Information Strategies of new Product Introduction in Vertical Markets

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1. Introduction

A substantial body of empirical and theoretical evidence has highlighted the importance of *online consumer reviews* for consumers and firms as a key source for product information. While the effect on consumers (the demand side of the market) has been the focus of many studies in the literature (see Wu et al. 2015 for a review), the repercussions on the supply side (e.g., competition between firms), are under-researched.

An increasingly dominant market strategy for retailers to boost sales is to make online consumer reviews available on their websites (Chevalier and Mayzlin 2006, Chintagunta et al. 2010). Meta-analytic evidence suggests that the number and rating of online reviews (volume and valence) exhibit significant positive sales elasticities (Floyd et al. 2014, You et al. 2015). The accepted view is that online reviews affect firms' profits positively. But is this always true? In the context of a new product introduction in a vertical market, are reviews beneficial for both retailers and manufacturers? The answer to this question is the core of this research.

As no reviews are typically available when a new product enters a market or if there are, they are limited, there is a lack of information about the new product quality provided from the consumer side. Manufacturers can adjust their advertising mix and get around this deficiency by releasing *technical information* about the product quality (e.g., the result of testing units or detailed product specifications), but as we are going to show, this may be counterproductive. In this work, we are keen to understand how the individual and joint effects of these two information sources (online reviews and technical specifications) influence the relationship between manufacturers and retailers in vertical markets.

The first source of information is product reviews and ratings (hereafter shortened as PRRs), which corresponds to the availability of information related to a product's perceived quality (post-purchase), encompassing consumer-sourced information (star ratings and their corresponding textual justification). Its availability is typically controlled by the retailer and is integrated into the purchase process, by making it available to consumers for browsing and reading before their purchase. PRRs are complemented by a second flow of information, which is under the control of the manufacturer and consists of product related technical information that describes product quality. Technical information can be provided either through advertising, availability of testing devices to opinion leaders (e.g., journalists) before release, and/or additional material through manufacturers' websites (e.g., videos or product manuals). While in several regulatory regimes manufacturers must disclose some level of technical information for getting market approval,[1] the release of additional information about product attributes and features is at their discretion (Mazis et al. 1981).

The joint impact of these two sources of information becomes evident when one considers entry of a new product in the market (Fishman and Hagerty 2003), as no reviews are available or review volume is not sufficiently high. The limited number of reviews may not be reliable because of possible bias induced by consumer self-selection in writing the reviews. Over time the bias tends to disappear as more reviews are written, giving formation to review valence (Li and Hitt 2008, Moe and Schweidel 2012). In the case when products have similar rating distributions or when ratings are not available, consumers tend to rely on other sources of information, such as product technical specifications. This is reflected in a worldwide industry survey from SocialMediaLink,[2] which suggests that the influence of product attributes on consumer valuation of product fit is higher than that of star ratings obtained from consumer reviews.

An argument that is often used in favor of online reviews is that those impact on product choice via a reduction of consumer uncertainty. This argument becomes even more important in our age of hyper-differentiation where multiple generations of the same products co-exist in the market to satisfy ever-changing consumer preferences (or to create those). While recent research has advanced our understanding of the impact of PRRs and product technical information on sales (Babic et al. 2016), such studies ignore the effect of previous generation product PRRs on the sales of differentiated products entering the market.[3]

A consistent body of studies on product line design addresses cannibalization between low quality and high quality products (e.g., Moorthy 1984, Desai 2001, Pedram and Balachander 2014, Joshi et al. 2015). However, to the best of our knowledge no study has

[1] E.g., the Federal Communications Commission (FCC) requirements for market access authorization forces manufacturers to provide a full disclosure of the technical characteristics of the device that are indicative of performance (e.g., screen size, battery life, processor speed, RAM size etc.).

[2] SocialMediaLink (2015): Leading factors making an online review or a recommendation influential according to social media users worldwide in 2014. Retrieved November 15, 2016, from https://www.statista.com/statistics/431829/leading-attributes-of-an-influential-online-review/.

[3] For example, after the new (second) version of the book *Running Lean: Iterate from Plan A to a Plan That Works* was sold on Amazon, the sales of its first version with 5-star rating exceeded the sales of its second version with lower ratings.

analyzed the possible detrimental effect of PRRs in a vertical market carrying multiple horizontally differentiated products of the type old and new.

Consumer willingness to purchase new products is reduced by uncertainty about product quality, particularly about perceived quality, which is a pervasive feature of many markets (e.g. Guo 2009). It is this uncertainty, together with the PRRs of the previous generation product, that exacerbates the cannibalization between different generation products from the same manufacturer. That said, in principle consumers who are uncertain about the quality of the new product could obtain information through free trials, advertisements, and/or third-party product reviews based on independent laboratory tests or expert valuations, but it remains unclear whether such disclosure of new product-related technical information effectively counters previous generation product PRRs.

When a seller offers an old and new product at the same time, the previous generation product having been on the market a longer time will have acquired a higher volume of PRRs than the new one, and if PRRs are highly positive (as assumed in this study) they will exacerbate cannibalization on the sales of the new product. The marketing reality is that when the same company produces both a positively reviewed previous generation product, and a new product of the same type with unknown perceived quality, the former will steal sales from the latter. PRRs also increase the market share of the previous generation product by intensifying the encroachment on the market share of a competitor's equivalent product. Interestingly, our results show that cannibalization induced by PRRs can harm retailers under certain conditions, but not directly manufacturers.

This study poses the following research questions in the context of a vertical market where manufacturers and retailers may compete using different channel structures. First, we ask: what is the effect of PRRs on inter- and intra-generational product competition, as well as their effect on retailers' decision to disclose them? We are interested in evaluating under which conditions retailers selling the new and old product benefit from making PRRs available on their web page, and by contrast, when a boycott of previous generation product PRRs is preferred by the retailer.

Second, we ask: What possible strategies can manufacturers use to manipulate retailer behavior on posting PRRs? In this study, we evaluate the effect of two strategies namely a more benevolent pricing towards retailers and/or the release of product related technical information.

Motivated by the above considerations, we analyze a multi-stage sequential game that facilitates the inclusion of product PRRs (controlled by the retailer) and technical information on product quality for a new product (controlled by the manufacturer) in a multi-product distribution channel. We assume that the previous generation product, of the multi-product channel, acquires PRRs from consumers in the first period (and the retailer decides whether or not to post them), which if posted positively affect its valuation in the second period (e.g. Kuksov and Lin 2010). Our analysis examines how PRRs (on the old product) and the manufacturer's technical information (on the new product), impact competition in the second period when the old and the new product distributed in a vertically separated channel compete with another manufacturer's product distributed in a vertically integrated channel.[4] Combining two different channels (integrated and separated) is informative, realistic, and useful, as it simplifies the complexity of the calculus.

The results of this analysis are most applicable to a non-integrated seller of multiple horizontally-differentiated products able to communicate information about these products to consumers. Considering the effect of PRRs on the multi-product manufacturer and his retailer, the findings indicate that the manufacturer always benefits from previous generation product PRRs. The retailer, on the other hand, under certain conditions does not benefit from the previous generation product PRRs; a finding that counters the intuitive assumption that PRRs are beneficial to sellers. The reason for such result is that PRRs exacerbate the cannibalization of the new generation product by the previous generation product. More specifically, they increase the profit of the existing product (positive effect) at detriment to the profit of the new product (negative effect). PRRs damage the retailer only, as for the manufacturer the gain tends to offset the loss of new product profits, as the loss can, at least partially, be passed on through wholesale prices. In fact, the manufacturer can manipulate the retailer's decision to post PRRs by offering reduced wholesale prices. However, this strategy can only be successful when competition is soft and when the quality of the new product is not too high. An alternative strategy at disposal of the manufacturer is controlling the release of technical information about the new product. However, as we

[4] Here, the two-period concept is used only to express the model background, so, rather than considering the first period, the analysis focuses primarily on the impact of the different information during the sales period after the new product enters the market. Taking the high-end smartphone market as an example: although iPhone4 was launched in October 2011, iPhone5 in November 2012, and Samsung Galaxy S3 in May 2012, iPhone4 and Galaxy S3 are the previous generation products produced by two different manufacturers, while iPhone5 is the new entrant.

will show, when uncertainty about the new product is limited, the efficacy of this strategy may not be effective for the manufacturer, as it further exacerbates cannibalization.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 outlines the model and highlights the assumptions. Section 4 models the impact of PRRs on the cannibalization of new products and provides an insight into the influence of product reviews and ratings on the release of new product-related technical information. Possible extensions of the model are outlined in Section 5.

Finally, the study concludes in Section 6 with a summary of the main findings and potential direction for future research. We provide supporting analysis and the corresponding proofs in the appendix.

2. Related work

The research questions addressed in this paper relate mostly to the literature on product information, with particular emphasis on the role of online consumer reviews and ratings. As several studies have empirically shown, the availability of online consumer reviews can affect long-term consumer purchase behavior, as a more positive rating environment can directly improve sales (Moe and Trusov 2011), and the social welfare generated by review systems can improve consumer choice (e.g. Duan et al. 2008, Li and Hitt 2008). In the extant literature, which frequently focuses on the evolution and sequencing of online ratings over time (e.g. Li and Hitt 2008), the impact of product reviews and online ratings on sales is typically measured using numeric variables that represent the valence and volume of reviews (Floyd et al. 2014, You et al. 2015).

Beyond investigating the profound effects of reviews on the demand side (sales), the availability and the characteristics of online reviews can also have an influence on firm's strategies. Few studies in the existing economics and marketing literature model the role of product reviews and product ratings from that perspective. For example, Shaffer and Zettelmeyer (2002) analyze the provision of third-party product reviews and their effect on the division of profits in a multi-product distribution channel. Chen and Xie (2005, 2008) examine the marketing communication strategies generated in response to third-party and consumer reviews, whereas Mayzlin (2006) first investigates the long-term viability of posting fake reviews (promotional chat) in the face of competition and consumer skepticism, and then delves into the role of firm-specific incentives that arise from the supply of fake reviews Mayzlin et al. (2014). Sun (2012) examines the informational role of the variance in product ratings by building a theoretical model in which ratings help consumers gauge how much they would enjoy a product.

The most closely related paper to our study is that by Kuksov and Xie (2010), who suggest that firms can modify their strategies to improve average consumer rating, and in this way stimulate further consumption. Our study is different from theirs, as rather than examining how an increase in average rating can help consumers update their product valuation, we consider the role of existing product reviews and ratings (which arguably are predominantly highly positive, as Chevalier and Mayzlin (2006) suggest, and thus we assume so here) of a manufacturer's existing product, on a new product they introduce in the market. Furthermore, in a recently related paper (Kwark et al. 2014) analyse the effect of online consumer reviews (information content) in a setting where consumers face the uncertainty about product quality and product fit (or product match). One of their findings is that information content has different effects for retailers and manufacturers, as these two agents benefit in a different way. Our study is similar to theirs, as we consider the role of different sources of product quality information under the control of either the retailer or the manufacturer, in a setting where reviews are overwhelmingly positive.

In a broader context, our analysis also relates to the literature centered around a manufacturer's voluntary provision of verifiable information designed to solve consumer uncertainty. For example, Guo and Zhao (2009) examine the effects of disclosure costs and disclosure timing on duopoly firms' equilibrium information-revelation strategies and payoffs, while Guo (2009) investigates optimal disclosure strategies and formats in a channel with bilateral monopolies. Anderson and Renault (2009) model a game between rival firms and their incentives to provide information, while Sun (2011) considers a monopolist selling a product on the Hotelling line and argues that the monopolist is more likely to disclose the technical information when vertical quality is higher. Koessler and Renault (2012) then provide new insights into firm provision of certified product information when consumer tastes are heterogeneous. All these studies outline equilibrium strategies for revealing product related technical information in a monopoly or competitive setting, and all point to technical information as the main factor considered by consumers. Most importantly for our research, they all propose that the manufacturer can benefit from the disclosure of technical information, regardless of whether the cost of disclosure is high or low.

This study comprehensively considers the impact of product information - made of information on new product quality and previous generation product PRRs in a multiple product distribution channel -, and demonstrates that PRRs are not always profitable for retailers, and that the disclosure of technical information is not always beneficial for manufacturers with differentiated products, even when the cost of disclosure is low. Based on this result, we analyze the possibility that the manufacturer may use his to control the retailer decision to post PRRs. We outline the model setup and the corresponding strategies on the sections that follow.

3. The model

We introduce a two-period model in a market where there are two distribution channels (A, B) competing with each other. Each channel distributes a single differentiated product, brought into the market in the first period. In the second period channel B launches a new product, B'. The new product can be either a new product in literal terms or a new iteration of an existing product. There are thus three differentiated products competing in the market in the second period.

