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New Product Design under Channel Acceptance: Brick-and-Mortar, Online-Exclusive, or Brick-and-Click

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In recent years, an increasing number of brick-and-mortar retailers have entered into the new brick-and-click era. Within this context, when a manufacturer presents a new product offering to a retailer, the ultimate decision is often made by the retailer regarding (1) whether to carry the new product, and (2) the channel outlet the product will be carried in (i.e., in-store only, online-exclusive, or brick-and-click). In response to this trend, we examine how a manufacturer may use product design to influence a dual-channel retailer's outlet designation decision. This is the first study to investigate a manufacturer's optimal product design strategy when a brick-and-mortar retailer expands online. We demonstrate that, to induce the retailer to carry a new product both offline and online, it may not always be optimal for the manufacturer to enhance product quality (compared with when the retailer only operates offline). With the online store addition, the retailer may also be incentivized to adjust his participation criterion to a level less than what is determined by his outside option.

Key words: marketing; new product design; multi-channel retailer; supply chain; game theory
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1. Introduction

In recent years, an increasing number of traditional brick-and-mortar retailers (e.g., Home Depot, Toys R Us) have transitioned into the new brick-and-click era to further expand their storefront as well as their customer bases (e.g., IBISWorld 2011a, Manhanttan Associates 2010, Hoover's Company's Report on Target, Wal-Mart, and Home Depot 2015). With the emerging trend of brick-and-mortar retailers opening online businesses, new product manufacturers often do not control whether a new product offering will be accepted, nor the channel outlet the product will be carried in (in-store only, online-exclusive, or brick-and-click). Instead, the retailer often makes ultimate decisions regarding whether to stock the new product and how the product will be sold to the consumer. This occurrence is widespread in numerous markets, such as toys, power tools, and apparel. In response to this trend, manufacturers have also started to take retailers' online storefront into consideration in their product planning (Retailing Today 2011, Warehouse Club Focus 2011).

With traditional brick-and-mortar retailers entering into the new brick-and-click era, we observe that manufacturers respond differently by trying to either enhance or lower the quality of their new product offerings. For example, MagnoGrip produces magnetized accessories (e.g., wristbands that hold nails and screws) that are currently designated as "online-exclusive" by Home Depot. In an interview with the San Francisco Business Times (2009), the owner of MagnoGrip discussed how the company would strive hard to enhance the quality of its product offerings so that they would eventually be accepted into Home Depot's physical stores. In contrast, historically Tiffany & Co. was renowned for only accepting high-end non-jewelry accessories (e.g., sterling goods, small leather items) from third-party manufacturers. Nevertheless, ever since the upscale retailer established its online business, a number of less-expensive, lower-quality offerings from these manufacturers have been added in Tiffany's brick-and-click store (Tiffany & Company: A Case Study, Blackburn 2004, Jewelry Stores in the US, IBISWorld, 2011b).

While we observe manufacturers' efforts to either increase or lower product quality when a brick-and-mortar retailer opens an online business, no extant research has formally examined a manufacturer's optimal product design strategy when such a retailer expands online. Although the driving forces behind manufacturers' quality choices could be multi-faceted in practice, the primary emphasis of this study is to examine how a manufacturer may use product design to influence a dual-channel retailer's channel outlet designation decision. This is the first study to investigate a manufacturer's (her) new product design strategy when a brick-and-mortar retailer (he) expands online. We also investigate how the profits of the manufacturer and the retailer are affected by the latter's decision to operate in dual channels.

Within our context, the key considerations faced by the manufacturer are as follows: First, the manufacturer must ensure that the retailer is willing to participate in the trade. In today's marketplace, retailers often serve as gatekeepers of new product introductions (e.g., Luo et al. 2007, Wall Street Journal 2005). As a result, when designing the new product, the manufacturer must take into account the opportunity cost incurred by the retailer when the latter decides to stock the new product. In the literature, the retailer's participation criterion is often operationalized such that the retailer will only stock a new product if he expects to earn at least a minimum profit (e.g., Anupindi and Bassok 1999, Desai 2000, and Luo et al. 2007).[1] Such a profit threshold mainly reflects the retailer's opportunity cost of accepting an alternative product into his store (i.e., his outside option). Recognizing the retailer's participation criterion is particularly useful in our context, because the retailer's opportunity cost of allocating his highly constrained physical shelf space to a new product is likely to be considerably higher than that of allocating virtual shelf space.[2] Such a difference in turn affects the manufacturer's new product design strategy when working with a dual-channel retailer.

Second, the manufacturer faces the following tradeoffs when deciding whether to design the new product to target the retailer's offline or online store. If the retailer decides to carry the new product in-store, the manufacturer will enjoy the physical display of her new product. However, in such cases, the manufacturer must satisfy the retailer's greater participation criterion, which may potentially hinder the manufacturer's profit. In contrast, if the new product is carried as an online-exclusive, consumers will not be able to physically inspect the product prior to product purchase. Such a drawback is particularly salient when the touch-and-feel of the new product plays an integral role in consumers' purchase decision, for instances, in product categories such as apparel, jewelry, accessories, furniture, home decor, and so on (Wankhade and Dabade 2010). Forrester Research (2008) notes that "most consumers still prefer stores… by shopping in stores, consumers can touch and feel items [and] avoid issues surrounding returns." This finding was also supported by Jupiter Research (Forrester Research 2009) and a consumer survey by PriceGrabber.com (Ofek et al. 2011). Because of unlimited shelf space in the retailer's online store, however, it is also relatively easier for the manufacturer to satisfy the retailer's participation criterion. Additionally, as the online storefront extends the market to consumers with no easy access to the retailer's brick-and-mortar store and offers additional benefits such as added convenience, greater time savings, and lower search cost (Lal and Sarvary 1999), the manufacturer has the potential to exploit such benefits and become more profitable by positioning her product for the retailer's online store.

1.1. Key Findings

We develop a game-theoretic model to capture the above tradeoffs faced by the new product manufacturer. Our key findings are summarized below.

Interestingly, to induce the retailer to carry a new product both offline and online, it may not always be optimal for the manufacturer to enhance product quality (compared with when the retailer only operates offline). In particular, when the online storefront is relatively less appealing for the retailer, for example, in product categories such as apparel and accessories where the lack of physical inspection is of major concern and the benefits of online shopping are relatively small, the manufacturer may strategically lower the quality of her new product (may even be lower than the optimal quality level in the online-exclusive option) so that the retailer will opt to make the product available in both channels. In contrast, for product categories whose online shopping benefits are ample and/or the lack of touch-and-feel is often considered less vital by consumers (e.g., appliances and electronics), the manufacturer may strategically enhance product quality to induce the retailer to carry it both offline and online.

The above findings stem from the greater probability of product mismatch faced by consumers when purchasing a newly introduced product online without physical inspection. As a result, the discrepancy between offline and online willingness-to-pay is greater in magnitude at higher quality levels. Consequently, when the touch-and-feel of the new product is crucial (e.g., apparel and accessories), to attract some consumers to the retailer's online store, a strategic manufacturer will introduce a product of lower quality to reduce the disutility of online purchase. Therefore, the retailer will find it more profitable to carry the new product both offling and online (rather offline only).

In contrast, when online shopping benefits are high and/or the lack of touch-and-feel is generally considered less vital by consumers (e.g., appliances and electronics), the manufacturer will increase the quality of her new product offering such that it would also be appealing to the retailer's offline store. As a result, the retailer will be incentivized to designate the new product to his brick-and-click store (rather than online only).

In both cases discussed above, the adjusted quality level of the new product also reduces the potential market cannibalization effect (i.e., margin loss) faced by the retailer and the manufacturer. When the new product is carried both offline and online, some consumers have the flexibility to purchase it from either channel outlet while others do not. We referred to the former as switch consumers. Because the retailer cannot price discriminate among consumers within each channel outlet, switch consumers may enjoy a positive surplus from purchasing the new product from whichever channel outlet that offers them with a greater utility. This positive surplus implies a margin loss, which in turn leads to the cannibalization effect.

In product categories where the touch-and-feel of the new product is crucial for consumers and the benefits of online shopping are relatively small (e.g., apparel and accessories), this positive surplus of switch consumers is an increasing function of product quality. In contrast, for product categories with ample online shopping benefits and/or whose physical inspection is less crucial (e.g., appliances and electronics), this positive surplus may decrease with product quality. As a result, the manufacturer's quality choices in both scenarios also align with reduced market cannibalization.

We also find that, with the addition of the online store, the retailer gains additional leverage and may obtain a profit greater than (rather than equal to) his opportunity cost of carrying an alternative product in each respective channel. The retailer receives such an extra surplus when the brick-and-click option emerges in equilibrium, which arises at intermediate values of the offline-participation criterion. And the retailer receives the most surplus, may even be the most profitable, at the tipping point where the brick-and-click option is just slightly more attractive for him than the online-exclusive option. At this point, the manufacturer must make the utmost adjustment in her product offering to induce the retailer to carry the product both offline and online. As a result, the retailer may be incentivized to adjust his participation criterion to a level less than what is determined by his outside option.

