L = 0, q_{b'}\right) =$$

$$\frac{-11u'^2}{384t} + \frac{3174u'(33u - 40t - 42v)}{576t} - \frac{11u^2}{384t} + \frac{u(20t + 21v)}{288t} + \frac{1700t}{14283} - \frac{1685v}{38088} - \frac{4235v^2}{67712t}.$$

There are two solutions $(u_1'^{**}, u_2'^{**})$ that satisfy $\Delta\pi_{BM}^{II} = 0$: $u_1'^{**} = u - \frac{40t}{33} - \frac{14v}{11} + \frac{\sqrt{38000t^2 + 98640tv - 36071v^2}}{253}$, $u_2'^{**} = u - \frac{40t}{33} - \frac{14v}{11} - \frac{\sqrt{38000t^2 + 98640tv - 36071v^2}}{253}$By comparing them with u_2' and u_3', we can get:When $t > \frac{121v}{120}$ and $u_2' < u' < \min\left\{u_3', u - \frac{40t}{33} - \frac{14t}{11} + \frac{\sqrt{38000t^2 + 98640tv - 36071v^2}}{253}\right\}$:

$$\begin{aligned} &\pi_{BM}\left(\hat{q}_{b'} \middle| v_b = v\right) - \pi_{BM}\left(q_{b'} \middle| v_b = 0\right) > 0 \\ &\pi_{BR}\left(\hat{q}_{b'} \middle| v_b = v\right) - \pi_{BR}\left(q_{b'} \middle| v_b = 0,\right) \geq 0. \end{aligned} \quad (15)$$

Thus Proposition 2 is proven.

Proof of Proposition 3 Subtracting $\pi_{BM}\left(\hat{w}_{b'}, \hat{w}_b \middle| v_b = v\right)$ (the scenario discounting wholesale prices and RE-I) from $\pi_{BM}\left(\widehat{q_{b'}} \middle| v_b = v\right)$ (the quality limitation scenario and RE-I), we get: $\Delta\pi_{BM}^{I} =$

$$\frac{75u'}{5696t} - \frac{u'(225u - 900t + 713v)}{8544t} + \frac{75u}{5696t} - \frac{u(900t - 713v)}{8544t} - \frac{3(1516800800tv - 3036016tv + 1784577v^2)}{54237312t}.$$

Similar to Proposition 2, there are two solutions (here denoted $u_1'^{*}, u_2'^{*}$) that satisfy $\Delta\pi_{BM}^{I} = 0$.

$$u_1'^{*} = u - 4t + \frac{713v}{225} + \sqrt{\frac{126736t^2}{4761} - \frac{16642288tv}{357075} + \frac{1207070777v^2}{53561250}},$$

$$u_2'^{*} = u - 4t + \frac{713v}{225} - \sqrt{\frac{126736t^2}{4761} - \frac{16642288tv}{357075} + \frac{1207070777v^2}{53561250}}.$$

By comparing them with u_2' and u_3' u_4', we can get Proposition 3.

Proof of Proposition 4 Following the logic of Section A, we get the equilibrium solutions when the location of the upgraded product is fluctuant:

$$
\begin{aligned}
p_{a'} &= \frac{u}{12} - \frac{v_a}{12} + \frac{v_b}{12} + \frac{\theta_1}{18} + \frac{2t}{3} + \frac{u'}{24} - \frac{u'}{12}\\
p_{a''} &= \frac{u}{24} + \frac{17v_a}{24} - \frac{17v_b}{24} - \frac{17t}{24} - \frac{u'}{24} + \frac{u'}{48} - \frac{11\theta_1}{36} + \frac{17t}{12}\\
p_{b'} &= \frac{17u'}{24} + \frac{7u'}{48} - \frac{v_a}{24} + \frac{v_b}{24} - \frac{17u}{24} - \frac{5\theta_1}{36} + \frac{5t}{4}\\
w_{a'} &= \frac{u}{36} + \frac{v_a}{18} - \frac{v_b}{18} - \frac{\theta_1}{9} - \frac{t}{4}\\
w_{b'} &= \frac{17u}{36} - \frac{2\theta_1}{9} + \frac{v_a}{18} - \frac{v_b}{18} + \frac{t}{4}.\\
D_{a'} &= \frac{42u+66v_a-42u'-66v+160t-20\theta_1+21u'}{2880}\\
D_{a''} &= \frac{-33u-42v_a+42v_b+18v+44\theta_1-33u'}{1080}.
\end{aligned}
$$

It is easy to derive $u_i'(\theta_1>1, i=1,2,3$ similarly to what we have done in the previous analysis–thus Proposition 4 is proven.