A feature of our model is that, for channel A, production and distribution are fully integrated, whereas, for channel B, they are vertically separated. Having only one distribution vertically separated is an assumption that unquestionably does help making the model tractable, but also has the benefit of being realistic, as asymmetry in vertical channel structures is a marketing reality. For example, Samsung opts for a separated structure, while Google tends to integrate its channel in order to control user experience (e.g., the recent launch of Google Pixel).

In this article, we study the impact of product review ratings and the release of product-related technical information by the producer in a multiple product distribution channel in which both the previous generation product and the new product coexist. The motivation is that consumers can use review ratings to learn about the value of the previous generation product and can utilize new product technical information to form expectations of the new product value.[5] We assume that most consumers are satisfied with the previous generation

[5] As aforementioned, consulting PRRs has become an increasingly common step in a consumer's purchasing cycle for all types of products and services, especially for previous generation products. A typical review aggregator (e.g. Amazon.com) asks for consumer ratings, not only for the product, but also for the merchant with those two measures being in general positively correlated.

product and have posted positive reviews or high ratings, which are accessible to other users in the second period. The assumption that PRRs are predominantly positive is key for the analysis that we aim at undertaking in this work, as we are keen to study the determinants of possible cannibalization of an existing product on a new product introduction, until the new product gains a sufficient number of PRRs.

Our analytical approach is developed according to a sequential game structure. We consider three differentiated products on sale in the market and assume that PRRs are available for the two products that were in the market already in the first period. We begin by asserting that there is uncertainty about the new product quality. Next, we relax this assumption and allow consumers to smooth out the level of uncertainty in the market by using any information available to them. Product information can be relaxed through direct manufacturer communication on product labels, third-party certifications, or advertisements. We analyze the retailer's response to PRRs and study the proactive strategies the manufacturer can utilize to affect the retailer's response.

In the next section we define some useful notation to introduce the assumptions the model relies upon.

3.1. Assumptions and Notations

When consumers have yet to experience a new product, PRRs can be the deciding factor towards their choice of new or old product. Key assumptions for our model are outlined and motivated below. The notation for variables and parameters that are relevant for the model is documented in Table 1.

Assumption 1. *Demand for a product does not decay over time.*

This assumption is chosen to rule out any dynamic strategic behavior by consumers and firms. This is an alternative view to the durable goods literature on product replacement (rollover), which agrees on the fact that new generation products displace previous generation products (see Liang et al. (2014)). In this study, we concentrate on the time-period where the two products - previous generation and new - overlap in the market.

Assumption 2. *The marginal cost of production is symmetric and without loss of generality is normalized to zero. Whereas, the marginal cost of quality is zero for previous generation products and is* $\frac{q_{B'}^2}{2}$ *for the new product.*

Table 1 Parameters and decision variables

Symbols	Definitions
q_A, q_B, $q_{B'}$	Quality for channel A's product, channel B's product, channel B's new product
θ_A, θ_B, $\theta_{B'}$	Consumer willingness to pay for channel A's product quality, channel B's product quality, channel B's new product quality
$\Delta\theta_B > 0$, $\Delta\theta_A > 0$	Increased willingness to pay for channel B's or channel A's previous generation (perceived) product quality caused by PRRs
a	Consumer expectations for the new product quality when no information is available
t	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 product, channel B's new product
π_i	Firm i's profit, with $i \in (AM, BM, BR)$, where M=manufacturer and R=retailer.

The assumption of zero marginal cost of production is shared with Villas-Boas (2004). Implicit in Assumption 2 is the belief that any quality cost is sunk for previous generation products. On the other hand, a new product requires a per-product investment cost for the manufacturer, whose amount depends on the quality level. The functional form that we have selected is in agreement with that employed by Desai (2001).

Assumption 3. *Positive PRRs posted by consumers who purchased channel B's previous generation product in the first period affect consumer valuation in the second period positively and increase their willingness to pay for it. This increased willingness to pay is captured by the term* $\Delta\theta_B > 0$.

Assumption 3 follows Kuksov and Xie's (2010) hypothesis, which states that first-period consumers who experience a positive utility from the purchase post their product review ratings (PRRs), and in this way disclose information on the high quality of the product, affecting future consumer utility positively.

Assumption 4. *PRRs do not affect consumer valuation for the new product. They only increase consumer willingness to pay for the previous generation product.*

Assumption 4 excludes that PRRs affect the brand value, which implicitly rules out any pass-through of PRRs on new products produced by the same developer. This assumption can be relaxed easily in our model by allowing that a proportion of PRRs is transmitted to the new product.

Assumption 5. *Consumer expectations of the new product quality when no information is available is given by $aq_{B'}$ (with $\frac{1}{2} < a < 1$).*

Following Guo (2009), we assume that consumer uncertainty about quality can be resolved completely with firms' disclosure efforts. Consumers are willing to update their beliefs about the product quality when new information is released. When full information is available consumers take decisions based on the true quality ($a = 1$). When full information is not available this assumption imposes a degree of risk aversion on consumer choice, as $\frac{1}{2} < a < 1$.

3.2. Sellers and Consumers

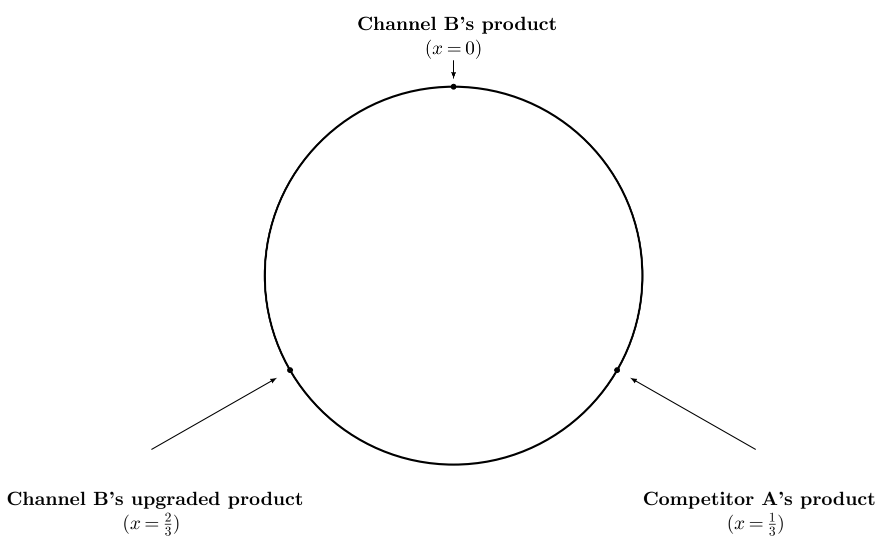
We represent a market in which three differentiated products are sold in the second period. Our model includes a manufacturer (BM) and a retailer (BR), in channel B, and a manufacturer (AM), in channel A. The manufacturer (BM) releases two differentiated products and sells them through BR to consumers. The other manufacturer (AM) sells a different previous generation product directly to consumers. Letting q_B be the quality of channel B's previous generation product, $q_{B'}$ the quality of the new product, and q_A the quality of channel A's previous generation product, we denote consumer expectations of the new product quality when no information is available with $aq_{B'}$.

We use a framework of localized competition to model the rivalry between three differentiated products produced by the two manufacturers.[6] Consumers are located uniformly on a circular market of unitary length (Salop 1979). Each consumer buys at most one product in the period. We 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 previous generation product is assumed to be at the zero point ($x_{BM} = 0$) of the Salop circular market; the location of B's new product is assumed to be at the two-thirds point ($x_{B'M} = \frac{2}{3}$), and the location of A's competing product is assumed to be at the one-third point ($x_{AM} = \frac{1}{3}$), as displayed in Figure 1. We relax also the assumption of equidistant location in the robustness check section (Section 5.1).

[6] A discussion of the main differences between localized and non-localized competition is available in Anderson et al. (1992).

Consumers are heterogeneous in their taste for product quality depending on their location. The willingness to pay for product quality is θ_B, $\theta_{B'}$ for channel B's previous and new generation products, and θ_A for channel A's previous generation product. To avoid cumbersome algebra we assume symmetry in willingness to pay for previous generation products, thus $\theta_A = \theta_B \equiv \theta$. This simplification means that both manufacturer B's previous generation product and manufacturer A's product have the same competitive edge.[7] To keep the model symmetric and simple, we assume that both products receive positive reviews, and impose a symmetric change in consumer valuation for the two products, $\Delta\theta_A = \Delta\theta_B = \Delta\theta > 0$. This simplification does not affect the main results of the paper and will be relaxed when asymmetry between channels is needed for the analysis.

Figure 1 Spatial circular market model of competition for the product entry



The magnitude of disutility that a consumer incurs from a mismatch between an ideal product and the product offered by the manufacturer is represented by the mismatch cost (t), (often called the degree of perceived differentiation between products in the literature (e.g. Liu and Cui (2010))).

[7] To illustrate this concept with an example, when new users are searching for a high-end smartphone, both iPhone6 (produced by Apple) and Galaxy S6 (produced by Samsung) offer very similar valuations for quality. Hence, this assumption accords with reality. Furthermore, we assume that channel B's previous generation product receives a large number of PRRs in the first period that positively affect consumer valuation in the second period and increase their willingness to pay for that same product, as in Kuksov and Xie (2010).

Given the three retail prices p_A, p_B and $p_{B'}$, the surplus of a consumer located at $0 \leq x < \frac{1}{3}$ is given by:[8]

$$V_A = (\theta + \Delta\theta)q_A - p_A - t(\frac{1}{3} - x)$$
$$V_B = (\theta + \Delta\theta)q_B - p_B - tx. \tag{1a}$$

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

$$V_A = (\theta + \Delta\theta)q_A - p_A - t(x - \frac{1}{3})$$
$$V_{B'} = \theta_{B'} a q_{B'} - p_{B'} - t(\frac{2}{3} - x). \tag{1b}$$

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

$$V_B = (\theta + \Delta\theta)q_B - p_B - t(1 - x)$$
$$V_{B'} = \theta_{B'} a q_{B'} - p_{B'} - t(x - \frac{2}{3}). \tag{1c}$$

3.3. Payoffs, Strategies, and Timing

To assess the impact of previous generation product PRRs on the multiple product distribution channel, we model the two manufacturers' and the retailer's decisions in a sequential game, as displayed in Figure 2. We first study the case where the manufacturer in the separate channel (B) does not have power to affect the retailer's disclosure behavior (panel (a) in the Figure). In this case, stage one is the time for retailer B to choose whether or not to post the PRRs.[9] In stage two, it is manufacturer B that chooses the quality of its new product ($q_{B'}$). 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 using backward induction to guarantee subgame perfection in a fully covered market. Note that in panel (a) the retailer's disclosure choice for PRRs precedes the manufacturer's quality and wholesale price decisions. When the new product enters the market, the retailer considers the cannibalization between the new product and the existing product and weights the negative and positive effects, and

[8] This specification of the consumer surplus function is similar to that used by Viswanathan (2005), Shulman et al. (2011), and Shulman (2013). For instance, Shulman et al. (2011) suggest that the modeling structure of holding the locations of a firm's products constant, in a competitive setting guarantees that the results are robust to the possibility that the firm relocates their products when facing competition.

[9] The order of manufacturer and retailer's decisions can be swapped without altering the main message from the game, as it is done in panel (a).

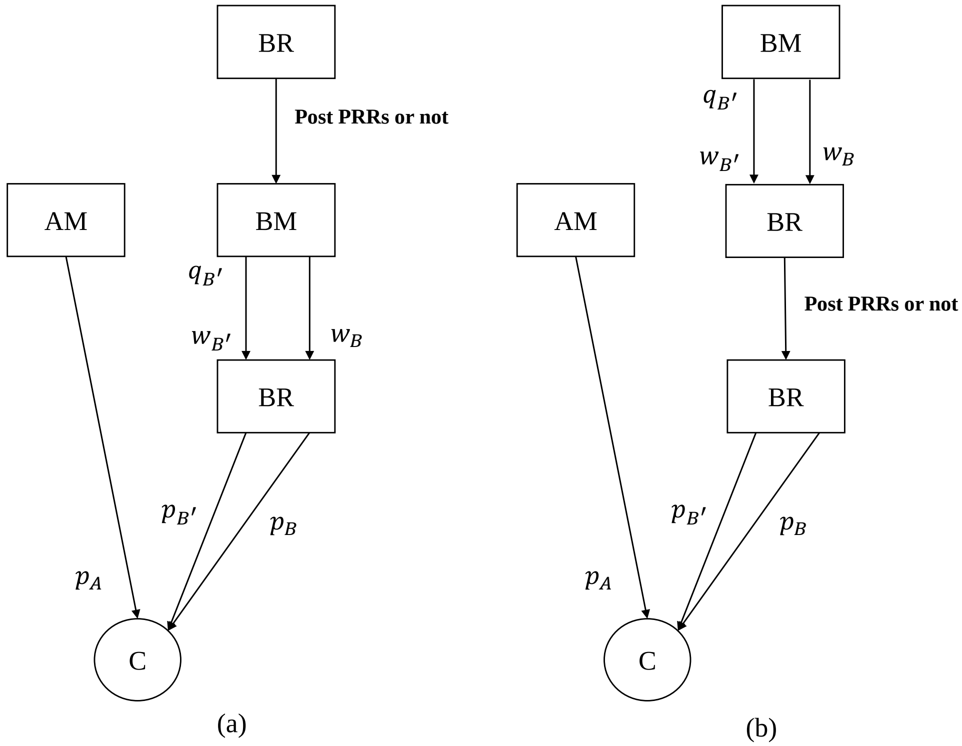


Figure 2 Channel A and B's decision tree

then decides whether to disclose the PRRs or not. The retailer decides the prices based on the wholesale prices the manufacturer sets. Another modeling strategy is to empower the manufacturer by allowing him to manipulate retailer's behavior via wholesale pricing. This strategy is viable if the retailer chooses whether or not to post PRRs after the manufacturer has chosen the wholesale price (see Figure 2, panel (b)). This is discussed in Section 4.2.1.