1.2. Related Literature

This study relates to a broad literature on how firms should optimally design their new products in a wide variety of contexts, such as consumer self-selection (Moorthy 1984), differential cost structure (Tyagi 2000), product cannibalization (Desai 2001), marketing-manufacturing trade-offs (Desai et al. 2001), network externality (Sun et al. 2004), heterogeneous buyer search costs (Kuksov 2004), uncertain demand (Tyagi 2006), reference group comparison (Amaldoss and Jain 2010), varying purchase histories (Zhang 2011), endogenous deliberation (Guo and Zhang 2012), stringent deadlines (Zhang 2016), and so on. We add to this literature by investigating how a manufacturer should design a new product when a brick-and-mortar retailer expands online.

Our research also builds upon a second stream of literature that studies manufacturer-retailer interactions in a distribution channel. For example, Jeuland and Shugan (1983) and Iyer (1998) have studied how a manufacturer can induce a retailer to offer the level of service and/or price that is also desired by the manufacturer. Tyagi (1999) examines how a retailer responds to a manufacturer's trade deals. More recently, with the emerging power of retailers in many product markets, several researchers have started to emphasize the retailer's critical role in the manufacturer's product design strategy within the context of a single-channel retailer (e.g., Luo 2011, Luo et al. 2007, Villas-Boas 1998, and Williams et al. 2011). We extend this line of research by providing the first formal analysis to examine how a manufacturer can strategically use product design to influence a dual-channel retailer's channel outlet designation decisions.

Lastly, this research can be linked to the literature that explores the market impact of online store adoption. From the perspective of the manufacturer, several researchers have examined a manufacturer's decision to complement its traditional channel with a direct channel, for example, an online store (e.g., Cai 2010, Cattani et al. 2006, Chen et al. 2008, Chiang et al. 2003, Kumar and Ruan 2006, Mukhopadhyay et al. 2008, Ryan et al. 2012, Tsay and Agrawal 2004). From the perspective of the retailer, researchers have studied whether a brick-and-mortar retailer should adopt a dual-channel strategy (e.g., Bernstein et al. 2008, Liu et al. 2006, Zhang 2009), and how the retailer's online-store addition affects his strategies such as pricing and in-store service (e.g., Ofek et al. 2011). We extend this literature by investigating how the online store addition of the retailer impacts the manufacturer's new product design decisions.

2. Model Setup

In this section we construct a stylized model to parsimoniously illustrate the key trade-offs faced by the new product manufacturer. In Section 4, we will relax a set of assumptions made here and discuss implications from several modifications and extensions to the main model.

In practice, not all consumers live within the geographical proximity of retailer's physical stores. For simplicity, we assume that consumers of proportion α have access to the retailer's offline store, and the remaining consumers do not have such access. To capture the potential additional reach of the retailer with his online store addition, we follow Ofek et al. (2011) by assuming that all consumers have access to the retailer's online store.

When the new product is carried as online-exclusive, consumers are unable to touch and feel the product when making a purchase decision. The lack of physical inspection is the primary concern of most consumers with online shopping in many product categories, such as apparel, jewelry, accessories, furniture, home decor, and so on (e.g., Forrester Research 2008, 2009). Therefore, compared to those who purchase the new product from the retailer's offline store, online consumers face a greater probability of product mismatch due to the lack of physical inspection. In line with Chiang et al. (2003), Shin (2007), Bernstein et al. (2008), and Wankhade and Dabade (2010), we conceptualize the disutility of online purchases as a probability of product mismatch due to consumer's inability to touch and feel the new product. Therefore, consumers' willingness-to-pay associated with purchasing a new product online is characterized as δq ($0 < \delta < 1$), with q being the intrinsic value of the product. Chiang et al. (2003) also provides empirical evidence that the value of the parameter δ varies by product category, ranging from 0.769 for shoes to 0.904 for books.[3]

Because the empirical results in Chiang et al. (2003) were collected back in 2003, we carried out an independent empirical study to elicit consumers' willingness-to-pay for purchasing a newly introduced product from a traditional vs. a web store (see details in Appendix S1). Our survey comprises a variety of product categories including apparel, consumer electronics, furniture, home appliances, jewelry, and books. We discover that consumers' willingness-to-pay for a newly launched product online without touch-and-feel is 70.46% of its offline equivalent for apparel, 85.33% for consumer electronics, 72.97% for furniture, 81.30% for home appliances, 73.78% for jewelry, and 87.17% for books. Consistent with Chiang et al. (2003), Bernstein et al. (2008), and the setup in our model, our empirical study further reveals that consumers' willingness-to-pay for a newly introduced product online without physical inspection is proportional to the intrinsic value of the product (rather than equivalent to the product's intrinsic value minus a fixed disutility term as proposed in some prior research).

We further account for the fact that consumers may differ in their online shopping skills (i.e., some consumers are more skillful than others in alleviating the probability of product mismatch without physically evaluating the product), which in turn results in consumers' heterogeneous susceptibility towards buying a new product online. For instance, certain consumers may possess greater expertise in the product category and/or have abundant experience with online shopping, and hence are less susceptible to the disutility associated with online purchases. Let's assume that consumers of proportion β are more skillful in this regard and hence attach less disutility (i.e., obtaining utility $\delta_h q$) towards online purchase. And consumers of proportion $1 - \beta$ are less skillful in this respect, and hence attach $\delta_l q$ (with $0 < \delta_l < \delta_h < 1$) towards online purchase.

Additionally, as compared to offline shopping, online purchases offer some unique benefits to consumers, such as added convenience, greater time savings, and lower search costs (e.g., Bhatnagar et al. 2000, Devaraj et al. 2002, Lal and Sarvary 1999). Accordingly, we denote an online shopping benefit of $s > 0$ when consumers purchase the product online. Therefore, parameters δ and s illustrate how the drawback-benefit tradeoff of online purchasing affects the endogenized product quality decision made by the manufacturer. For example, when q is sufficiently low, $\delta q + s$ may be greater than q such that purchasing the new product online becomes a more attractive option for some consumers. As illustrated later, this role of product quality in such a trade-off leads to strategic interactions between the manufacturer's product quality decision and the retailer's channel outlet choice.[4]

In Table 1, we summarize the four consumer types along with each type's proportion and its utility of offline and online purchases. The total market size is normalized to unity. We also assume that consumer heterogeneity with respect to online shopping skills is high enough, that is, $\delta_h > \delta_l/\beta$, such that (1) serving only the more-online-skilled segment and (2) serving less- and more-online-skilled segments are both likely to arise in equilibrium. Furthermore, as online shopping accounts for less than 10% of all U.S. shopping (U.S. Census Bureau News 2015), we assume that there are more offline shoppers than consumers who are more skilful in online shopping, that is, $\alpha > \beta$.

Following Desai (2000), Anupindi and Bassok (1999), and Luo *et al*. (2007), the retailer's participation criterion is operationalized as a minimum profit

Table 1 Consumer Types and Utilities of Offline (U_1) and Online Purchase(U_2)

Consumer type	Proportion	U_1	U_2
More-online-skilled, offline-accessible	$\alpha\beta$	$q - p$	$\delta_h q + s - p$
Less-online-skilled, offline-accessible	$\alpha(1 - \beta)$	$q - p$	$\delta_l q + s - p$
More-online-skilled, offline-inaccessible	$(1 - \alpha)\beta$	/	$\delta_h q + s - p$
Less-online-skilled, offline-inaccessible	$(1 - \alpha)(1 - \beta)$	/	$\delta_l q + s - p$

threshold that is exogenously given and known to the manufacturer. As discussed in Luo et al. (2007), because retailers today often face numerous new product offerings, the use of an exogenously given minimum profit threshold is likely to be many retailers' most effective way of deciding whether to accept or reject a new product. Additionally, given that manufacturers and retailers operating in such markets often have ongoing relationships, this profit threshold is usually known to the manufacturer.

Let us denote the retailer's participation criterion for his offline and online stores as R and r, respectively, with $R > r$, because the retailer's opportunity cost of adding a new product to his highly constrained physical store is likely to be considerably higher than that of carrying the new product online. We further denote the retailer's profit from the new product when carrying it offline as π_1^r, online as π_2^r, and both offline and online as π_3^r. By maximizing his profit from these three options and ensuring the participation criterion, that is, $\max(\pi_1^r + r, \pi_2^r + R, \pi_3^r) \geq R + r$, the retailer determines whether and where to carry the new product. Our rationale for the retailer's channel outlet designation rule is that, when carrying the new product in one channel outlet only, the retailer can make at least his corresponding participation criterion by carrying an alternative product in the other outlet. This is consistent with Bernstein and Marx (2010) as well as our definition of the retailer's participation criteria. The manufacturer's unit cost of producing the product, $c(q) = cq^2$, is specified as a convex, increasing function of product quality, q.

The game proceeds as follows: The manufacturer decides the quality (q) and the wholesale price (w) of the new product, taking into account the retailer's participation criteria for his offline and online stores. Conditional on the new product's quality (q) and wholesale price (w), the retailer maximizes his profit by deciding whether to accept the product and, if so, the choice of the channel outlet, as well as the corresponding retail price (p).

3. The Analysis

In this section, we present analysis and results from the main model. All results presented here are obtained analytically and proofs are provided in Appendix S2. The formal expressions of equilibrium quality, price, and profits in all lemmas and propositions can also be found in Appendix S2.

3.1. Brick-and-Mortar Only (Baseline Model)

The manufacturer moves first by deciding the quality q and wholesale price w of the new product to maximize her profit

$$\pi^m(q, w) = (w - cq^2) \cdot Q(p), \tag{1}$$

subject to the retailer's participation constraint, $\pi^r(p; q, w) \geq R$.