Proof of Proposition 5 When $u_a=q_a\theta_a>u_b=q_b\theta_b$, we get

$$\pi_{BR}(v_b>0)-\pi_{BM}(v_b'=0)=\frac{v_b(-24u_a-93v_b+80t-69u'-93v)}{1728t}$$

$$\pi_{BM}(\hat{q}=q_{b'})-\pi_{BM}(\hat{q}=\alpha q_{b'})=\frac{\alpha'(1-\alpha)(1+\alpha)(33\alpha^2u'+33u'-24u_a-42v_b+80t-132v)}{1152t}.$$

Q4 From the first equation, if u_a is sufficiently high ($q_a\theta_a=u_a>\frac{93v_b-93v-69u'+80t}{24}$), $\pi_{BM}(v_b>0)-\pi_{BM}(v_b=0)<0$.For the second equation, we assume consumers have higher quality evaluation for the new product than the incumbent products in the paper: $u'>\alpha^2u'>u_a+v, u_b+v$, it means consumers have higher valuation for the new product even there is only partial technical information of new product available (α is sufficiently high in our paper), i.e., they have a taste for novelty, if product a has higher quality valuation than product b and becomes sufficiently high, u_a+v approaches α^2u', from the second equation, we use u_a+v to replace u' and α^2u', then get $\pi_{BM}(\hat{q}=q_{b'})-\pi_{BM}(\hat{q}=\alpha q_{b'})>\frac{u'(1-\alpha)(1+\alpha)(33(u_a+v)+33(u_a+v)-24u_a-42v_b+80t-132v)}{1152t}=\frac{u'(1-\alpha)(1+\alpha)(42u_a-42v_b+80t-66v)}{1152t}$, as $u_a>u_b$, $t>\frac{121v}{120}$ $\pi_{BM}(\hat{q}=q_{b'})-\pi_{BM}(\hat{q}=\alpha q_{b'})>0$. Thus Proposition 5 is proven.

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Footnotes

Text Footnotes

[1] https://www.kantarworldpanel.com/cn-en/news/E-commerce-and-O2O-fueled-FMCG's-recovery-in-China.

[2] https://zhuanlan.zhihu.com/p/135849914.

[3] This strategy can be carried out by controlling the volume of reviews, the response to reviews and other actions that facilitate the number of reviews or positive content.

[4]

This assumption also allows us to focus on the vertical competition between the manufacturer and the platform seller, rather than analyzing the other channel's response. Our analysis results are applicable to a non-integrated seller of multiple horizontally differentiated products able to apply consumer reviews about these products to consumers.

[5] We assume that demand for a product does not decay over time. This assumption is chosen to rule out any dynamic strategic behaviour by consumers and firms. This is a common view of FMCG products, because it is fast consumption withhigh repeated purchase frequency. In this study, we concentrate on the time-period where the two products, incumbent and new, overlap in the market.

[6] This specification of the consumer surplus function is similar to that used by Viswanathan (2005), Shulman et al. ([Instruction: Please update Shulman et al. to ShulmanAnne and Savaskan (2011). Thanks]ShulmanAnne and Savaskan, 2011), and Shulman (2013). For instance, Shulman et al. ([Instruction: Please update to ShulmanAnne and Savaskan (2011). Thanks.]ShulmanAnne and Savaskan, 2011) suggest that the modelling structure of holding the locations of a firm's products constant in a competitive setting guarantees that the results are robust enough to the point that the firm might relocate their products when facing competition.

[7] The order of manufacturer's and the platform seller's decisions can be swapped without altering the main message from the game.

[8] This paper analyses the interaction between the platform seller BS and manufacturer BM. In the rest of the paper when the manufacturer and the platform seller are unspecified, the titles refer to the manufacturer and the platform seller of the multiple-product channel *B*.

[A decomposition of the marginal profit may guide our understanding of the effect of RE-I:

$$\frac{d\pi_{BM}}{dw_b} + \frac{d\pi_{BM}}{dw_b} = \left(\frac{dw_b}{dw_b}D_b + \frac{dD_b}{dw_b}w_b\right) + \left(\frac{dw_{b'}}{dw_b}D_{b'} + \frac{dD_{b'}}{dw_b}w_{b'}\right) = \left(\frac{1}{2}D_b + \frac{11}{48}w_b\right) + \left(0D_{b'} - \frac{7}{48}w_{b'}\right) \quad (6a)$$

$$\frac{d\pi_{BS}}{dw_b} + \frac{d\pi_{BS}}{dw_b} = \left(\frac{dw_b - w_b}{dw_b}D_b + \frac{dD_b}{dw_b}(p_b - w_b)\right) + \left(\frac{d(p_{b'} - w_{b'})}{dw_b}D_{b'} + \frac{dD_{b'}}{dw_b}(p_{b'} - w_{b'})\right) = \left(\frac{1}{24}D_b + \frac{11}{48}(p_b - w_b)\right) + \left(-\frac{1}{24}D_{b'} - \frac{7}{48}(p_{b'} - w_{b'})\right) = \left[\frac{1}{24}(5D_b - D_{b'})\right] + \left[\frac{1}{48}(11(A$$

(6b)For the platform seller BS, more intense competition from PE-P causes a drop in profit from the new product by $\frac{v_b}{24}$, which is offset by an increase in profit from the incumbent product by $\frac{5v_b}{24}$ (Equation 6b). Instead, for manufacturer BM, RE-I has no influence on the profit from the new product and the positive impact on the profit from the incumbent product exceeds that of the platform seller (Equation 6a). Therefore, the manufacturer takes greater advantage from RE-I, and this justifies area $C_{2,3}$ in Fig. 3.

9[Instruction: Please separate this equation (6b) into two parts to show the hiding part.]

]

[10] When $\delta \to \frac{3}{2}$ the new product can be seen as an iteration of an existing product, in which case the new product is of higher quality than the existing one but in terms of horizontal product differentiation is very similar.

Queries and Answers

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