It is also possible to allow the manufacturer to release technical information to contrast, at least partially, the retailer's decision to post PRRs. For instance the first stage in Figure 2(a) can be preceded by a initial stage where manufacturer B can decide whether or not to disclose full technical information. The new game would be a five-stage game. As first mover, the manufacturer would have the power of controlling the technical information for the new product, which may affect the retailer's PRR disclosure strategy. This is the core of Section 4.2.2. Alternatively, adding a fifth stage to the game in Figure 2(b), would allow us to study the combined effect of the two strategies. The discussion of this extended game structure is presented in Section 4.2.3.

As both previous generation products have been in the market for some time, we assume that their qualities q_A and q_B are exogenous in period 2. The following Lemma suggests that, given symmetry in consumer willingness to pay, the two previous generation products have the same quality in equilibrium.

LEMMA 1. *If prior to the introduction of the new product B' consumer willingness to pay for manufacturer B's previous generation product quality is the same as that for manufacturer A's product quality, i.e. $\theta_A = \theta_B \equiv \theta$, then product B and product A will be of the same quality in equilibrium, $q_A = q_B \equiv q$, even when channels are characterized by a different vertical structure.*

These results are in line with the findings of Moorthy (1984) and Desai (2001). 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. As product B and product A are priced at the same marginal cost and consumers have the same valuation for products, both have the same quality.

4. Analysis and Results

Our analysis relies on the assumptions listed in the previous section. From Lemma 1 we know that, because of symmetry in willingness to pay, incumbent products have the same quality. For notational convenience we define $\theta_A q_A = \theta_B q_B = \theta q \equiv u$, and similarly for the new product we have $\theta_{B'} q_{B'} \equiv u'$. Under this new notation u represents consumer valuation for the symmetric previous generation product quality, and u' is the corresponding one for the new product. PRRs for previous generation products affect positively consumer willingness to purchase these products, i.e. $\Delta\theta_B > 0$, $\Delta\theta_A > 0$, leading to a positive shift in quality product valuation ($\Delta u_B > 0$, $\Delta u_A > 0$).

Based on Lemma 1 ($q_A = q_B \equiv q$), we use the notation to simplify the formulas in final solutions, unless asymmetry is needed.

With this new notation we formulate the demand function for each product in the presence of PRRs (but in the absence of information on the new product quality):

$$\begin{aligned} D_A &= \frac{3u - 6p_A + 2t - 3au' + 3p_{B'} + 6\Delta u_A - 3\Delta u_B + 3p_B}{6t} \\ D_B &= \frac{3u + 6\Delta u_B - 3\Delta u_A - 6p_B + 3p_A + 2t - 3au' + 3p_{B'}}{6t} \\ D_{B'} &= \frac{-6u + 3p_A + 2t + 6au' - 3\Delta u_B - 3\Delta u_A + 3p_B - 6p_{B'}}{6t}. \end{aligned} \tag{2}$$

To simplify the notation that follows we impose the symmetry in the effect of PRRs, yielding: $\Delta u_A = \Delta u_B = \Delta u > 0$. We work with simplifying assumption, though at times to gain clarity we will write down the general asymmetric case.

To shield against negative demands in equilibrium we enforce that consumer valuation for the new product is within the interval:

$$\max\left\{\frac{2(33u+33\Delta u-20t)}{33(2a-1)},0\right\} < u' \leq \frac{2(21u-12\Delta u+20t)}{21(2a-1)}, \tag{3}$$

which requires that both manufacturers' products have sufficient competitive power edge to guarantee an above zero demand. To ensure that the interval in Equation 3 is well behaved, we assume a sufficiently large degree of product differentiation $t > \frac{121}{120}\Delta u$ - a condition that is always satisfied in absence of PRRs. Incidentally, such condition dictates that there is room for the three differentiated products to compete with each other in the market. Therefore, the results we draw in the paper are for markets in which the three differentiated products have sufficient competitive power to attract positive demand.

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

$$\begin{aligned}\pi_{AM} &= p_A D_A \\ \pi_{BR} &= (p_B - w_B)D_B + (p_{B'} - w_{B'})D_{B'} \\ \pi_{BM} &= w_B D_B + (w_{B'} - \frac{q_{B'}^2}{2})D_{B'}.\end{aligned} \tag{4}$$

4.1. Passive manufacturer

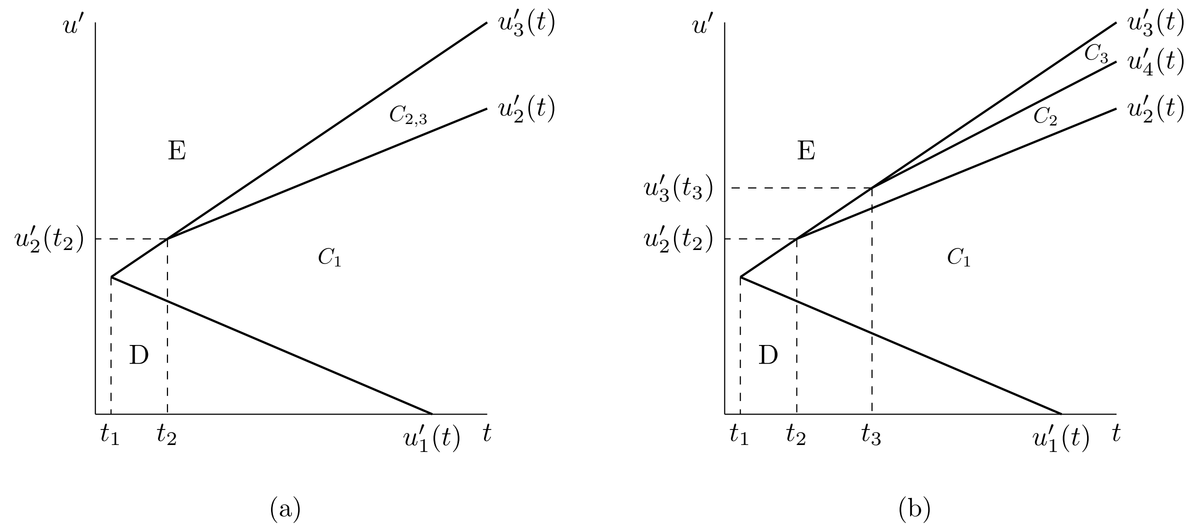
We begin the analysis by evaluating the firms' equilibrium strategies in presence and absence of PRRs for manufacturer B's previous generation product. Therefore we work with the structure depicted in Figure 2(a). We first study the situation with uncertainty about the new product quality, i.e. we first set $\hat{q}_{B'} = aq_{B'} < q_{B'}$, recalling that $\frac{1}{2} < a < 1$. We investigate which combinations of degree of product differentiation and consumer valuation for the new product quality (t, u') guarantee the posting of PRRs as an equilibrium in the market, and then highlight the area where there is conflict of interest between the retailer and manufacturer. We use the concept of subgame perfection to solve the game.

THEOREM 1. *Compared to a case in which previous generation PRRs are absent, the presence of PRRs in a vertically separated channel (channel B) leads to the following results:*

a) The manufacturer always benefits from previous generation product PRRs.

b) The retailer does not directly benefit from previous generation product PRRs, unless consumer valuation for the new product is sufficiently small.

Figure 3 Optimal strategies for PRRs



Thresholds for t	Thresholds for u'	Parameters value
$t_1 = \frac{121}{120}\Delta u$	$u'_1 = \frac{2(33u+33\Delta u-20t)}{33(2a-1)}$	$\Delta u = 0.2$
$t_2 = \frac{289}{120}\Delta u$	$u'_2 = \frac{2(138u+45\Delta u+80t)}{69(2a-1)}$	$u = 1$
$t_3 = \frac{36+7\sqrt{979}}{60}\Delta u$	$u'_3 = \frac{2(21u-12\Delta u+20t)}{21(2a-1)}$	$a = 0.75$
	$u'_4 = \frac{2(1587u-2421\Delta u+920t+6\sqrt{89}\sqrt{\Delta u(2131\Delta u+690t)})}{1587(2a-1)}$	

Theorem 1 suggests that the manufacturer with multiple products, which is manufacturer B in our case, benefits from previous generation product PRRs, as long as each of their differentiated products has a competitive edge that guarantees an above-zero demand (captured by areas C_1 and $C_{2,3}$ in Figure 3(a)). By contrast, the retailer only benefits from PRRs if the new product has a relatively weak competitive edge, that is, if consumer valuation to purchase the new product is sufficiently small (area C_1 as claimed in item b). Theorem 1b) is justified by the following inequalities:

$$[\pi_{BR}(\Delta u_A > 0, \Delta u_B > 0) - \pi_{BR}(\Delta u_A > 0, \Delta u_B = 0)] > 0 \text{ if } (t, u') \in C_1 \tag{5}$$
$$[\pi_{BR}(\Delta u_A > 0, \Delta u_B > 0) - \pi_{BR}(\Delta u_A > 0, \Delta u_B = 0)] \leq 0 \text{ if } (t, u') \in (C_{1,2}).$$

Two factors influence the retailer's profits. First, the increased demand for the previous generation product has an adverse effect on the new product market share because of substitutability between products. Second, PRRs cause a drop in the price of the new product, which together with the cannibalization of market shares contribute towards retailer's profit deflation. The drop in the new product price squeezes retailer's margin - as wholesale prices remain unchanged. Interestingly, as competition is relaxed (larger values of t), the range of consumer valuation for the new product that satisfies profitable PRRs widens, but so does that where retailers prefer not to post PRRs. Soft competition increases the profitability and therefore can be used as a buffer against cannibalization. Put differently, the more intense competition is, the less room there is for PRRs at high values of consumer valuation for the new product. The reason for this result is that PRRs exacerbate the cannibalization of the existing product on the new product and this is particularly severe when there is a particularly high valuation for the new product. PRRs raise the profit of the existing product (positive effect) at detriment of the profit of the new product (negative effect), but the negative effect only affects the retailer.[10]

In the next section, we study two situations where the manufacturer can incentivize retailer's behavior to post reviews. First, we give the manufacturer full bargaining power in setting the wholesale price, and observe that there exists a range of product differentiation and quality valuation in which the manufacturer will find it optimal to set a lower wholesale price to prevent the retailer from not posting reviews online, according to the game tree

[10] A decomposition of the marginal profit may guide our understanding of the underlying effect of PRRs:

$$\frac{d\pi_{BM}}{d\Delta u_B} + \frac{d\pi_{B'M}}{d\Delta u_B} = \left(\frac{dw_B}{d\Delta u_B} D_B + \frac{dD_B}{d\Delta u_B} w_B\right) + \left(\frac{dw_{B'}}{d\Delta u_B} D_{B'} + \frac{dD_{B'}}{d\Delta u_B} w_{B'}\right)$$
$$= \left(\frac{1}{2} D_B + \frac{11}{48t} w_B\right) + \left(0 D_{B'} - \frac{7}{48t} w_{B'}\right) \tag{6a}$$

$$\frac{d\pi_{BR}}{d\Delta u_B} + \frac{d\pi_{B'R}}{d\Delta u_B} = \left(\frac{d(p_B - w_B)}{d\Delta u_B} D_B + \frac{dD_B}{d\Delta u_B} (p_B - w_B)\right) + \left(\frac{d(p_{B'} - w_{B'})}{d\Delta u_B} D_{B'} + \frac{dD_{B'}}{d\Delta u_B} (p_{B'} - w_{B'})\right)$$
$$= \left(\frac{5}{24} D_B + \frac{11}{48t} (p_B - w_B)\right) + \left(-\frac{1}{24} D_{B'} - \frac{7}{48t} (p_{B'} - w_{B'})\right)$$
$$= \left[\frac{1}{24} (5D_B - D_{B'})\right] + \left[\frac{1}{48t} (11(p_B - w_B) - 7(p_{B'} - w_{B'}))\right]. \tag{6b}$$

For the manufacturer the increase in profit from the existing product is the result of both a larger demand and higher wholesale price, whereas the drop in profit from the new product is the outcome of a reduction in demand only, not accompanied by a reduction in the wholesale price. In markets with sufficient competitive power, as the one we study in this paper, Equation 6a is always positive (as shown in the appendix). By contrast, for the retailer the loss in new product profit is caused both by a joint drop in demand and price. In fact, Equation 6b is characterized by both sections in square brackets having common sign, for all $\{t, u'\}$, which basically means that a study on the determinants of optimal demand (the first section in square brackets) is what is needed to unravel the mechanism that explains why there are situations where it is not optimal for retailers to post PRRs. For a given level of positive review rating and sufficiently high degree of product differentiation, an increase in the quality of the new product will lead to a drop in the demand for the old product, whose effect is larger when the degree of product differentiation is smaller. Thus, for a sufficiently large degree of product differentiation the drop in new product demand is limited. This explains line u_2 drawn in Figure 3.

depicted in Figure 2(b). Then, in a subsequent section we extend the four-stage sequential game to a fifth stage game by including the release of technical information as a decision choice.