Given the new product offering, the retailer decides the retail price by maximizing his profit

$$\pi^r(p) = (p - w) \cdot Q(p), \tag{2}$$

where the demand $Q(p) = \alpha$ if $p \leq q$; 0 otherwise.

Lemma 1 (Equilibrium under a Brick-and-Mortar Retailer).

(1) The manufacturer designs the new product so that the retailer receives just enough profit to be willing to participate in the trade.
(2) The equilibrium product quality, $q_0 = \frac{1}{2c}$, is independent of the retailer's participation criterion, R.
(3) The channel introduces a new product only when the retailer's participation criterion is not too high, that is, $R \leq \frac{\alpha}{4c}$.

Lemma 1 suggests that, when operating the offline store only, the retailer obtains a profit equal to his participation criterion R (i.e., the retailer's participation constraint, $\pi^r \geq R$, is always binding). As the game leader, the manufacturer exploits the remaining surplus in the distribution channel. More importantly, the manufacturer's quality choice does not vary with the retailer's participation criterion. When facing a single-channel, brick-and-mortar retailer, as R increases, the manufacturer will adjust her wholesale price (rather than product quality) in order to satisfy the retailer's participation criterion. This finding is in line with Munson and Rosenblatt (1999) and Geylani et al. (2007) which suggest that, prior to the brick-and-click era, as the traditional retailer (such as Home Depot and Wal-Mart) enhances its ability to attract product offerings from various vendors (higher R in our context), manufacturers typically respond by lowering wholesale prices to guarantee the retailer's participation in the trade.

3.2. Brick-and-Mortar or Online-Exclusive: A Solution to Limited Shelf Space

In this subsection, we examine a scenario where the retailer designates the new product as either offline- or online-exclusive. This setup enables us to parsimoniously illustrate the fundamental tradeoffs faced by the manufacturer and the retailer, without the complication of accounting for market cannibalization when the product is available both offline and online. We will extend our analysis to include the brick-and-click option in the subsequent subsection 3.3.

Under this setup, the manufacturer decides the quality q and wholesale price w of the new product in order to induce the retailer to carry her product in his physical store (denoted $I = 1$) or as an online-exclusive (denoted $I = 2$), by maximizing her profit as follows

$$\pi^{m*} = \max\left\{\begin{array}{c} \pi_1^m = \max_{(q,w)}\left[(w - cq^2)\cdot Q_1(p)\right] \\ \text{s.t.,}\left\{\begin{array}{l}\pi_1^r + r \geq R + r \\ \pi_1^r + r \geq \pi_2^r + R\end{array}\right. \\ \pi_2^m = \max_{(q,w)}\left[(w - cq^2)\cdot Q_2(p)\right] \\ \text{s.t.,}\left\{\begin{array}{l}\pi_2^r + R \geq R + r \\ \pi_2^r + R \geq \pi_1^r + r\end{array}\right. \end{array}\right\}. \quad (3)$$

In (3), π_1^m is the manufacturer's maximum profit if the retailer decides to carry her product as an offline-exclusive. The manufacturer decides the optimal quality q and wholesale price w of her new product subject to (1) the retailer's participation constraint that the retailer's total profit is no lower than the profit level determined by his outside options, that is, $\pi_1^r + r \geq R + r$; and (2) the retailer's incentive compatibility constraint that the retailer gains more profits by carrying it offline than online, that is, $\pi_1^r + r \geq \pi_2^r + R$. Similarly, π_2^m is the manufacturer's maximum profit if the retailer carries the new product as online-exclusive. In such cases, the manufacturer decides q and w subject to (1) the retailer's participation constraint, that is, $\pi_2^r + R \geq R + r$, and (2) the retailer's incentive compatibility constraint that the retailer gains more profit by carrying the new product online than offline, that is, $\pi_2^r + R \geq \pi_1^r + r$.

Given the quality q and wholesale price w offered by the manufacturer, the retailer chooses among carrying the new product as offline-exclusive ($I = 1$), online-exclusive ($I = 2$), or not carrying the product at all ($I = 0$), as well as the optimal retail price p in the corresponding channel outlet. The retailer maximizes his profit as follows:

$$\pi^{r*} = \max_{(I)}\left\{\begin{array}{ll} \pi_1^r + r = \max_{(p)}[(p - w)\cdot Q_1(p) + r] & \text{if } I = 1 \\ \pi_2^r + R = \max_{(p)}[(p - w)\cdot Q_2(p) + R] & \text{if } I = 2 \\ R + r & \text{if } I = 0 \end{array}\right\}. \quad (4)$$

When carrying the new product offline, the retailer faces the following demand function $Q_1(p) = \begin{cases}\alpha & \text{if } p \leq q \\ 0 & \text{otherwise}\end{cases}$. His total profit from both channel outlets in this case equals the sum of π_1^r and r (with r representing the profit the retailer receives from carrying an alternative product online). When the retailer carries the product online, the demand function is given by $Q_2(p) = \begin{cases}1 & \text{if } p \leq \delta_l q + s \\ \beta & \text{if } p \in (\delta_l q + s, \delta_h q + s] \\ 0 & \text{otherwise}\end{cases}$. His total profit from both channel outlets in this case equals to the sum of π_2^r and R. When the retailer does not accept the new product into either channel, he gains a profit equal to his outside options (i.e., $R + r$).

Compared with the baseline model, the online store addition introduces an incentive compatibility constraint into the retailer's considerations, that is, the retailer must decide where to carry the product (offline-exclusive vs. online-exclusive), in addition to whether to participate in the trade. This poses an additional challenge for the manufacturer in motivating the retailer to carry the new product in the channel outlet that is also desired by her. The introduction of this incentive compatibility constraint further entails important implications for both the manufacturer and the retailer.

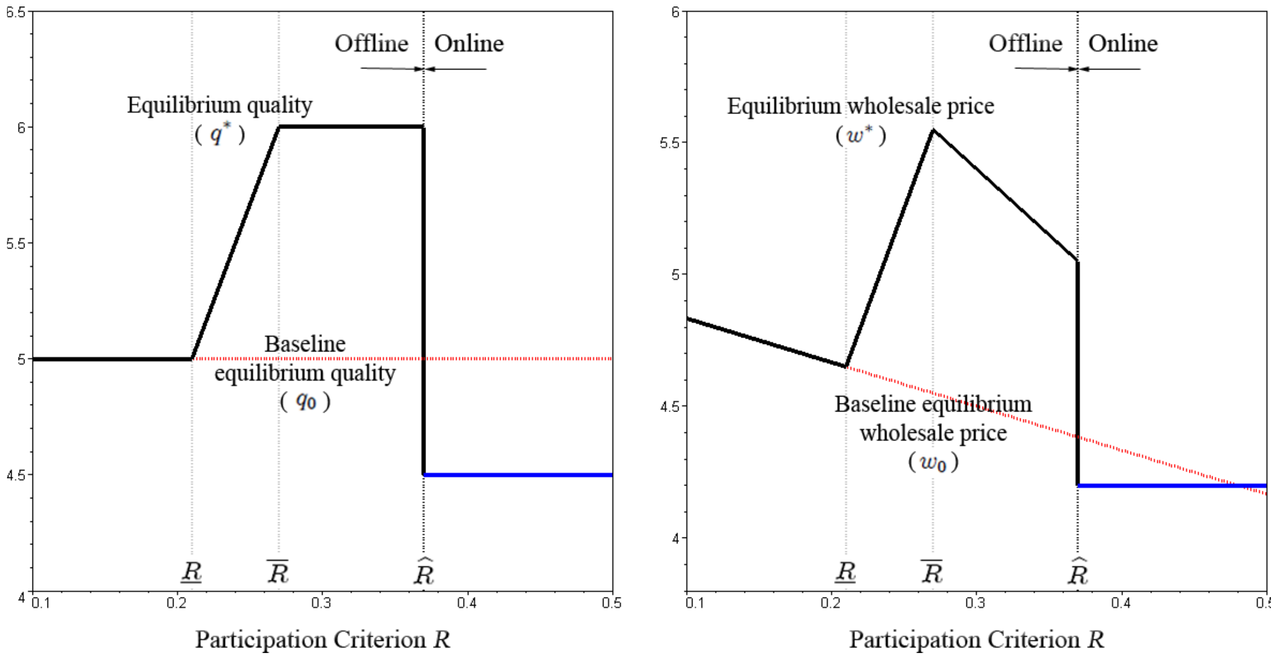
The equilibrium outcomes are discussed in Propositions 1 and 2. Figures 1 and 2 depict how equilibrium quality, wholesale price, and profits change as a function of the retailer's offline-participation criterion R (while keeping r constant).[5] To illustrate the impact of the retailer's online store addition, we also include equilibrium outcomes from the baseline model in dotted lines in all figures.

PROPOSITION 1 (EQUILIBRIUM QUALITY IN BRICK-AND-MORTAR VS. ONLINE-EXCLUSIVE).