4.2. Manufacturer's strategies

We examine the conditions where the manufacturer can influence retailer boycott action through the setting of a more favorable (for the retailer) wholesale price.

4.2.1. The effect of wholesale prices We investigate the retailer's optimal decision in the third stage of the game, given wholesale prices $w_{B'}$ and w_B. In this situation, the retailer does not boycott PRRs if and only if their profit in the presence of PRRs exceeds that in their absence.

LEMMA 2. *In equilibrium, the retailer does not boycott PRRs if and only if*

$$\pi_{BR}(w_B, w_{B'} \mid \Delta u_A > 0, \Delta u_B > 0) - \pi_{BR}(w_B, w_{B'} \mid \Delta u_A > 0, \Delta u_B = 0) = \\ = \frac{\Delta u_B(138 w_{B'} + 93\Delta u_B - 48\Delta u_A - 186 w_B + 138u + 80t - 138au')}{432t} \geq 0. \tag{7}$$

We study the existence of a unique cut-off point on the wholesale prices, $\hat{w}_{B'}$ and $\hat{w}_B$, thus a threshold on the ability to manipulate retailer's decision on whether or not to post PRRs. The manufacturer's profit maximization problem is now constrained by the retailer's profit when posting PRRs or not:

$$\max_{\hat{w}_{B'}, \hat{w}_B} \Pi_{BM}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_A > 0, \Delta u_B > 0) = (\hat{w}_{B'} - \frac{q_{B'}^2}{2}) D_{B'} + \hat{w}_B D_B \tag{8}$$

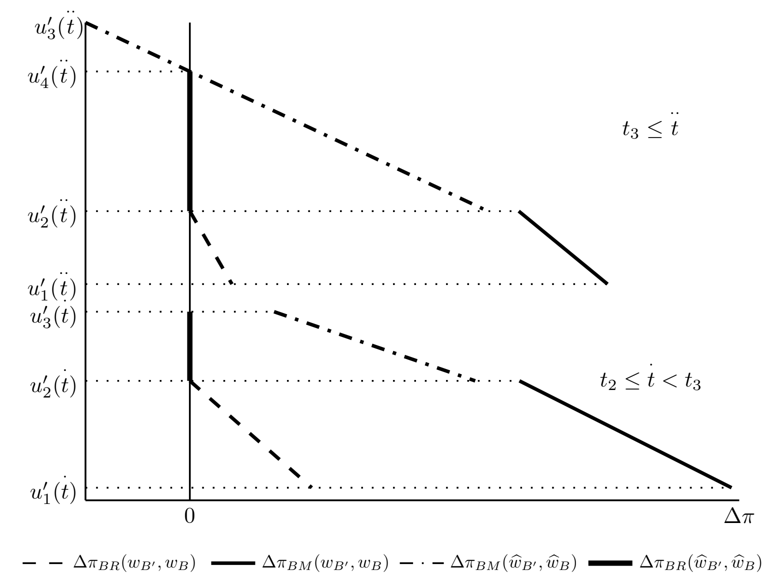
$$\text{s.t. } \frac{\Delta u_B(138 w_{B'} + 93\Delta u_B - 48\Delta u_A - 186 w_B + 138u + 80t - 138au')}{432t} \geq 0. \tag{9}$$

We determine the equilibrium by resolving manufacturer B's trade-off between distorting the wholesale prices downward and inducing the retailer to support PRRs. When choosing to reduce the wholesale prices to prevent the retailer from boycotting, manufacturer B must guarantee no harm to their profits. In other words, manufacturer B's profits cannot be lower than when PRRs are absent: $\pi_{BM}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_A > 0, \Delta u_B > 0) \geq \pi_{BM}(w_{B'}, w_B \mid \Delta u_A > 0, \Delta u_B = 0)$.

PROPOSITION 1. *When combinations of product differentiation and consumer valuation for the new product are within a certain range ($(t, u') \in C_2$ in Figure 3(b)), the manufacturer with multiple products (i.e., B) can manipulate the retailer's decision to boycott PRRs, by distorting the wholesale prices downward to $\hat{w}_{B'} < w_{B'}$ and $\hat{w}_B < w_B$.*

The wholesale prices thus serve not only to extract surplus from the retailer, but also as means to control retailer's behavior toward PRRs. That is, the manufacturer may cut the wholesale prices to induce the retailer to disclose previous generation product PRRs.

Figure 4 The effect of discounting wholesale prices on the retailer's and manufacturer's profit



Thresholds for t and u'	Thresholds for $\Delta\pi$	Parameters value
See Figure 3	$\pi_{BR}(w_{B'}, w_B \mid \Delta u_A > 0, \Delta u_B > 0) - \pi_{BR}(w_{B'}, w_B \mid \Delta u_A > 0, \Delta u_B = 0)$ $\pi_{BM}(w_{B'}, w_B \mid \Delta u_A > 0, \Delta u_B > 0) - \pi_{BM}(w_{B'}, w_B \mid \Delta u_A > 0, \Delta u_B = 0)$ $\pi_{BR}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_A > 0, \Delta u_B > 0) - \pi_{BR}(w'_B, w_B \mid \Delta u_A > 0, \Delta u_B = 0)$ $\pi_{BM}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_A > 0, \Delta u_B > 0) - \pi_{BM}(w_{B'}, w_B \mid \Delta u_A > 0, \Delta u_B = 0)$	$\Delta u = 0.2$ $u = 1$ $\dot{t} = 0.3$ $\ddot{t} = 1$

The concept stated in Proposition 1 is depicted in Figure 4. On the vertical axis we have consumer valuation for the new product. The use of subscripts is consistent with those employed for the lines plotted in Figure 3. In the horizontal axis we have the change in profits, calculated from the benchmark situation of no PRRs. The bottom panel studies the change in profits for a middle range of product differentiation, $t_2 \leq \dot{t} < t_3$, a range for which in Figure 3(b) we have seen there was no area C_3 (where the manufacturer is unable to incentivize retailers' behavior via reduced wholesale prices). We note that for low values of consumer valuation for the new product, $u_1'(\dot{t}) \leq u'(\dot{t}) < u_2(\dot{t})$ both the manufacturer and the retailer gain positive profits from PRRs. On the other hand, for the higher range of consumer valuation $u_2'(\dot{t}) \leq u'(\dot{t}) < u_4'(\dot{t})$ the retailer finds it not profitable to post PRRs, otherwise they would face negative profits (the dashed line would continue beyond zero). If the retailer does not post PRRs the change in profits for the manufacturer is zero (as the graph plots the difference between profits with PRRs and without PRRs). Here, the manufacturer has an incentive to give away part of their profits to incentivize the retailer to post PRRs. For this range of consumer valuation the manufacturer shall gain from PRRs and the retailer finds it optimal to post PRRs. Similarly, the top panel studies the situation for larger values of product differentiation, $\ddot{t} \geq t_3$. This range includes area C_3 in Figure 3(b). For this new range of product differentiation we have an interesting range of consumer valuation, $u'_4(\ddot{t}) \leq u'(\ddot{t}) < u'_3(\ddot{t})$, where the manufacturer finds it not optimal to incentivize PRRs and therefore PRRs are not posted by the retailer.

In the presence of PRRs cannibalization of the new product causes a loss to manufacturer B's retailer, prompting the retailer not to post the reviews. The manufacturer can counteract this loss by offering the manufacturer more favorable wholesale prices, as to change retailers attitude towards PRRs. This strategy by the manufacturer only pays when the valuation for the new product (u') is not too large.

As can be seen in Figure 4 when the valuation for the new product is within the ranges $u'_2(\dot{t}) \leq u' < u'_3(\dot{t})$ or $u'_2(\ddot{t}) \leq u' < u'_4(\ddot{t})$, the retailer's profits in the presence of PRRs are lower than when they are absent. However, the converse is not true for manufacturer B's profits, as they can extract more benefits from the PRRs because of a larger demand and higher wholesale prices for the existing product, while accompanying the drop in profits from the new product is the outcome of a reduction in demand only (not enhanced by a reduction in the wholesale prices), meaning that as u' increases in the presence of PRRs, manufacturer B's profits decrease more slowly than those of the retailer. Hence, when the differentiated products in the same market have their own competitive edges, the increased demand and wholesale prices of the previous generation product dominate manufacturer B's profits in the presence of PRRs.

Some attention should be paid to the case of large consumer valuation for the new product, $u'_2(\ddot{t}) \leq u'(\ddot{t}) < u'_4(\ddot{t})$, particularly that an increase thereof has a negative effect on the profits of both manufacturer B and its retailer when PRRs are present. The analysis discussed above focuses on the competition between three products, with the domain of u' restricted to guarantee above-zero demand for the three products. We now extend this domain to show that when the valuation of the new product is high enough and PRRs exist, a previously unconsidered case arises: manufacturer A's product demand can stop being positive. That is, when u' rises to a sufficiently high level, the benefits of the PRRs for channel B are counteracted by the negative effects of cannibalization of the new product. In fact, if u' becomes high enough, the manufacturer's profits in the presence of PRRs are lower than when they are absent.

In the next section, we study how the release of technical product information under the control of the manufacturer may affect the retailer's decision of whether or not posting PRRs.

4.2.2. The effect of technical information In the previous section the manufacturer was not given the choice of releasing technical information. We now relax this restriction and allow the manufacturer to choose whether or not to release technical information. We do that by adding an initial stage to the four-stage game depicted in Figure 2(a). In this new situation, the retailer needs to be aware of the implications that this new strategy might bring, and in response they can alter their action regarding PRRs. The results presented in Theorem 1 (retailer's choice of whether or not posting PRRs) and Proposition 1 (manufacturer's choice of whether or not discounting wholesale prices) remain valid in the presence of this new strategy.

We recall that new product quality with no provision of product information is $aq_{B'}$, with $\frac{1}{2} < a < 1$, and that the release of technical information exacerbates the valuation for the new product quality, as $(a = 1)u' > au$. To simplify the analysis, we assume that the cost of providing product information is negligible and is therefore set to zero.[11] To shield against nonnegative demands in equilibrium we enforce the following range for the new product quality:

$$\max\left\{\frac{2(33u + 33\Delta u - 20t)}{33(2a-1)}, 0\right\} < u' \leq \frac{2(21u - 12\Delta u + 20t)}{21}. \tag{10}$$

Furthermore, to guarantee the inequality, we impose the additional restriction on the domain of the degree of product differentiation, $t > \frac{33(14u+8a\Delta u+3\Delta u-14au)}{40(11a-2)}$.

In Lemma 3 below, we discuss the change in retailer's response regarding PRRs in the presence of technical information provided by the manufacturer. We highlight that there are feasible combinations of low degree of product differentiation, limited uncertainty about the new product quality, and reduced consumer valuation of the new product quality, where the release of technical information can discourage the retailer from posting PRRs.

[11] The internet makes the cost of disclosing product information low. For example, for Amazon and eBay it is very cheap to post PRRs and product information on their website.

LEMMA 3. *The disclosure of technical information affects retailer's decision to post PRRs negatively if: products are sufficiently homogeneous, consumer's uncertainty about the new product is sufficiently low, and consumer valuation of the new product is relatively high:*

$$\begin{cases} \frac{33(14u+8a\Delta u+3\Delta u-14au)}{40(11a-2)} < t \leq \frac{93}{40}(u+\Delta u) \\ \frac{3036u+2013\Delta u-40t}{22(138u+45\Delta u+80t)} < a < 1 \\ u_2'(a=1) = \frac{138u+45\Delta u+80t}{69} < u' \leq \min\left\{u_2'(a), u_3'(a=1) = \frac{2(21u-12\Delta u+20t)}{21}\right\}. \end{cases} \tag{11}$$

Lemma 3 highlights that conditions where the retailer prefers not to post PRRs if the manufacturer were to release technical information exist. To close the loop we refine the conditions in Lemma 3 and study when the manufacturer would find it optimal not to release technical information to avoid discouraging the retailer from posting PRRs. This occurs only when consumer uncertainty about the product quality is limited, that is, when by introducing technical information adds little to what consumers know already about the product (in our mathematical notation this happens when the parameter a is sufficiently close to 1). This behaviour is described by the following inequations:

$$\begin{aligned} &[\pi_{BR}(\Delta u_A > 0, \Delta u_B > 0, 1/2 < a < 1) - \pi_{BR}(\Delta u_A > 0, \Delta u_B = 0, 1/2 < a < 1)] > 0 \\ &[\pi_{BR}(\Delta u_A > 0, \Delta u_B > 0, a = 1) - \pi_{BR}(\Delta u_A > 0, \Delta u_B = 0, a = 1)] \leq 0. \end{aligned} \tag{12}$$

When the conditions highlighted in Lemma 3 are met, if consumers have technical information available their valuation for the new product may rise at a level that can strengthen cannibalization towards the new product market share, and indirectly intensify the negative effect of PRRs. For a subset of the conditions in Lemma 3 retailers' willingness to post PRRs is weakened when there is technical information.

Putting together Theorem 1 and Lemma 3 we get the message that the retailer would not post PRRs in the presence of product-related technical information when the valuation for the new product belongs to a well-defined interval. Within this interval, the retailer is willing to post PRRs when consumer's uncertainty about the new product quality is low (a is high). This means that the manufacturer can limit the availability of technical information under certain circumstances, as to convince the retailer to post PRRs. This is the essence of the next proposition.

Proposition 2. *When consumer expectations for new product quality, product differentiation and quality valuation are within the ranges:* ($1 > a \geq \frac{198u+125\Delta u+9\sqrt{455}\Delta u}{11(31\Delta u+18u)}$, $(t, u') \in C^{**}$), *the manufacturer will choose not to disclose technical information, and in response, the retailer shall post PRRs.*

Proposition 2 shows that there are conditions where the manufacturer may prefer not to use one of his strategies (the release technical information) and gain from the retailer posting PRRs. When consumers have limited uncertainty about the new product quality, the increase in revenues brought in by PRRs is superior to the loss in revenues caused by the cannibalization of the new product. The manufacturer can give up the benefit from technical information to gain access to larger profit from PRRs. In Figure 5a we present an example of this strategy. The area C^{**} highlights combinations of new product quality and degree of product differentiation where the manufacturer prefers not to disclose technical information and the retailer chooses to post PRRs.

4.2.3. The manufacturer's optimal strategies: Distort wholesale prices or Limit technical information? Propositions 1 and 2 are the result of a sequential modeling of two alternative strategies that can affect the retailer's attitude towards PRRs. We have seen that the manufacturer can control either the technical information or wholesale prices to influence retailer's decision of whether or not to post PRRs. Now, we try and combine the two strategies when $(t, u') \in C^{**}$(as previously defined).

Proposition 3. *For a sufficiently low level of consumer uncertainty* ($1 > a > a^*$)*:*

1) It is optimal for the manufacturer to limit the availability of technical information and for the retailer to post PRRs if $(t,\, u') \in C_1^{**}$ *(see Figure 5b).*

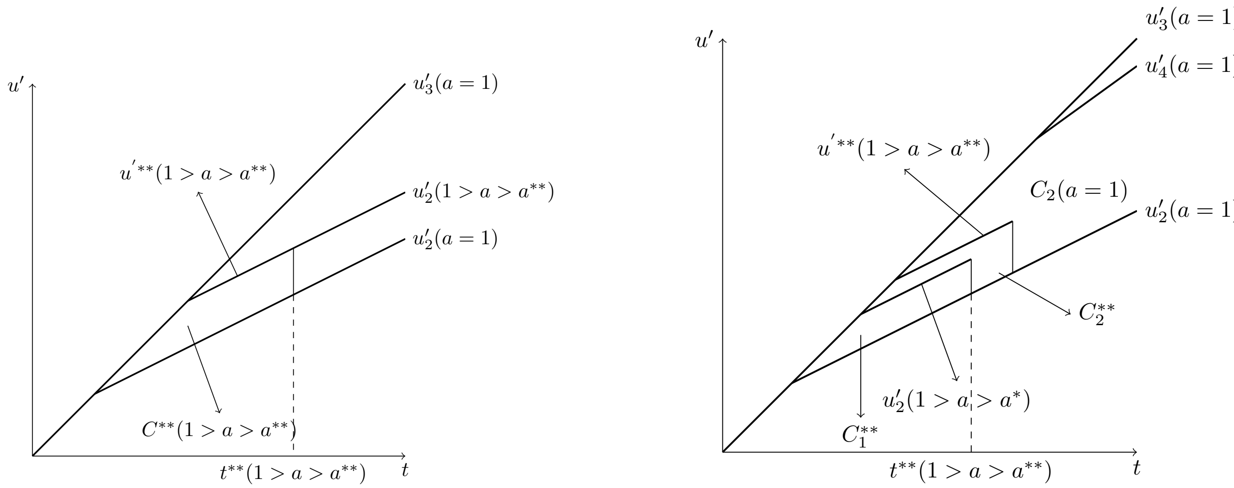
2) The optimal strategy for the manufacturer is to discount wholesale prices and disclose product-related technical information, and for the retailer to post PRRs if $(t,\, u') \in C_2^{**}$ *(see Figure 5b).*

Proposition 3 is the outcome of the following inequalities:

$$[\pi_{BM}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_A, \Delta u_B > 0, a = 1) - \pi_{BM}(w_{B'}, w_B \mid \Delta u_A, \Delta u_B > 0, 1/2 < a < 1)] < 0 \text{ if } (t,\, u') \in C_1^{**}$$
$$[\pi_{BM}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_A, \Delta u_B > 0, a = 1) - \pi_{BM}(w_{B'}, w_B \mid \Delta u_A, \Delta u_B > 0, 1/2 < a < 1)] > 0 \text{ if } (t,\, u') \in C_2^{**}. \tag{13}$$

Proposition 3 gives conditions (for a sufficiently large value of a) where the retailer may need to combine discounted wholesale prices along with the release of technical information (area C_2^{**}) versus doing nothing (area C_1^{**}).

Figure 5 Manufacturer's optimal strategies



(a) Limited technical information (b) The equilibrium

The equilibrium $((t,\, u') \in C^{**} \equiv (C_1^{**} \bigcup C_2^{**}),\, a^* = \frac{35244u+22250\Delta u+9\sqrt{17309165\Delta u}}{1958(31\Delta u+18u)})$		
The range of u'	Manufacturer's optimal strategy	Retailer's response
$u'_4(a=1) < u' < u'_3(a=1)$	DTI, $w_{B'}$, w_B	No PRRs
$u' \subseteq C_2^{**}$, $C_2(a=1)$	DTI, $\hat{w}_{B'}$, $\hat{w}_B$	PRRs
$u' \subseteq C_1^{**}$	NOT DTI, $w_{B'}$, w_B	PRRs
$u' \subseteq other$	DTI, $w_{B'}$, w_B	PRRs

When a is sufficiently high and $(t\, u') \in C^{**}$, the positive effect of technical information on firm's profitability is relatively low and PRRs plays the dominant role. The manufacturer can get around the conflict between release of technical information and the posting of PRRs by discounting wholesale prices. In area C_2^{**} the strategy of discounting wholesale prices is adopted by the manufacturer to offset retailer's loss from PRRs. In area C_1^{**} the manufacturer does not need to implement any strategy as the retailer finds optimal to post PRRs without the manufacturer giving discounts or releasing technical information.

5. Extensions

5.1. Change of product location on new product information strategy

We have so far assumed that the products are located at an equal distance from one another, and have used a generic reference to the nature of the new product in relation to the previous one as regards to the degree of differentiation. We now turn to the case where the new product is very similar to the existing product.[12] This refinement makes obsolete the assumption of equidistance between product locations. In order to be able to capture

[12] A possible refinement of this concept would be the case of product iteration, where a new product in this case is of higher quality than the existing one, but in terms of horizontal product differentiation is very similar. Our modeling is general to allow for this extension, but here we focus on the more interesting case of a new product introduction.

the closeness in substitutability we introduce a new parameter δ, which defines how much closer or farther away the new product is from the previous generation product produced by the same manufacturer (inter-products distance).

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

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

$$\begin{aligned} V_B &= u + \Delta u_B - p_B - tx \\ V_A &= u + \Delta u_A - p_A - t(\frac{1}{3} - x), \end{aligned} \tag{14a}$$

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

$$\begin{aligned} V_A &= u + \Delta u_A - p_A - t(x - \frac{1}{3}) \\ V_{B'} &= au' - p_{B'} - t(\frac{2}{3}\delta - x). \end{aligned} \tag{14b}$$

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

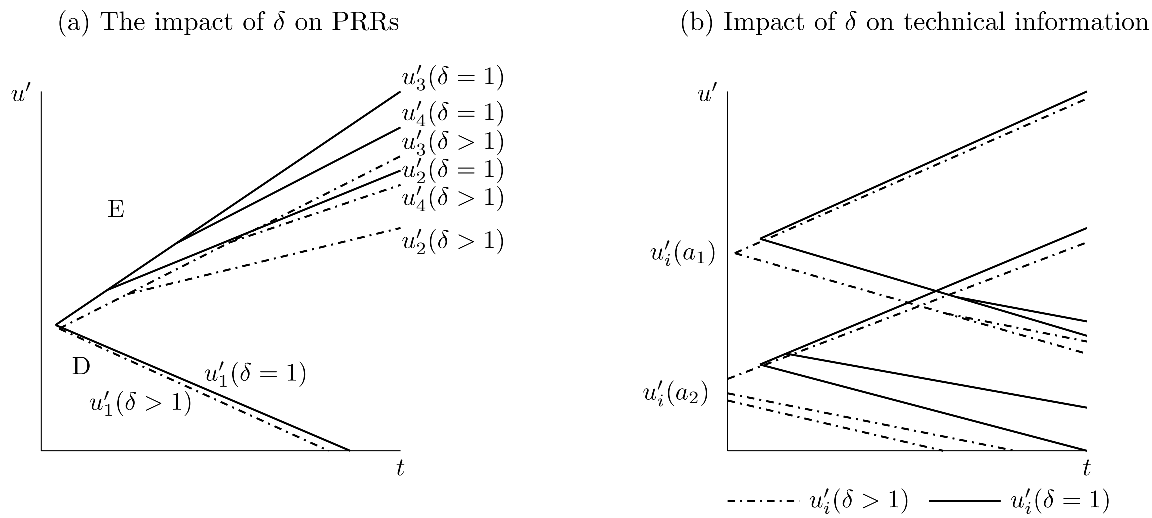
$$\begin{aligned} V_{B'} &= au' - p_{B'} - t(x - \frac{2}{3}\delta) \\ V_B &= u + \Delta u_B - p_B - t(1 - x). \end{aligned} \tag{14c}$$

In the following proposition, we analyze the effect of product location on the information strategy.

Proposition 4. *A drop in differentiation between new and previous generation product intensifies the cannibalization caused by PRRs. Incidentally, the disclosure of technical information softens the negative effect of cannibalization (and enhances the effect of the disclosure of technical information).*

Proposition 4 states that an increase in the parameter δ, which corresponds to an increase in the similarity between new and old products, narrows down the area in which the seller benefits from PRRs (area $C_{2,3}$ in Figure 3). By contrast, the feasible area where the seller benefits from the technical information widens (as shown in Figure 6).

Figure 6 **Impact of closeness/openness of product differentiation**



5.2. Fierce competition from the opponent

Hitherto we have assumed that the previous generation products of both manufacturers have the same competitive edge; that is, both products are symmetric in quality valuation ($\theta_A q_A = \theta_B q_B \equiv u$). Now, we remove symmetry and assume that product A has highly more of a competitive edge than product B, $\theta_A q_A > \theta_B q_B$.