(1) *There exists a critical offline-participation criterion, $\hat{R}$, such that the manufacturer will design the new product to target the retailer's offline store if $R \leq \hat{R}$; online store otherwise.*
(2) *When R is in an intermediate region, $R \in (\underline{R}, \hat{R}]$, the manufacturer will enhance product quality (compared with when the retailer only operates offline), that is, $q^* > q_0$, to induce the retailer to carry it offline. When $R > \hat{R}$, a product of lower quality, that is, $q^* = \frac{\delta_h}{2c}$ or $\frac{\delta_l}{2c} < q_0$, will be introduced to target the retailer's online store.*

With the addition of the online store, in order to induce the retailer to carry the new product in the channel outlet that is also desired by the manufacturer, the latter is compelled to adjust the quality of her new product offering when R is not too low. In particular, the magnitude of the retailer's offline-participation criterion R directly impacts the manufacturer's equilibrium quality choice. This contrasts to the baseline model in which the equilibrium

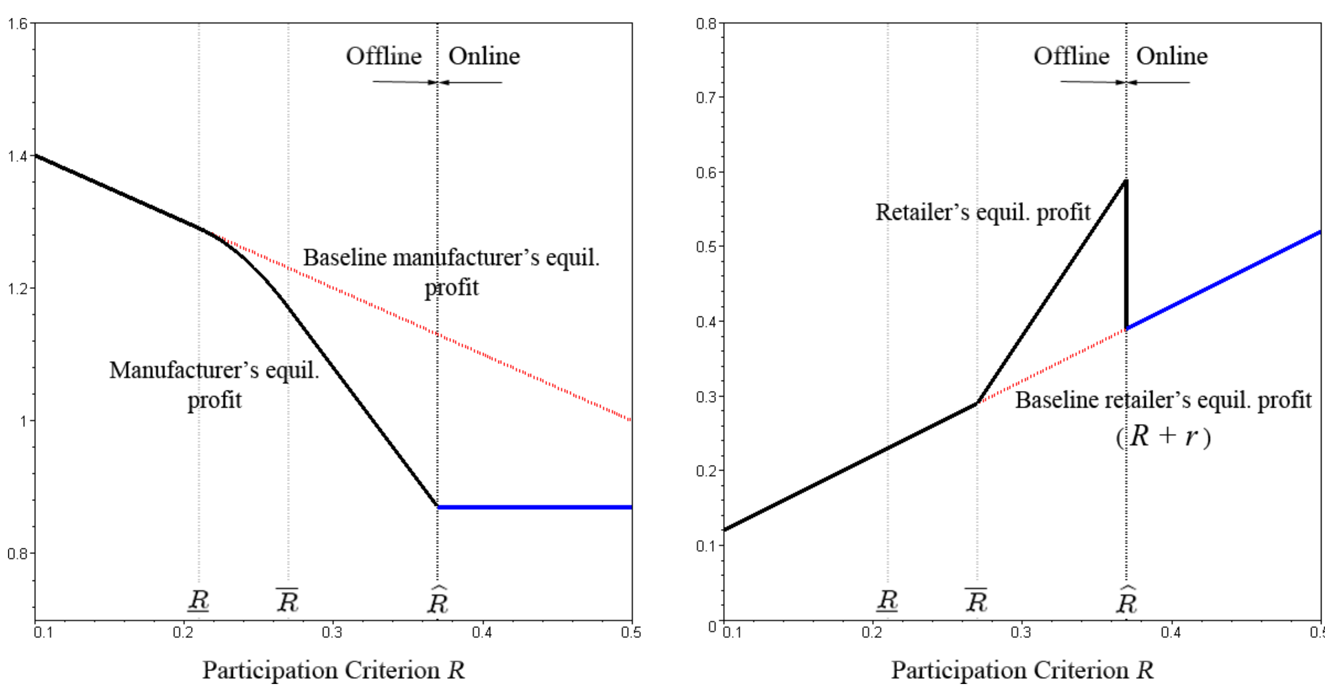
Figure 1 Equilibrium Quality and Wholesale Price as a Function of *R*. (We use $\alpha = 0.8$, $\beta = 0.5$, $\delta_h = 0.95$, $\delta_l = 0.4$, $c = 0.35$, $s = 0.01$, and $r = 0.02$.)



(a) Equilibrium Quality.

(b) Equilibrium Wholesale Price.

Figure 2 Equilibrium Profits as a Function of *R*. (The Parameter Values are the Same as Those in Figure 1.)



(a) Manufacturer's Profit.

(b) Retailer's Profit.

quality is independent of R. Generally, the equilibrium quality first (weakly) increases then (weakly) decreases with R.

When R is sufficiently small (i.e., $R < \underline{R}$), the manufacturer will behave the same as if the retailer's online store were absent, that is, product quality is independent of R (Figure 1a). With a sufficiently small opportunity cost (R) of allocating physical shelf space to a new product, the option of carrying the new product online is not attractive to the retailer. Consequently, the retailer's incentive compatibility constraint is not active in this region. Therefore, the manufacturer only needs to satisfy the participation criterion, that is, the profit that the retailer gains from the product is at least R, or $\pi_1^r + r \geq R + r$, is the only active constraint. In this case, the manufacturer behaves the same as in the baseline model, that is, as if the online store were absent. Namely, to satisfy the retailer's participation constraint, the manufacturer only reduces the wholesale price (Figure 1b). As in the baseline model, the retailer gains exactly his participation criterion $R + r$ in this region, as illustrated in Figure 2b.

When R is intermediate, that is, $R \in (\underline{R}, \overline{R}]$, the manufacturer is compelled to enhance product quality ($q^* > q_0$). In this region, with increasing R, the incentive compatibility constraint, $\pi_1^r + r \geq \pi_2^r + R$, comes into play. Namely, the retailer will only allocate the new product to his offline store if he deems this strategy more profitable than carrying it as online-exclusive. Unlike wholesale price, product quality has a differential impact on consumers' offline vs. online willingness-to-pay. Given that the disutility of online purchase is proportional to product quality, consumers may prefer to purchase a product offline rather than online when its quality is sufficiently high. Consequently, a strategic manufacturer will increase the quality of her new product such that the retailer will opt to carry it offline as desired by the manufacturer. Meanwhile, the manufacturer is able to compensate for her higher variable cost resulting from higher product quality by charging a higher wholesale price. In this region, both participation and incentive compatibility constraints are active for the retailer (i.e., the retailer receives $R + r$). However, the increase in the wholesale price does not fully compensate for the increase in the manufacturer's cost. As a result, the manufacturer's profit continues to decrease and is lower than her profit in the benchmark model.

When the offline-participation criterion reaches $\overline{R}$, further enhancing product quality becomes too costly for the manufacturer. Therefore, to induce the retailer to carry the new product offline, the manufacturer will maintain product quality at the highest possible level while reducing the wholesale price. Due to the decreasing wholesale price along with high product quality, the retailer obtains more than his participation criterion $R + r$ when $R \in (\overline{R}, \hat{R}]$ as shown in Figure 2b (we will provide more details on the underlying mechanism of this result when we discuss Proposition 2). In this region, while his incentive compatibility constraint is active, the retailer's participation constraint is no longer binding, that is, $\pi_1^r + r > R + r$, that is, $\pi_1^r > R$.[6]

When the offline-participation criterion reaches the tipping point $\hat{R}$, inducing the retailer to carry the product offline is no longer economical for the manufacturer. Instead, the manufacturer will induce the retailer to carry the product online by choosing a quality lower than that of the baseline model (i.e., $q^* = \frac{\delta_h}{2c}$ or $\frac{\delta_l}{2c} < q_0$). Given the online shopping benefit s and a relatively small disutility of purchasing a low-quality product online, consumers find it more desirable to purchase the new product online than offline (i.e., $\delta_h q + s$ or $\delta_l q + s > q$). In such cases, the retailer also finds it more profitable to carry the new product online.

The resulting equilibrium profits stemming from the strategic interactions between the manufacturer and the retailer are summarized in Proposition 2 below.

Proposition 2 (Equilibrium Profits in Brick-and-Mortar vs. Online-Exclusive).

(1) *When $R \in (\overline{R}, \hat{R}]$, the retailer obtains more than his offline-participation criterion R from carrying the new product offline.*
(2) *When R is at the tipping point (i.e., $\hat{R}$) where the offline option is just slightly more desirable than the online option for the manufacturer, the retailer enjoys the most surplus from carrying the new product offline and may even be the most profitable.*
(3) *When R is sufficiently high, the manufacturer also becomes better off with the addition of the retailer's online store.*

In the intermediate region, that is, $R \in (\overline{R}, \hat{R}]$, the retailer is able to gain more than his offline-participation criterion R from carrying the new product offline, that is, $\pi_1^r > R$. In this region, in order to satisfy the retailer's incentive compatibility constraint, that is, to ensure that the offline option is more profitable than the online option to the retailer, the manufacturer raises her product quality to a sufficiently high level such that consumers' utility of purchasing the product offline is significantly higher than that of purchasing it online. Hence, the retailer is able to price the product high in his offline store, and consequently obtains more than his offline-participation criterion R.

Such an effect becomes stronger when the offline-participation criterion R increases. As R gets larger, the online option becomes more attractive for the retailer. To induce the retailer to allocate the new product to his offline store, the manufacturer has to further decrease wholesale price while keeping quality at the highest possible level. Consequently, the retailer gains the most possible surplus, defined by $\pi_1^r - R$, at the tipping point $\hat{R}$ where the offline option is just slightly more desirable than the online option for the manufacturer, as shown in Figure 2b. That is, at $\hat{R}$, the retailer enjoys the most leverage in his relationship with the manufacturer. Meanwhile, the manufacturer's profit is lowest at this point. An interesting implication from this finding is that, in such cases, rather than specifying the highest possible R, the retailer may be incentivized to adjust his participation criterion to a level less than what is determined by his outside option.

When R increases beyond $\hat{R}$, the retailer's profit drops back to his participation criterion, $R + r$. Additionally, when R is very high, the manufacturer also benefits from the retailer's online store addition. As shown in the dotted line in Figure 2a, without the retailer's online store, the manufacturer's profit is strictly decreasing in R. With the retailer expanding online, the manufacturer's profit (the solid line) will surpass that in the baseline model (the dotted line) when R is sufficiently high.

3.3. Brick-and-Click, Offline-Exclusive, or Online-Exclusive

As the primary focus of this research, we discuss in this subsection the case where the retailer considers the following complete set of options for the manufacturer's new product: offline-exclusive ($I = 1$), online-exclusive ($I = 2$), brick-and-click (denoted $I = 3$), and not carrying it in either store ($I = 0$).

Different from subsection 3.2., when the product is carried both offline and online, some consumers (i.e., switch consumers) can choose between purchasing the new product offline or online, depending on from which channel outlet they can obtain a higher utility. We study how the presence of these switch consumers influences the manufacturer's equilibrium product quality choice, as well as the profits of the manufacturer and the retailer. Given that nearly 80% of multichannel retailers price items consistently across channels (Forrester Research 2004, National Retail Federation 2006), we follow the norm in the literature (e.g., Liu et al. 2006, Ofek et al. 2011) by assuming that the retailer sets the same price for the new product if carrying it both offline and online.

The game setup is similar to that described in subsection 3.2, with the exception that the manufacturer now needs to satisfy two incentive compatibility constraints in maximizing her profit in each scenario,

$$\max\left\{\begin{array}{c} \pi_1^m = \max_{(q,w)}\left[(w - cq^2)\cdot Q_1(p)\right] \\ \text{s.t.,}\left\{\begin{array}{c} \pi_1^r + r \geq R + r \\ \pi_1^r + r \geq \pi_2^r + R \\ \pi_1^r + r \geq \pi_3^r \end{array}\right. \\ \pi_2^m = \max_{(q,w)}\left[(w - cq^2)\cdot Q_2(p)\right] \\ \text{s.t.,}\left\{\begin{array}{c} \pi_2^r + R \geq R + r \\ \pi_2^r + R \geq \pi_1^r + r \\ \pi_2^r + R \geq \pi_3^r \end{array}\right. \\ \pi_3^m = \max_{(q,w)}\left[(w - cq^2)\cdot Q_3(p)\right] \\ \text{s.t.,}\left\{\begin{array}{c} \pi_3^r \geq R + r \\ \pi_3^r \geq \pi_1^r + r \\ \pi_3^r \geq \pi_2^r + R \end{array}\right. \end{array}\right\}, \quad (5)$$

and the retailer maximizes the following profit:

$$\max_{(I)}\left\{\begin{array}{ll} \pi_1^r + r = \max_{(p)}[(p - w)\cdot Q_1(p) + r] & \text{if } I = 1 \\ \pi_2^r + R = \max_{(p)}[(p - w)\cdot Q_2(p) + R] & \text{if } I = 2 \\ \pi_3^r = \max_{(p)}[(p - w)\cdot Q_3(p)] & \text{if } I = 3 \\ R + r & \text{if } I = 0 \end{array}\right\}, \quad (6)$$

where Q_1, Q_2, and Q_3 are given in Table 2.

From the retailer's perspective, the brick-and-click option can only be more profitable than the offline- or online-exclusive option if it can attract more demand at the same price. Hence, the region of particular interest is $p \in (\delta_l q + s, \hat{p}]$, where the retailer receives demand $\alpha + (1 - \alpha)\beta$, which is higher than the respective demand in either the offline-exclusive (with demand α) or online-exclusive option (with demand β) at the same price (Table 2). Note that such a region is non-empty only when $q > \delta_l q + s$. When choosing the brick-and-click option, the retailer will set the retail price at the upper bound of the region, that is, $p^* = \hat{p} = \begin{cases} q & \text{if } q \leq \frac{s}{1-\delta_h} \\ \delta_h q + s & \text{otherwise} \end{cases}$. As shown in Table 2, in other regions, the retailer receives the same demand as in offline-or online-exclusive.

Consequently, from the retailer's perspective, the brick-and-click option can be a profitable strategy with an intermediate price and an intermediate demand. In other words, the brick-and-click option provides the retailer with an additional lever to fine-tune the volume-margin tradeoff he faces. At the same time, the brick-and-click option is a potentially profitable strategy for the manufacturer as well, because her quality choice can influence from which channel outlet consumers would purchase the new product. Table 3 further provides each consumer segment's channel outlet choice when the product is available both offline and online. In this region, the

Table 2 Product Demand in Brick-and-Click Vs. Offline-Exclusive Vs. Online-Exclusive

Price region	$Q_1(p)$	$Q_2(p)$	$Q_3(p)$	Comparison
If $p \leq \delta_l q + s$	α	1	1	$Q_3 = Q_2$
If $p \in (\delta_l q + s, \hat{p}]$	α	β	$\alpha + (1-\alpha)\beta$	$Q_3 > Q_1$; $Q_3 > Q_2$
If $p \in (\hat{p}, \delta_h q + s]$	α	β	β	$Q_3 = Q_2$
If $p \in (\delta_h q + s, \max[\delta_h q + s, q]]$	α	0	α	$Q_3 = Q_1$
If $p > \max[\delta_h q + s, q]$	0	0	0	

where $\hat{p} = \min[\delta_h q + s, \max[\delta_l q + s, q]]$.

Table 3 Consumer Purchase Behavior under Brick-and-Click

Consumer type	$p^* = q$ if $q \leq \frac{s}{1-\delta_h}$	$p^* = \delta_h q + s$ if $q > \frac{s}{1-\delta_h}$
More-online-skilled, offline-accessible	**Purchase online**	**Purchase offline**
Less-online-skilled, offline-accessible	Purchase offline	Purchase offline
More-online-skilled, offline-inaccessible	Purchase online	Purchase online
Less-online-skilled, offline-inaccessible	No purchase	No purchase

more-online-skilled, offline-accessible consumers (i.e., switch consumers) have the flexibility of purchasing the product either offline with utility $q - p$ or online with utility $\delta_h q + s - p$, whichever is greater.

Hence, the manufacturer can potentially influence consumers' purchase behavior by designing her product at different quality levels. In other words, the presence of switch consumers enhances the manufacturer's ability to use product quality to influence the retailer's channel designation choice. We investigate how such a demand re-direction effect has additional implications for the manufacturer's quality choice, as well as the manufacturer's and the retailer's profits. Figures 3–4 illustrate how the equilibrium quality and profits change with the retailer's offline-participation criterion R.[7]

PROPOSITION 3 (EQUILIBRIUM QUALITY IN BRICK-AND-CLICK, OFFLINE-EXCLUSIVE, OR ONLINE-EXCLUSIVE).

(1) *When $R \leq \hat{R}_1$, the manufacturer will design the new product to target the retailer's offline store only; when $R \in (\hat{R}_1, \hat{R}_2]$, brick-and-click; when $R > \hat{R}_2$, online-exclusive.*

(2) *When δ_h and/or s is low, in order to induce the retailer to carry the new product in his brick-and-click store, the manufacturer may design a product of lower quality, that is, $q^* \leq \frac{\delta_h}{2c} < q_0$; otherwise, a higher quality product, that is, $q^* \geq q_0 = \frac{1}{2c}$ may be introduced.*