PROPOSITION 5. *If competitor's previous generation product has significantly higher quality than multiple product channel's previous generation product, then*

a) The retailer will not post previous generation PRRs; no matter how high or low the willingness to purchase the new product is; and

b) The manufacturer of product B's can choose to disclose technical information on the new product quality if the willingness to purchase the new product and/or the perceived product differentiation are/is high in the presence of PRRs; otherwise, the opposite holds true.

Manufacturer B's previous generation product PRRs induce demand stealing, not only of manufacturer A's previous generation product, but also of B's own new product. However, now cannibalization of product A is much reduced - because of the superior quality of product A. When cannibalization of product A is relatively small, the benefit of increased demand of B's previous generation product due to PRRs is not sufficient to offset the loss caused by cannibalization of the new product margin.

5.3. When is it optimal to release a new product in the presence of PRRs?

We now examine the case where the launch of the new product is an optimal strategy in a situation when PRRs are either present or not, and consumers have no uncertainty about the new product ($a = 1$). PRRs increase consumer valuation for the previous generation product, so the demand for the new product may decrease, with negative side effects on manufacturer's decision of whether or not produce the new product at all. The main objective in this section is to assess how PRRs may influence equilibrium for the release of the new product, and the seller's profitability, in comparison to those in the benchmark case of launching the new product in the presence or absence of PRRs. In the situation without new product introduction, the locations of the two products A and B are spaced symmetrically in the unit circle and because of symmetry they share equally the whole market. After deriving the demand functions we can solve the equilibrium results in this case by using backward induction to guarantee subgame perfection in a fully covered market. We compare the equilibrium strategies:

$$\begin{aligned}&\pi_{BM}(\Delta u_B > 0, \Delta u_A > 0|B', B) \text{ vs. } \pi_{BM}(\Delta u_B > 0, \Delta u_A > 0|B)\\&\pi_{BM}(\Delta u_B > 0, \Delta u_A = 0|B', B) \text{ vs. } \pi_{BM}(\Delta u_B > 0, \Delta u_A = 0|B),\end{aligned} \tag{15}$$

which allow us to deduce the following proposition.

Proposition 6. *Manufacturer B does not to sell the new product in the presence of PRRs if the increase in valuation triggered by PRRs on previous generation product B is far greater than that for product A, and if consumer valuation for the new product and/or perceived product differentiation is/are low in the presence of PRRs; otherwise, the opposite is true.*

Proposition 6 suggests that PRRs affect the strategy of introducing the new product. In the case of presence of PRRs, the seller can charge the buyer the extra price because of the increased willingness to pay triggered by PRRs. However, if the willingness to buy the new product is low the profit in the situation with PRRs is larger than that produced by the new product. In such a case, the release of the new product does harm to the profit in the presence of PRRs.

6. Conclusions

In this study we examined the effects of two information sources, namely (a) product reviews and ratings (PRRs) of a previous generation product and (b) information on the quality (or product-related technical information) of a new product or version, in the context of distribution channel carrying multiple products. Our results have theoretical implications related to the literature on product information disclosure by considering the cannibalization effect PRRs exacerbate between differentiated products. The analysis also yields several important insights that can inform managerial decisions related to the strategy of communicating product information in markets where differentiated products from the same manufacturer co-exist at the same time.

First, this paper sheds light on the cannibalization induced by previous generation product PRRs and consumer uncertainty about the new product. Specifically, it demonstrates that PRRs are not always beneficial for the retailer, a finding that contradicts the assumed positive attitude that retailers have on enabling consumers to post their reviews and ratings. Our finding suggests that attention should be given on inducing consumer PRRs for a previous generation product only when the new product has a low competitive edge. This result also brings new insight to the ever-growing literature on online consumer reviews and electronic word-of-mouth by suggesting that under certain conditions (such as the introduction of a new product to the market), product reviews and ratings are not always beneficial for the retailer. Also, our study provides insights into the understanding of cannibalization phenomena by resolving consumer uncertainty through disclosure of product-related technical information on new product quality. Specifically, when previous generation product PRRs are present, seller disclosure of such information is advisable only when the new product has a high competitive edge.

Second, by modeling the manufacturer and retailer's decisions in a five-stage game, we further show that the manufacturer with multiple products can strategically manipulate wholesale price cuts or limit the availability of technical information for the new product to affect the retailer's attitude toward PRRs. Taken together, both findings suggest that when deciding on any information disclosure strategy, sellers should always carefully scrutinize consumer willingness to purchase the new product and the degree of customer uncertainty on the new product.

Our findings point to several promising avenues for further research on information disclosure strategies in distribution channels. It might be interesting, for example, to examine a similar case over two periods or to study the effects of channel structure and competition on optimal information disclosure strategies. For instance, whereas in this paper we neglect another channel's response, this aspect could be amply addressed by modeling two channels' information disclosure strategies for a previous generation 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.

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Appendix A: Equilibrium outcomes

In this section we derive the equilibrium outcomes for the three-stage subgame: quality, wholesale prices and prices. We recall symmetry and denote with u the interactions $\theta_A q_A$ and $\theta_B q_B$, and with u' the interaction $\theta_{B'} q_{B'}$. Furthermore from notational convenience, we label with Δu_A and Δu_B the interactions $\Delta\theta q_A$ and $\Delta\theta q_B$.

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

$$V_B = u + \Delta u_B - p_B - tx$$

$$V_A = u + \Delta u_A - p_A - t(\frac{1}{3} - x).$$

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

$$V_A = u + \Delta u_A - p_A - t(x - \frac{1}{3})$$

$$V_{B'} = au' - p_{B'} - t(\frac{2}{3} - x),$$

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

$$V_{B'} = au' - p_{B'} - t(x - \frac{2}{3})$$

$$V_B = u + \Delta u_B - p_B - t(1 - x).$$

By setting $u + \Delta u_B - p_B - tx = u + \Delta u_A - p_A - t(\frac{1}{3} - x)$ and $au' - p_{B'} - t(x - \frac{2}{3}) = u + \Delta u_B - p_B - t(1 - x)$, one gets the demand for product B

$$D_B = \frac{3u + 6\Delta u_B - 3\Delta u_A - 6p_B + 3p_A + 2t - 3au' + 3p_{B'}}{6t}.$$

By making $u + \Delta u_B - p_B - tx = u - p_A - t(\frac{1}{3} - x)$ and $u + \Delta u_A - p_A - t(x - \frac{1}{3}) = au' - p_{B'} - t(\frac{2}{3} - x)$, we obtain the demand for product A,

$$D_A = \frac{3u - 6p_A + 2t - 3au' + 3p_{B'} - 3\Delta u_B + 6\Delta u_A - 3p_B}{6t}.$$

Finally, imposing $au' - p_{B'} - t(\frac{2}{3} - x) = u + \Delta u_A - p_A - t(x - \frac{1}{3})$ and $au' - p_{B'} - t(x - \frac{2}{3}) = u + \Delta u - p_B - t(1 - x)$, we recover the demand for the new product,

$$D_{B'} = \frac{-6u + 3p_A + 2t + 6au' - 3\Delta u_B - 3\Delta u_A + 3p_B - 6p_{B'}}{6t}.$$

Plugging D_A, D_B, $D_{B'}$ respectively into $\pi_{AM} = p_A D_A$, $\pi_{BR} = (p_B - w_B)D_B + (p_{B'} - w_{B'})D_{B'}$ and solving the first-order condition, yields to the subgame perfect equilibrium prices p_A, p_B, $p_{B'}$

$$p_A = \frac{u}{6} - \frac{\Delta u_B}{6} + \frac{4t}{9} + \frac{\Delta u_A}{3} - \frac{au'}{6} + \frac{w_B}{6} + \frac{w_{B'}}{6}$$

$$p_B = \frac{u}{12} + \frac{5\Delta u_B}{12} - \frac{\Delta u_A}{3} + \frac{5t}{9} - \frac{au'}{12} + \frac{7w_B}{12} + \frac{w_{B'}}{12}$$

$$p_{B'} = -\frac{5u}{12} - \frac{\Delta u_B}{12} - \frac{\Delta u_A}{3} + \frac{5t}{9} + \frac{5au'}{12} + \frac{w_B}{12} + \frac{7w_{B'}}{12}.$$

Substituting p_A, p_B, $p_{B'}$ into D_A, D_B, $D_{B'}$, and plugging them into $\pi_{BM} = w_B D_B + (w_{B'} - \frac{q_{B'}^2}{2})D_{B'}$, by applying first order conditions (FOCs) to it with respect to w_B and $w_{B'}$, we obtain

$$w_{B'} = \frac{q_{B'}^2}{4} + \frac{5t}{6} - \frac{u}{2} + \frac{au'}{2} - \frac{\Delta u_A}{2}$$
$$w_B = \frac{5t}{6} + \frac{\Delta u_B}{2} - \frac{\Delta u_A}{2}.$$

Now we explain how the manufacturer B decides the quality level of the new product. Moorthy (1984) and Desai (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 $(\theta_{B'} q_{B'} - 1/2 q_{B'}^2)$ in the presence of technical information for the new product or the absence of it $(a\theta_{B'} q_{B'} - 1/2 q_{B'}^2)$, the optimal quality levels in the two situation respectively are $q_{B'} = \theta_{B'}$ or $q_{B'} = a\theta_{B'}$. We also get the above results by substituting w_B, $w_{B'}$ and D_A, D_B, $D_{B'}$, into $\pi_{BM} = w_B D_B + (w_{B'} - \frac{q_{B'}^2}{2})D_{B'}$ and $u' = \theta_{B'} q_{B'}$ by applying FOCs to it with respect to $q_{B'}$.

This paper aims to study the manufacturer's strategies on motivating retailer's supportive response for PRRs, it is important to keep the quality of new product in the same level in presence or absence of the technical information, especially while studying the strategy whether disclose the technical information or not. It has no sense to compare the two situations in the presence or absence of the technical information, if the quality of the new product is different. Therefore, we assume that the manufacturer always chooses the optimal quality level for the new product $q_{B'} = \theta_{B'}$ whatever the situation is, because he can disclose the technical information to solve the uncertainty problem of consumers, but when he chooses the optimal quality level in absence of the technical information $q_{B'} = a\theta_{B'}$, he cannot get the optimal profit by disclosing the technical information. Another reason is that the manufacturer can easily choose whether disclose the technical information or not in the short run, but cannot change the level of quality of the new product easily which is a long-term decision, because it involves capital investments which may not be easily reversible in the short run.

So the equilibrium outcomes are based on $q_{B'} = \theta_{B'}$:

$$p_A = \frac{u}{12} - \frac{\Delta u_B}{12} + \frac{\Delta u_A}{6} + \frac{13t}{18} + \frac{u'}{24} - \frac{au'}{12}$$
$$p_B = \frac{u}{24} + \frac{17\Delta u_B}{24} - \frac{2\Delta u_A}{3} - \frac{au'}{24} + \frac{u'}{48} + \frac{10t}{9}$$
$$p_{B'} = \frac{17au'}{24} + \frac{7u'}{48} - \frac{\Delta u_B}{24} - \frac{2\Delta u_A}{3} - \frac{17u}{24} + \frac{10t}{9}$$
$$w_{B'} = \frac{au'}{2} + \frac{5t}{6} - \frac{u}{2} - \frac{\Delta u_A}{2} + \frac{u'}{4}$$
$$w_B = \frac{5t}{6} + \frac{\Delta u_B}{2} - \frac{\Delta u_A}{2}.$$

To shield against nonnegative demands in equilibrium, in presence or absence of PRRs, we enforce the following condition: u' must satisfy $\max\left\{\frac{2(33\Delta u+33u-20t)}{33(2a-1)}, 0\right\} < u' \leq \frac{2(21u-12\Delta u+20t)}{21(2a-1)}$. It is deliberately assumed that $t > \frac{121}{120}\Delta u$ to ensure that the interval in this equation is well behaved.

Appendix B: Proofs

Proof of Lemma 1

When q_A and q_B are endogenous in the game, the cost to produce quality q is $\frac{q^2}{2}$. The profit functions are given by:

$$\pi_{AM} = (p_A - \frac{q_A^2}{2})D_A$$
$$\pi_{BR} = (p_B - w_B)D_B$$
$$\pi_{BM} = (w_B - \frac{q_B^2}{2})D_B.$$

We can obtain get the demand for product A and product B from the surplus function in the equilibrium decisions:

$$D_A = \frac{t - \theta_B q_B + p_B + \theta_A q_A - p_A}{2t}, \tag{16}$$
$$D_B = \frac{\theta_B q_B - p_B + t - \theta_A q_A + p_A}{2t}. \tag{17}$$

We model the two manufacturers (AM, BM) and one retailer's (BR) decisions in a three-stage game. In stage 1, manufacturer A and manufacturer B respectively decide on the quality of the existing products (q_B, q_A). The wholesale price (w_B) for product B is set in stage 2 by manufacturer B. In stage 3, retailer B and manufacturer A decides 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 once $\theta_B = \theta_A$.