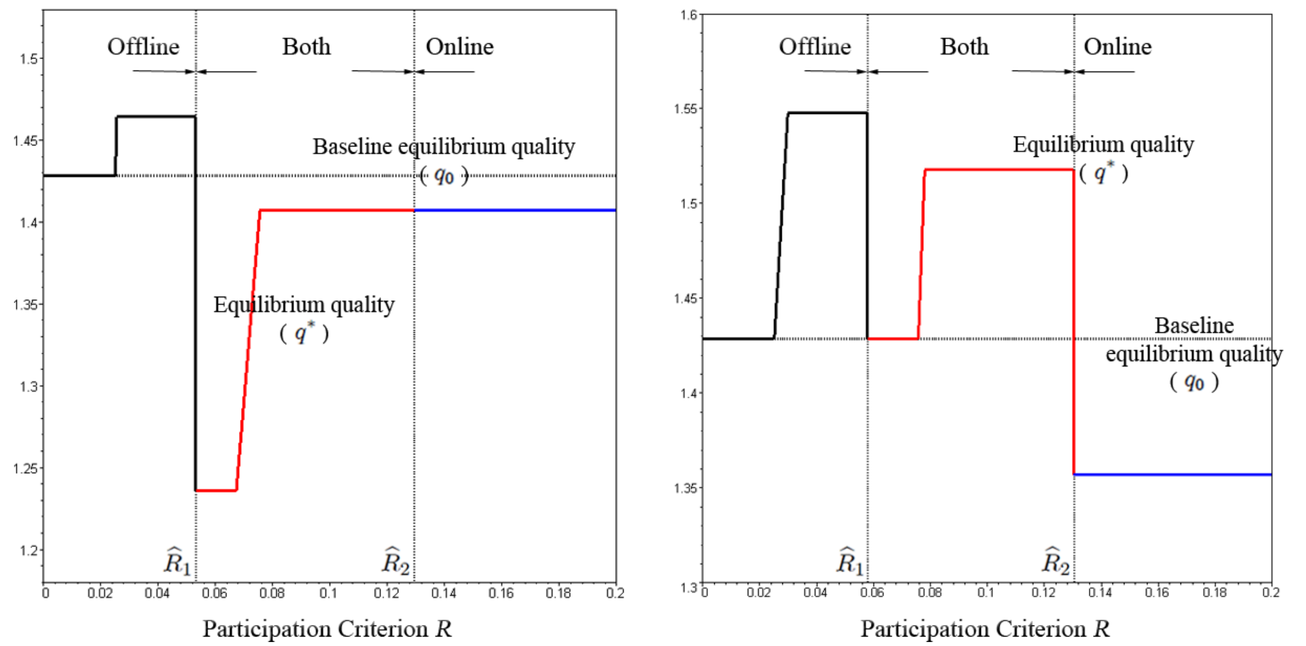
We obtain the following new insights. First, the brick-and-click option emerges in equilibrium at intermediate values of R. When R is low or high, the manufacturer finds it more profitable to design the new product to target the retailer's offline-exclusive or online-exclusive options in a fashion similar to that described in subsection 3.2. Nevertheless, when R is intermediate, the manufacturer obtains the most profit by targeting the retailer's brick-and-click store. As a result, compared to subsection 3.2, the manufacturer must adjust her product quality in a wider range, along with a reduced wholesale price, to incentivize the retailer to carry it in both of his channel outlets. Second, consumers' dual channel purchase flexibility strengthens the manufacturer's ability to use product quality (i.e., in a wider range) to influence the retailer's channel outlet choice. In particular, the manufacturer may strategically lower the quality of her new product to induce the retailer to carry it both offline and online.

When the online storefront is relatively less appealing to consumers, that is, δ_h and/or s is low, (e.g., in product categories such as apparel and jewelry), the manufacturer will offer a lower-quality product (maybe even lower than the optimal quality level in the online-exclusive option), such that the disutility of purchasing the new product online is considerably alleviated. As a percentage of the intrinsic value of the product, the disutility of online purchase is smaller at lower-quality levels. This in turn may motivate some consumers to purchase the new product online. As a result, the retailer may be induced to allocate the product both offline and online (rather than offline only).

In this case, market cannibalization, stemming from switch consumers' dual channel purchase flexibility, is also reduced at low quality levels. Specifically, if carrying the product both offline and online, the retailer will have to set the retail price at online consumers' valuation, that is, $p = \delta_h q + s$, which is lower than offline consumers' valuation, that is, $\delta_h q + s < q$. Consequently, the switch consumers will obtain a positive surplus (i.e., $(1 - \delta_h)q - s$) by purchasing the product offline. This positive surplus implies a margin loss (i.e., cannibalization). As an increasing function of q, such a cannibalization effect can be reduced at low quality levels.

Our results described above can be related to Tiffany's non-jewelry accessories example given earlier in our paper. In such categories, the likelihood of

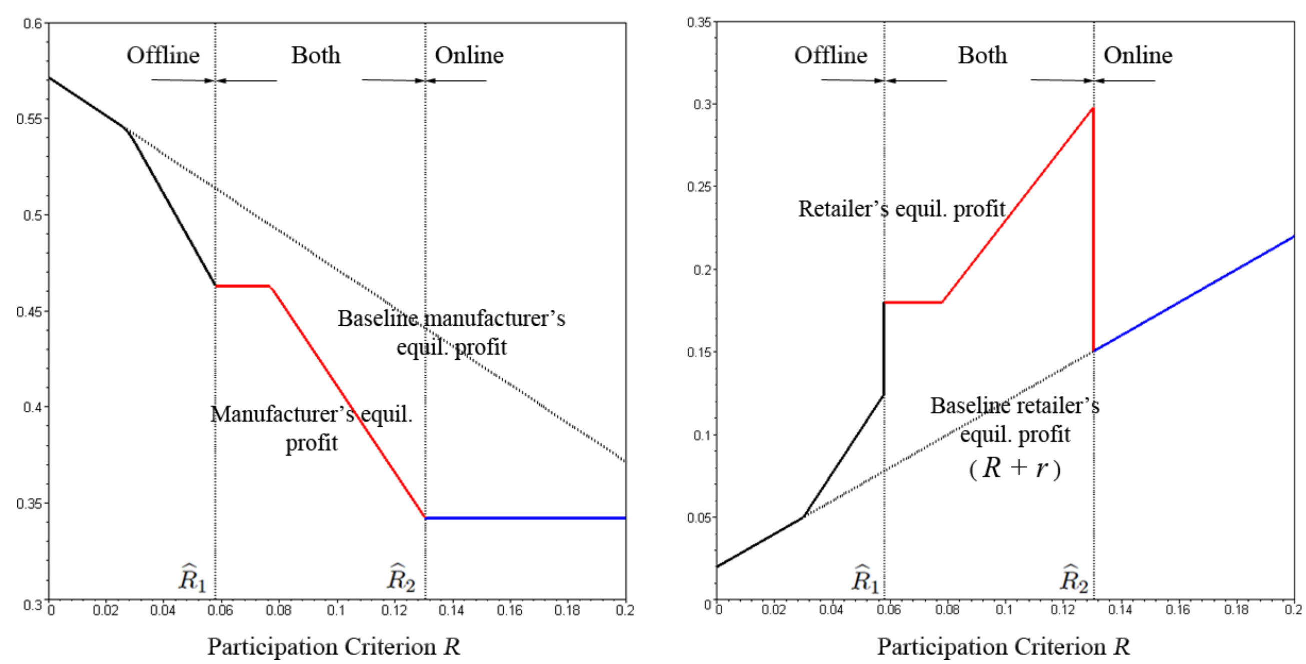
Figure 3 Equilibrium Quality as a Function of R. (We use $\alpha = 0.8$, $\beta = 0.5$, $\delta_h = 0.95$, $\delta_l = 0.4$, $c = 0.35$, $s = 0.01$ for (a), $s = 0.08$ for (b) and $r = 0.02$.)



(a) When s and/or δ_h is Small.

(b) When s and/or δ_h is High.

Figure 4 Equilibrium Profits as a Function of R When δ_h and/or s is High. (We Omit Figures When δ_h and/or s is Low due to Similarity. The Parameter Values are the Same as Those in Figure 3a.)



(a) Manufacturer's Profit.

(b) Retailer's Profit.

product mismatch without touch-and-feel is often quite high. Therefore, when the offline-participation criterion is intermediate, a strategic third-party manufacturer may lower the quality of her product offering so that Tiffany will opt to carry it both offline and online (rather than offline only).

In contrast, when the online storefront is relatively more appealing to the consumer, that is, δ_h and/or s is high, (e.g., in product categories such as appliances and electronics), the manufacturer is compelled to design a product of higher quality (compared to the baseline model) in order to enhance the relative benefit of inspecting the new product in-store so that the retailer will not opt for the online-exclusive option. Recall that the relative benefit of physical inspection (i.e., the discrepancy in consumer's offline and online willingness-to-pay) is greater for higher quality products. In such cases, offline consumers' product valuation (q) is lower than that of online consumers ($\delta_h q + s$). As a result, the market cannibalization effect (i.e., switch consumers' positive surplus, $s - (1 - \delta_h)q$, via purchasing the product online) is reduced at higher product quality levels.

Relating to the magnetized accessories example from MagnoGrip discussed earlier in our paper, because the specifications and functions of such products are more-or-less self explanatory, the lack of touch and feel may not be a central concern for some consumers. Consequently, at intermediate values of R, the manufacturer may enhance the quality of these products to induce the retailer to carry them both offline and online (rather than online only).

PROPOSITION 4 (EQUILIBRIUM PROFITS IN BRICK-AND-CLICK, OFFLINE-EXCLUSIVE, OR ONLINE-EXCLUSIVE).

(1) When the new product is carried both offline and online, the retailer receives strictly more than $R + r$.
(2) At the tipping point where the brick-and-click option is just slightly more profitable for the manufacturer than the online-exclusive option, the retailer receives the most surplus and may even be the most profitable.

At the intermediate region of R, that is, $R \in (\hat{R}_1, \hat{R}_2]$, when the product is carried both offline and online, in either case discussed above (Figure 3a or b), the retailer always receives more than $R + r$ (Figure 4b). In this region, the manufacturer must ensure that the retailer receives more profit by carrying her product in his brick-and-click store rather than offline-exclusive or online-exclusive. The manufacturer is able to meet this requirement by adjusting her product quality as well as offering a low wholesale price (See Figure B1 in Appendix S2). Consequently, the retailer receives strictly more than $R + r$ under the brick-and-click option. When δ_h and/or s is low, the majority of the retailer's surplus originates from his offline store; online store otherwise. As R approaches $\hat{R}_2$, with an increasing opportunity cost of stocking the new product offline, the online-exclusive option becomes more attractive for the retailer. As a result, the manufacturer has to forego more profit to satisfy the retailer's incentive compatibility constraint. Consequently, the retailer receives the most surplus at the tipping point $\hat{R}_2$.