Proof of Theorem 1a

Compare the two cases $\pi_{BM}(\Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0)$ and $\pi_{BM}(\Delta u_A = \Delta u > 0, \Delta u_B = 0)$. When there is no product related technical information available the difference in profit is

$$\pi_{BM}(\Delta u_A > 0, \Delta u_B > 0) - \pi_{BM}(\Delta u_A > 0, \Delta u_B = 0) = \frac{\Delta u_B(-42au' + 40t + 33\Delta u_B - 24\Delta u_A + 66u_B - 24u_A + 21u')}{288t}.$$

Imposing symmetry $\Delta u_A = \Delta u_B \equiv \Delta u > 0$, we can infer the indifference threshold $u'_{BM} = \frac{42u+9\Delta u+40t}{21(2a-1)}$, beyond which the manufacturer benefits from PRRs:

if $u' > \frac{42u+9\Delta u+40t}{21(2a-1)}$, $\pi_{BM}(\Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0) - \pi_{BM}(\Delta u_A = \Delta u > 0, \Delta u_B = 0) < 0$

if $u' \leq \frac{42u+9\Delta u+40t}{21(2a-1)}$, $\pi_{BM}(\Delta u_B = \Delta u > 0, \Delta u_A = \Delta u > 0) - \pi_{BM}(\Delta u_A = \Delta u > 0, \Delta u_B = 0) \geq 0$

Because u' and t must satisfy $\max\left\{\frac{2(33\Delta u+33u-20t)}{33(2a-1)}, 0\right\} \leq u' < \frac{2(21u-12\Delta u+20t)}{21(2a-1)}$ and $t > \frac{121}{120}\Delta u$.

We compare $\frac{42u+9\Delta u+40t}{21(2a-1)}$ with $\frac{2(33u+33\Delta u+-20t)}{33(2a-1)}$ and $\frac{2(21u-12\Delta u+20t)}{21}$, and get $\frac{42u+9\Delta u+40t}{21(2a-1)} > \frac{2(21u-24\Delta u+20t)}{21(2a-1)} > \frac{2(33u+33\Delta u-20t)}{33(2a-1)}$.

So when u' satisfies $\max\left\{\frac{2(33u+33\Delta u-20t)}{33(2a-1)}, 0\right\} < u' \leq \frac{2(21u-12\Delta u+20t)}{21(2a-1)}$ and $t > \frac{121}{120}\Delta u$, $\pi_{BM}(\Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0) - \pi_{BM}(\Delta u_A = \Delta u > 0, \Delta u_B = 0) > 0$.

Proof of Theorem 1b

Compare the two cases $\pi_{BR}(\Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0)$ and $\pi_{BR}(\Delta u_A = \Delta u > 0, \Delta u_B = 0)$, and get

$$\pi_{BR}(\Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0) - \pi_{BR}(\Delta u_A = \Delta u > 0, \Delta u_B = 0) = \frac{\Delta u_B(80t - 48\Delta u_A + 93\Delta u_B + 186u_B - 48u_A - 69(2a-1)u')}{1728t}.$$

We can infer indifference threshold $u'_{BR}=\frac{138u+45\Delta u+80t}{69(2a-1)}$, beyond which the retailer benefits from PRRs.
if $u'>\frac{138u+45\Delta u+80t}{69(2a-1)}$, $\pi_{BR}(\Delta u_A=\Delta u>0,\Delta u_B=\Delta u>0)-\pi_{BR}(\Delta u_A=\Delta u>0,\Delta u_B=0)<0$
if $u'\leq\frac{138u+45\Delta u+80t}{69(2a-1)}$, $\pi_{BR}(\Delta u_A=\Delta u>0,\Delta u_B=\Delta u>0)-\pi_{BR}(\Delta u_B=\Delta u>0,\Delta u_B=0)\geq 0$,
which proves Theorem 1b.

Lemma 2

Similar to the solution in Appendix A, plugging D_A, D_B, $D_{B'}$ respectively into $\pi_{AM}=p_AD_A$, $\pi_{BR}=(p_B-w_B)D_B+(p_{B'}-w_{B'})D_{B'}$ and solving the first-order conditions yields p_A, p_B, $p_{B'}$, so that we get the subgame perfect equilibrium solutions:

$$p_B=\frac{u}{12}+\frac{5\Delta u_B}{12}-\frac{\Delta u_A}{3}+\frac{5t}{9}-\frac{au'}{12}+\frac{7w_B}{12}+\frac{w_{B'}}{12}$$
$$p_{B'}=-\frac{5u}{12}-\frac{\Delta u_B}{12}-\frac{\Delta u_A}{3}+\frac{5t}{9}+\frac{5au'}{12}+\frac{w_B}{12}+\frac{7w_{B'}}{12}$$
$$D_B=\frac{21u+33\Delta u_B-12\Delta u_A-21au'-33w_B+20t+21w_{B'}}{72t}$$
$$D_{B'}=\frac{-33u-21\Delta u_B-12\Delta u_A+33au'-33w_{B'}+20t+21w_B}{72t}.$$

Comparing $\pi_{BR}(w_{B'},w_B\mid\Delta u_A=\Delta u>0,\Delta u_B=\Delta u>0)$ with $\pi_{BR}(w_n,w_B\mid\Delta u_A=\Delta u>0,\Delta u_B=0)$, then we demonstrate that the retailer does not boycott PRRs conditional on the manufacturer charging wholesale prices $\hat{w}_{B'}$ and $\hat{w}_B$, so

$\pi_{BR}(\hat{w}_{B'},\hat{w}_B\mid\Delta u_A=\Delta u>0,\Delta u_B=\Delta u>0)$-$\pi_{BR}(w_{B'},w_B\mid\Delta u_A=\Delta u>0,\Delta u_B=0)$
$=\frac{\Delta u_B(138w_{B'}+93\Delta u_B-48\Delta u_A-186w_B+138u+80t-138au')}{432t}\geq 0.$

Proof of Proposition 1

We put the constraint $\frac{\Delta u_B(138w_{B'}+93\Delta u_B-48\Delta u_A-186w_B+138u+80t-138au')}{432t}>0$ into $\pi_{BM}=w_BD_B+(w_{B'}-\frac{q^2_{B'}}{2})D_{B'}$, then the Lagrangian for the manufacturer's problem is

$\max\Pi(\hat{w}_{B'},\hat{w}_B,\lambda)=\hat{w}_BD_B+(\hat{w}_{B'}-\frac{q^2_{B'}}{2})D_{B'}+\lambda(138w_{B'}+93\Delta u_B-48\Delta u_A-186w_B+138u+80t-138au')$,

and the Kuhn-Tucker conditions for optimality are:

$\frac{\delta\Pi(\hat{w}_{B'},\hat{w}_B,\lambda)}{\delta\hat{w}_{B'}}=\frac{33au'+20t-33u+21\hat{w}_B-33\hat{w}_{B'}-21\Delta u_B-12\Delta u_A}{72t}-\frac{11(\hat{w}_{B'}-\frac{q^2_{B'}}{2})}{24t}+\frac{7\hat{w}_B}{24t}+138\lambda$
$\frac{\delta\Pi(\hat{w}_{B'},\hat{w}_B,\lambda)}{\delta\hat{w}_B}=-\frac{21au'-20t-21u+33\hat{w}_B-21\hat{w}_{B'}-33\Delta u_B+12\Delta u_A}{72t}+\frac{7(\hat{w}_{B'}-\frac{q^2_{B'}}{2})}{24t}-\frac{11\hat{w}_B}{24t}-186\lambda$
$\frac{\delta\Pi(\hat{w}_{B'},\hat{w}_B,\lambda)}{\delta\lambda}=138\hat{w}_{B'}+93\Delta u_B-48\Delta u_A-186\hat{w}_B+138u+80t-138au'$.

Because $\hat{w}_{B'}>0$ and $\hat{w}_B>0$, we can get

$\hat{w}_B=\frac{545t}{534}+\frac{115u}{356}-\frac{115au'}{356}+\frac{\Delta u_B}{2}-\frac{109\Delta u_A}{178}+\frac{155q^2_{B'}}{712}$
$\hat{w}_{B'}=\frac{425t}{534}-\frac{201u}{356}+\frac{201au'}{356}+\frac{155q^2_{B'}}{712}-\frac{85\Delta u_A}{178}$.

In addition, $q_{B'}=\theta_{B'}$. The condition that the manufacturer reduces the wholesale price to induce the retailer not to boycott the positive review ratings must ensure that his profit would not be harmed. In other words, his profit in the case of consumer positive reviews shall not be less than in the case without consumer positive reviews $\pi_{BM}(\hat{w}_{B'},\hat{w}_B\mid\Delta u_A=\Delta u>0,\Delta u_B=\Delta u>0)\geq\pi_{BM}(w_{B'},w_B\mid\Delta u_A=\Delta u>0,\Delta u_B=0)$. Compare $\pi_{BM}(\hat{w}_{B'},\hat{w}_B\mid\Delta u_A=\Delta u>0,\Delta u_B=\Delta u>0)$ with $\pi_{BM}(w_{B'},w_B\mid\Delta u_A=\Delta u>$

$0, \Delta u_B = 0)$, we get $\pi_{BM}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0) - \pi_{BM}(w_{B'}, w_B \mid \Delta u_A = \Delta u > 0, \Delta u_B = 0) = \frac{4761(2a-1)^2 u'^2 - 12(2a-1)u'(920t+1587u-2421\Delta u)+4(69u+40t)^2-36\Delta u(203\Delta u+1614u+1400t)}{-307584t}$.

The solutions yields u' of above equation are

$\hat{u}'_1 = \frac{2(1587u-2421\Delta u+920t+6\sqrt{89}\sqrt{\Delta u(2131\Delta u+690t)})}{1587(2a-1)}$

and

$\hat{u}'_2 = \frac{2(1587u-2421\Delta u+920t-6\sqrt{89}\sqrt{\Delta u(2131\Delta u+690t)})}{1587(2a-1)}$

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

$\pi_{BM}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0) \geq \pi_{BM}(w_{B'}, w_B \mid \Delta u_A = \Delta u > 0, \Delta u_B = 0)$.

If the inequalities ($t > \frac{289}{120}\Delta u$ and $\frac{2(21u+20t-24\Delta u)}{21(2a-1)} \geq u' > \frac{(138u+45\Delta u+80t)}{69(2a-1)}$) hold, the retailer can boycott the positive reviews when his profit is hurt by positive reviews, i.e. when ($\pi_{BR}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_B > 0, \Delta u_A > 0) - \pi_{BR}(w_{B'}, w_B \mid \Delta u_A = \Delta u > 0, \Delta u_B = 0) < 0$).

By comparing $\hat{u}'_1$ and $\hat{u}'_2$, with $\frac{2(21u+20t-24\Delta u)}{21(2a-1)}$ and $\frac{(138u+45\Delta u+80t)}{69(2a-1)}$, we have that if $t > \frac{289\Delta u}{120}$ and $\frac{138u+45\Delta u+80t}{69(2a-1)} < u' \leq min\left\{\frac{2(21u+20t-24\Delta u)}{21(2a-1)}, \hat{u}'_1\right\}$, the manufacturer can reduce the wholesale prices to $\hat{w}_{B'}$, $\hat{w}_B$, as to induce the retailer not to boycott the positive reviews $\pi_{BM}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0) \geq \pi_{BM}(w_{B'}, w_B \mid \Delta u_A = \Delta u > 0, \Delta u_B = 0)$ and promise in return $\pi_{BR}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0) \geq \pi_{BR}(w_{B'}, w_B \mid \Delta u_A = \Delta u > 0, \Delta u_B = 0)$. Thus Proposition 1 is proven.

Proof of Lemma 3

From the Theorem 1, we can deduct that if $u'_2(a=1) = \frac{138u+45\Delta u+80t}{69} < u' \leq u'_3(a=1) = \frac{2(21u-12\Delta u+20t)}{21}$, the retailer is unwilling to post PRRs when there is technical information and if $u'_2(a) = \frac{138u+45\Delta u+80t}{69(2a-1)} < u' \leq u'_3(a) = \frac{2(21u-12\Delta u+20t)}{21(2a-1)}$ in the situation without technical information, he does not post PRRs. By compare with $u'_2(a=1), u'_3(a=1), u'_2(a), u'_3(a)$, we obtain that if $u'_2(a=1) < u' \leq \min\{u'_2(a), u'_3(a=1)\}$, the retailer does not post PRRs in the presence of technical information, where he would have done so in absence of technical information. With the condition $\max\left\{\frac{2(33u+33\Delta u-20t)}{33(2a-1)}, 0\right\} < u' \leq \frac{2(21u-12\Delta u+20t)}{21}$ that shields against nonnegative demands in equilibrium, so u' must satisfy $u'_2(a=1) = \frac{138u+45\Delta u+80t}{69} > \frac{2(33u+33\Delta u-20t)}{33(2a-1)}$ (when $\frac{3036u+2013\Delta u-40t}{22(138u+45\Delta u+80t)} < a < 1$). Therefore, Lemma 3 can be obtained.