4. Model Extensions

In this section, we relax a set of assumptions made in the main model. Such extensions enable us to derive further insights into a strategic manufacturer's new product design decision when a brick-and-mortar retailer expands online. All detailed analyses of the extensions can be found in Appendix S2.

4.1. Manufacturer Charging Different Wholesale Prices Offline and Online

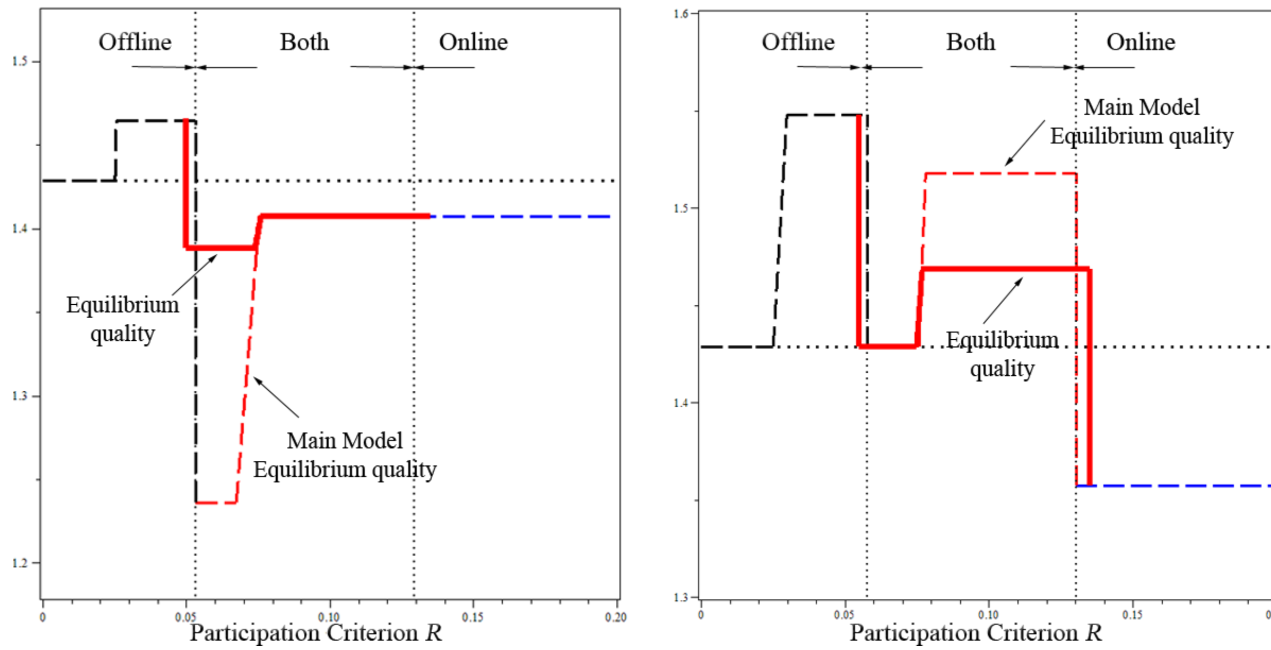
In this extension, we consider a case where the manufacturer charges different wholesale prices for selling the new product offline and online. Let us denote the offline and online wholesale prices by w_1 and w_2, respectively. The following Lemma 2 summarizes our results when the product is carried both offline and online. The new equilibrium quality and wholesale prices in the brick-and-click region are depicted in Figures 5–6, with results from the main model denoted in dash lines and those from this extension in solid lines. When the product is carried offline- or online-exclusive, our results remain the same as in the main model.

LEMMA 2 (DIFFERENT WHOLESALE PRICES OFFLINE AND ONLINE). *In the case of brick-and-click,*

(1) The manufacturer's quality decisions remain qualitatively the same as in the main model.
(2) With different wholesale prices offline and online, the manufacturer does not need to adjust her quality to the same extent as in the main model. When δ_h and/or s is low, the equilibrium quality is higher than that in the main model, but is still lower than that in the baseline model. When δ_h and/or s is high, the equilibrium quality is lower than that in the main model, but is still higher than that in the baseline case.
(3) With increasing R, the manufacturer first offers a lower online wholesale price than offline, then a lower offline wholesale price than online.

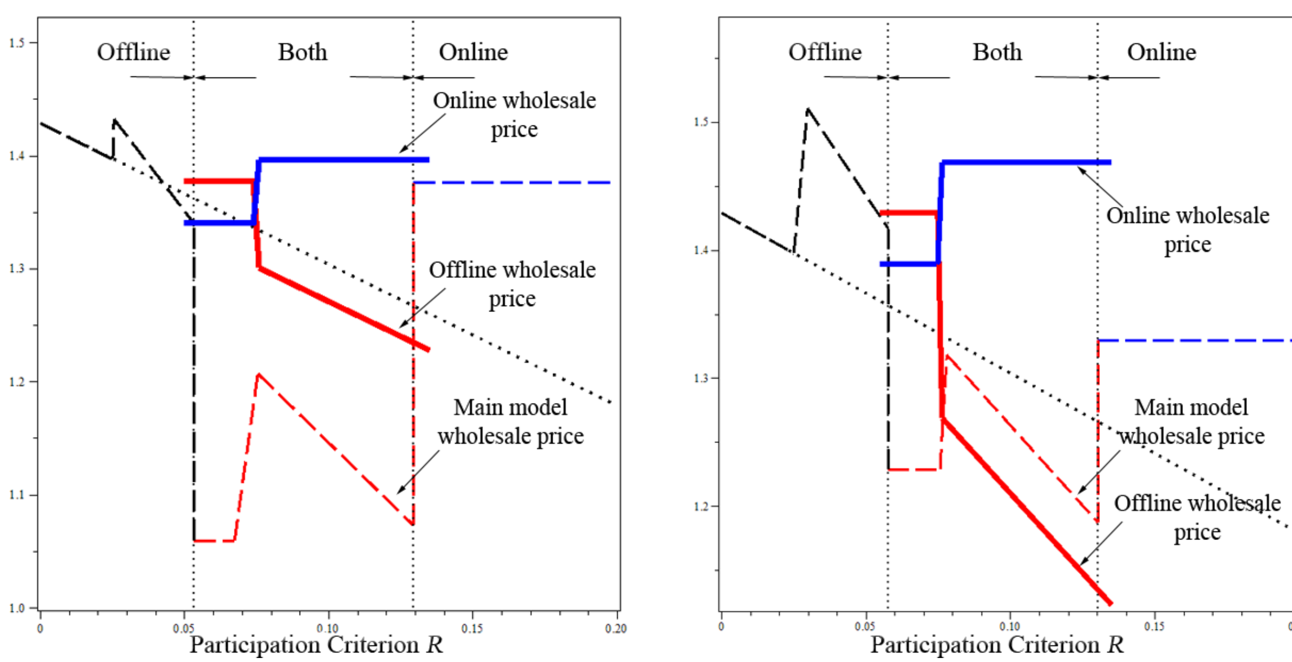
When offering different wholesale prices offline and online, the manufacturer enjoys a greater leverage in inducing the retailer to carry the new product in his brick-and-click store. Consequently, while her quality decisions remain qualitatively the same as before, the manufacturer does not need to adjust product quality to the same extent as in the main model. In the brick-and-click region, at low values of R, the manufacturer offers a lower wholesale price online

Figure 5 Equilibrium Quality as a Function of *R* When Manufacturer Can Charge Two Wholesale Prices (The Parameter Values are the Same as Those in Figure 3.)



(a) When s and/or δ_h is Small. **(b)** When s and/or δ_h is High.

Figure 6 Equilibrium Wholesale Prices as a Function of *R* When Manufacturer Can Charge Two Wholesale Prices. (The Parameter Values are the Same as Those in Figure 3.)



(a) When s and/or δ_h is Small. **(b)** When s and/or δ_h is High.

than offline (i.e., $w_2^* < w_1^*$). At low values of R, carrying the product as offline-exclusive is highly attractive to the retailer. To induce the retailer to carry the product in his brick-and-click store rather than offline store only, the manufacturer strategically charges a lower wholesale price online to make the product relativley more attractive for the retailer's online store. Similarly, because the retailer finds the online-exclusive option highly attractive at high values of R, the manufacturer opts to charge a lower price offline to enhance its attractiveness of the offline store so that the retailer will carry the product as brick-and-click rather than online-exclusive. Intuitively, the manufacturer's profit increases and the retailer's profit decreases as compared with the main model. Nevertheless, the retailer still gains more than $R + r$ in the intermediate region of R as in the main model.

4.2. Retailer Charging Different Retail Prices Offline and Online

We now examine whether our main insights hold if the retailer is able to charge different retail prices for the new product offline and online. Let us denote the offline and online prices by p_1 and p_2, respectively. In this case, the retailer has two possible pricing strategies and all other cases are dominated by either the online-exclusive or the offline-exclusive option. The two possible pricing strategies are as follows: (1) charging $p_1 = q$ to offline buyers, and $p_2 = \delta_h q + s$ to online buyers, in which case all consumers buy except for the less-online-skilled, offline-inaccessible consumers of size $(1 - \alpha)(1 - \beta)$; and (2) charging $p_1 = q$ to offline buyers, and $p_2 = \delta_l q + s$ to online buyers, in which case all consumers buy. As shown in Appendix S2, compared with strategy (2), the retailer under strategy (1) gains less demand but a higher profit margin. Hence, given (q, w), the retailer chooses (1) over (2) when δ_h or q is sufficiently high (such that p_2 is sufficiently high), that is, when the profit margin is sufficiently higher than that in (2). This in turn compels the manufacturer to design a high quality product in order to induce the retailer to opt for strategy (1); low quality otherwise. Therefore, our key insights still hold, that is, when δ_h is high enough, the manufacturer will introduce a high quality product to target the retailer's brick-and-click store; low quality otherwise. Note that under strategy (1), the cannibalization effect goes away. Under the second strategy, the cannibalization effect still exists because the more-online-skilled, offline-accessible consumers obtain a positive surplus, $(\delta_h - \delta_l)q$, by purchasing the product online.