Proof of Proposition 2

By comparing $\pi_{BM}(\Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0, \frac{1}{2} < a < 1)$ (limited availability of technical information and PRRs) with $\pi_{BM}(\Delta u_A = \Delta u > 0, \Delta u_B = 0, a = 1)$ (full information of technical information and no PRRs) we get:

$$\Delta\pi^{**}_{BM} = \pi_{BM}(\Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0, \tfrac{1}{2} < a < 1) - \pi_{BM}(\Delta u_A = \Delta u > 0, \Delta u_B = 0, a = 1) =$$

$$\frac{33au'^2(a-1)}{288t} + \frac{u'(45\Delta u - 66ua + 40ta - 40t + 66u - 66\Delta ua)}{288t} + \frac{\Delta u(9\Delta u + 42u + 40t)}{288t}.$$

Define $F(u') \equiv 33au'^2(a-1) + \frac{u'(45\Delta u-66ua+40ta-40t+66u-66\Delta ua)}{288t} + \Delta u(9\Delta u + 42u + 40t)$ and notice that $F(u')$ is concave in u'. From Theorem 1, we know that when $u'_2(a=1) = \frac{138u+45\Delta u+80t}{69} < u' < \frac{138u+45\Delta u+80t}{69(2a-1)}$, which shown that the retailer would favor to post PRRs in absence of product technical information and choose not to post PRRs in the presence of technical information.

There are two solutions ($u'^{**}_1(a) < u'_2(a=1) < u'^{**}_2(a)$) that satisfy the constraint ($F(u'^{**}_1) = F(u'^{**}_2) = 0$) and there are two solutions (t^{**}_1 and t^{**}_2) that satisfy $F(u'_2(a=1)) = 0$. Given the functional form of $F(u')$, we have that when $u_1'^{**} < u' < u_2'^{**}$, $F(u') > 0$, and when $t_1^{**} < t < t_2^{**}$, $F(u_2'(a=1)) > 0$. So we have that if $u_2'(a=1) < u' < u_2'^{**}$, $\Delta\pi_{BM}^{**} > 0$.

We also verify that when $1 > a \geq \frac{198u+125\Delta u+9\sqrt{455}\Delta u}{11(31\Delta u+18u)}$, $t_1^{**} < t_2 < t_2^{**}$. By combining this result with the one above, we get that when $1 > a \geq \frac{198u+125\Delta u+9\sqrt{455}\Delta u}{11(31\Delta u+18u)}$, $t_2 < t < t_2^{**}$, and $u_2'(a=1) < u' < \min\{u_2'^{**}, u_3'(a=1), u_2'\}$, $\Delta\pi_{BM}^{**} > 0$. We label t_2^{**}, as t^{**}, and $u_2'^{**}$ as u'^{**} in the paper.

$u_1'^{**}, u_2'^{**} = \frac{(2(20t-33u)(a-1)-3\Delta u'(22a-15))}{66a(1-a)} \pm \frac{1}{66a(1-a)}(4a^2(40t(10t-33u-66\Delta u')+99u(11u+8\Delta u')+792\Delta u'^2)-4a(20t(40t-132u-177\Delta u')+99u(22u+23\Delta u')+1188\Delta u'^2)+80t(20t-66u-45\Delta u)+9(22u+15\Delta u)^2)^{\frac{1}{2}}$ and

$t^{**} = \frac{3(44(15\Delta u+46u)a^2-\Delta u(1327a-874)-46u(1+43a))}{160(22a+23)(1-a)} + \frac{69\sqrt{\frac{9a^2(150u+113\Delta u)^2}{25}+\frac{36(75u+49\Delta u)^2}{25}-\frac{9a(300u+211\Delta u)^2}{50}-\frac{\Delta u^2(16192a^2-16928-1289a)}{50}}}{160(22a+23)(1-a)}$.

Thus Proposition 2 is proven.

Proof of Proposition 3

Subtracting $\pi_{BM}(w_{B'}, w_B|\Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0, \frac{1}{2} < a < 1)$ (limit availability of technical information and PRRs) from $\pi_{BM}(\hat{w}_{B'}, \hat{w}_B \mid \Delta u_A = \Delta u > 0, \Delta u_B = \Delta u > 0, a = 1)$ (discount wholesale prices and provide technical information, and PRRs), we get:

$\Delta\pi_{BM}^{*} = \frac{9(529+3916a^2-3916a)u'^2+Bu'+C}{-307584t}$. Define $G(u') = -9(529+3916a^2-3916a)u'^2 - Bu' - C$ and notice that $G(u')$ is concave in u' when $1 > a > \frac{1}{2} + \frac{15}{1958}\sqrt{1958}$. Similarly to Proposition 2, there are two solutions (here denoted $u_1'^{*}$, $u_2'^{*}$) that satisfy $G(u') = 0$. When $t_2 < t < t^{*}$ (under the condition $1 > a > a^{*} = \frac{35244u+22250\Delta u+9\sqrt{17309165}\Delta u}{1958(31\Delta u+18u)}$), $G(u_2'(a=1)) < 0$, and when $1 > a > a^{*}$, $t_2 < t < t^{*}$, $u_2'(a=1) < u' < \min\{u_2', u_3'(a=1)\}$, $\Delta\pi_{BM}^{*} < 0$.

The terms of interest are: $u_1'^{*}, u_2'^{*} = \frac{2(178a(33u+33\Delta u'-20t)+4480t-4287u-6426\Delta u)}{3(3916a(a-1)+529)} \pm \frac{4}{3(3916a(a-1)+529)}(267a^2(40t(150t-1485u-803\Delta u')+66u(225u+1163\Delta u')+30195\Delta u'^2)-801a(20t(400t-1635u-1418\Delta u')+33u(300u+1313\Delta u')+22858\Delta u'^2)+5340t(900t-1935u-2648\Delta u')+8811(450u+1163\Delta u)(u+\Delta u))^{\frac{1}{2}}$, and

$t^{*} = \frac{3(4094u(44a+1)(a-1)+89\Delta u(660a^2-1327a-575))}{14240(22a+23)(1-a)} + \frac{23\sqrt{64160100u^2(a-1)^2+285156u\Delta u(a-1)(31a-301)+89\Delta u^2(258215-63640a+64949a^2)}}{14240(22a+23)(1-a)}$.

Thus Proposition 3 is proven.

Proof of Proposition 4

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

$$p_A = \frac{u}{12} - \frac{\Delta u_B}{12} + \frac{\Delta u_A}{6} + \frac{\delta t}{18} + \frac{2t}{3} + \frac{u'}{24} - \frac{au'}{12}$$

$$p_B = \frac{u}{24} + \frac{17\Delta u_B}{24} - \frac{2\Delta u_A}{3} - \frac{au'}{24} + \frac{u'}{48} - \frac{11\delta t}{36} + \frac{17t}{12}$$

$$p_{B'} = \frac{17au'}{24} + \frac{7u'}{48} - \frac{\Delta u_B}{24} - \frac{2\Delta u_A}{3} - \frac{17u}{24} - \frac{5\delta t}{36} + \frac{5t}{4}$$

$$w_{B'} = \frac{au'}{2} + \frac{17t}{18} - \frac{\delta t}{9} - \frac{u}{2} - \frac{\Delta u_A}{2} + \frac{u'}{4}$$

$$w_B = \frac{19t}{18} - \frac{2\delta t}{9} + \frac{\Delta u_B}{2} - \frac{\Delta u_A}{2}$$

$$D_B = \frac{42u + 66\Delta u_B - 42au' - 24\Delta u_A + 60t - 20\delta t + 21u'}{288t}$$
$$D'_B = \frac{-66 - 4266\Delta u_B + 6642au' - 24\Delta u_A + 36t + 4\delta t - 3u'}{288t}.$$

Thus Proposition 4 is proven.

Proof of Proposition 5

When $q_A\theta_A > q_B\theta_B$, we get

$\pi_{BR}(\Delta u_A > 0, \Delta u_B > 0) - \pi_{BR}(\Delta u_A > 0, \Delta u_B = 0) = \frac{\Delta u_B(-80t-93\Delta u_B+48\Delta u_A-186u_B+48u_A+69u'(2a-1))}{-1728t}$

$\pi_{BM}(\hat{q} = q_{B'}) - \pi_{BM}(\hat{q} = aq_{B'}) = \frac{u'(1-a)(33u'a-42u_B+40t-42\Delta u_B-24u_A-24\Delta u_A)}{288t}$

From the first equation, $\frac{d(\pi_{BL}(\Delta u_A>0,\Delta u_B>0)-\pi_{BL}(\Delta u_A>0,\Delta u_B=0))}{du_A} < 0$, so if u_A is sufficiently high ($q_A\theta_A = u_A > \frac{5t}{3} + \frac{31u_B}{8} + \frac{31\Delta u_B}{16} - \Delta u_A - \frac{23(2a-1)u'}{16}$), $\pi_{BR}(\Delta u_A > 0, \Delta u_B > 0) - \pi_{BR}(\Delta u_A > 0, \Delta u_B = 0) < 0$. From the second equation, if $u' > \frac{2(4u_A+7u_B+4\Delta u_A+7\Delta u_B)}{11a}$ or $t > \frac{3\Delta u_A}{5} + \frac{21\Delta u_B}{20} + \frac{3u_A}{5} + \frac{21u_B}{20}$, $\pi_{BM}(\hat{q} = q_{B'}) - \pi_{BM}(\hat{q} = aq_{B'}) > 0$. Thus Proposition 5 is proven.

Proof of Proposition 6

By referring to the utility function in Appendix A, we can deduce the demand of B and A when there is no new product in the market, by making $u + \Delta u_B - p_B - tx = u + \Delta u_A - p_A - t(\frac{1}{3} - x)$ and $u + \Delta u_A - p_A - t(x - \frac{1}{3}) = u + \Delta u_B - p_B - t(1 - x)$, we can get:

$$D_B = \frac{2\Delta u_B - 2\Delta u_A - 2p_B + 2p_A + t}{2t}$$
$$D_A = \frac{2\Delta u_A - 2\Delta u_B + 2p_B - 2p_A + t}{2t}.$$

Similarly to what we have shown in Appendix A, we get:

$$\pi_{BM}(\Delta u_B > 0, \Delta u_A > 0|B', B) - \pi_{BM}(\Delta u_B > 0, \Delta u_A > 0|B) =$$
$$\frac{99u'^2+12(20t-21\Delta u_B-12\Delta u_A-33u)u'-12\Delta u_B(32t-42u-9\Delta u_B)-96\Delta u_A(t-3u-3\Delta u_B)-480tu+152t^2+396u^2}{3456t}.$$

We obtain two solutions: u'_{BM1} and u'_{BM2}, each ensuring that the above equation equals zero when $(2\sqrt{11} - 6)(\Delta u_A - \Delta u_B) < t < (-2\sqrt{11} - 6)(\Delta u_A - \Delta u_B)$ and $\Delta u_B > \Delta u_A$. It is easy to show that when $\Delta u_A \geq \Delta u_B$, there are no solutions for the above equation (because of the convexity in u'), so $\pi_{BM}(\Delta u_B > 0, \Delta u_A > 0|B', B) - \pi_{BM}(\Delta u_B > 0, \Delta u_A > 0|B) > 0$.

Only for $\Delta u_B > \Delta u_A$, there are two solutions satisfying $u'_{BM1} < u' < u'_{BM2}$, $\pi_{BM}(\Delta u_B > 0, \Delta u_A > 0|B', B) - \pi_{BM}(\Delta u_B > 0, \Delta u_A > 0|B) < 0$. We assume that $\Delta u_B > \Delta u_A = 0$ (The increased valuation triggered by PRRs on the previous generation product in channel B is far greater than that for the product in channel A), so that we can explain the proposition easily and simplify the analysis. Therefore, we can get that when $\frac{121\Delta u_B}{120} < t < 2(3 + \sqrt{11}\Delta u_B)$ and $u'_{BR,BM2} = \frac{14\Delta u_B}{11} - \frac{40t}{33} + 2u + \frac{2\sqrt{16\Delta u_B^2+24tt\Delta u-2t^2}}{11} > u' > \frac{2(33u+33\Delta u-20t)}{33}$, $\pi_{BM}(\Delta u_B > 0, \Delta u_A > 0|B', B) - \pi_{BM}(\Delta u_B > 0, \Delta u_A > 0|B) < 0$.

Thus Proposition 6 is proven.