4.3. Retailer Dictating Wholesale Price

In this extension, we analyze a scenario where the retailer dictates wholesale price. Under this setup, the retailer will set the wholesale price, w, slightly above the manufacturer's cost, that is, cq^2, such that the manufacturer gains no profit.

In such cases, the manufacturer's ability to use product design to influence the retailer's channel outlet designation decision is vastly reduced. Because the retailer sets the wholesale price $w = cq^2$ regardless of R, the optimal quality is independent of R in all cases. Hence, the retailer's total profit is independent of R in the brick-and-click and offline-exclusive cases. In the case of online-exclusive, the retailer's profit is increasing in R because his total profit equals his online profit plus R. Therefore, the retailer will carry the product as brick-and-click or offline-exclusive when R is low; online-exclusive when R is high. This contrasts to findings from our main model where the manufacturer is able to adjust her product quality to motivate the retailer to carry the product as offline-exclusive, online-exclusive, or brick-and-click when R varies.

In practice, the degree to which the focal retailer is involved in setting wholesale prices varies from market to market. For example, Wal-Mart is known for dictating wholesale prices and other terms of the contract (PBS Frontline 2004). In such cases, the key findings from our main model do not apply. Meanwhile, our conversations with industry executives also reveal that the price setting scheme in our main model is applicable to a large number of industry practices (such as the relationship between Stanley Black & Decker and Home Depot; and that between Mattel and Toys R Us). In such cases, the relative power of the two firms is not as extreme as in the case of Wal-Mart.

Consequently, our conjecture is that the manufacturer's ability to use product quality to influence the retailer's channel outlet designation decision is positively associated with her relative power in the distribution channel. With a notable exception of Wal-Mart, when the retailer does not dictate wholesale price, manufacturers may greatly enhance the success of her new product introduction by taking into account the former's channel outlet designation decisions in her product design decisions.

4.4. Two Different Qualities Intended for Two Different Channels

In this extension, we analyze a scenario where the manufacturer offers two products with quality levels, q_1 and q_2, with $q_2 < q_1$ (along with two wholesale price, w_1 and w_2, with $w_2 < w_1$), intended for the two different store fronts of the dual channel retailer. Given the overall complexity of this model setup, we limit our attention to the focal manufacturer's quality choices around the tipping points where her best strategy is to switch from offering a single product (targeting either the offline or online store of the retailer) to offering two different qualities intended for the two different channels. We emphasize our analysis to such regions because, with attempts to incentivize the retailer to carry the product(s) in the channel outlet(s) also desired by the manufacturer, the latter often has incentives to considerably adjust the quality level of her product offering(s) around such tipping points.

We discover that, in such cases, the high quality product is intended for the offline channel and the low quality product is intended for the online channel. The manufacturer mainly uses the lower quality product ($q_1^* = \frac{1}{2c}$) as a lever to influence whether the retailer will accept both products or only one product offering. Specifically, the manufacturer offers (1) a relatively high online quality ($q_2^* = \frac{\delta_h}{2c}$) when δ_h and/or s is high; and (2) a relatively low online quality ($q_2^* = \frac{\delta_l}{2c}$ or $\frac{\delta_l}{2c} - \frac{(\delta_h - \delta_l)\alpha}{c(1-\alpha)}$) when δ_h and/or s is medium or low.

From the retailer's perspective, one key benefit of the brick-and-click option is that he can sell the products to both offline and online consumers (as compared to the cases of offline- or online- exclusive). Nevertheless, as illustrated earlier, one potential caveat of the brick-and-click option is that some consumers may obtain a positive surplus given their flexibility of choosing which channel to make a purchase. As a result, the dual-channel retailer may face a potential market cannibalization effect.

When the online storefront is relatively more appealing to the consumer (i.e., δ_h and/or s is high), the manufacturer needs to ensure that the retailer will opt to the brick-and-click option rather than the online-exclusive option. Under this scenario, by offering a relatively high quality product online ($q_2^* = \frac{\delta_h}{2c}$), the two product offerings from the manufacturer can eliminate the potential market cannibalization associated with the brick-and-click option. Therefore, with the combination of selling to more consumers and no market cannibalization effect, the retailer enjoys a greater profit from selling two different versions of the product in the two channels than selling only one product online. In this case, the switch consumers are indifferent in purchasing either the online or the offline product. And because the retailer charges a relatively high retail price for the online product, the market is not fully covered (the less-online-skilled, offline inaccessible consumers opt to no purchase).

In contrast, when the online channel is relatively less attractive for the consumer (i.e., δ_h and/or s is medium or low), the manufacturer needs to incentivize the retailer to choose the brick-and-click option rather than the offline-only option. In this scenario, two subcases arise. When δ_h and/or s is medium, the manufacturer reduces the online product quality to $\frac{\delta_l}{2c}$. And the retailer finds it most profitable to carry both products by charging a low online price (while keeping the offline price the same as in the offline-exclusive option). In this case, switch consumers opt to purchase the online product. When δ_h and/or s is low, the manufacturer further reduces the online product quality to $\frac{\delta_l}{2c} - \frac{(\delta_h-\delta_l)\alpha}{c(1-\alpha)}$. In this case, the retailer also reduces the retail price of the offline product such that the switch consumers are indifferent in purchasing either product. In both subcases, the switch consumers enjoy a positive surplus. Nevertheless, because the market is fully covered in both subcases, the retailer enjoys the utmost market expansion effect under the brick-and-click option. Overall, the market expansion effect dominates the market cannibalization effect. Therefore, the retailer still gains more profit by selling product q_1 offline and product q_2 online, rather than selling only one product offline.

To summarize, when offering two different quality levels intended for retailer's two different channels, the manufacturer will strategically adjust the quality level of the low quality product such that the brick-and-click option becomes more attractive to the retailer than the alternative options. Similar in spirit to the main model, the optimal quality level of the low quality product depends on the relative attractiveness of the online storefront to the consumer (i.e., the values of δ_h and/or s). A relatively high quality will be offered online when δ_h and/or s is high; low online quality otherwise.

4.5. Two-Part Tariff Supply Contract

We now consider a scenario where the manufacturer adopts a two-part tariff pricing scheme, that is, a per-unit wholesale price and a fixed fee. The fixed fee serves to allocate profits between the manufacturer and the retailer (Cachon and Lariviere 2005). Being the first mover, the manufacturer is able to charge a fixed fee such that the retailer never makes more than his participation criteria, $R + r$. Such a fixed fee, however, does not affect the equilibrium quality that the manufacturer chooses in order to influence the relative attractiveness of the two channel outlets to the retailer. This is reflected in the retailer's best response function, as specified in Appendix S2, in choosing which channel outlet to carry the product. Because the fixed fee does not interact with product quality in the retailer's best response function or the manufacturer's profit function (i.e., it drops out of the FOCs), the equilibrium quality will remain qualitatively the same as in the main model. In this case, the fixed fee fully absorbs the retailer's extra surplus.

4.6. Retailer's Endogenous Participation Criterion

In this extension, we account for the possibility of an endogenous retailer participation criterion. In such cases, the retailer is subject to a maximum possible participation criterion, $R_{\max}$ which is determined by his outside option. When $R_{\max}$ is sufficiently low or high, the retailer will set his participation criterion at the maximum possible level. Nevertheless, when $R_{\max}$ is intermediate, the retailer may be better-off by adjusting his participation criterion to a level lower than $R_{\max}$.

An examination of the retailer's profit in Figure 4b explains the rationale. When $R_{\max}$ falls in the region to the immediate right of $\hat{R}_2$, it is obvious that a strategic retailer will set his participation criterion at the tipping point $\hat{R}_2$ rather than at $R_{\max}$, because the retailer will gain more profit at $\hat{R}_2$ than at $R_{\max}$. In contrast, the retailer will set his participation criterion at $R_{\max}$ when (1) $R_{\max} < \hat{R}_2$, or (2) when $R_{\max} > \hat{R}_2$ and $R_{\max}$ is sufficiently high such that the profit achieved at $R_{\max}$ is greater than that at $\hat{R}_2$. The role of $r_{\max}$ is similar.

Consequently, the intermediate region where the retailer carries the product both offline and online will enlarge. Specifically, the upper bound of the region ($\hat{R}_2$ in Figure 4b) will extend to the right because the retailer will set his participation criterion at the tipping point $\hat{R}_2$ when $R_{\max}$ falls in the region to the immediate right of $\hat{R}_2$. It is also worth noting that the equilibrium quality level remains the same as in the main model, because the retailer's endogenous participation criterion does not affect the basic premises of the manufacturer's profit maximization.

4.7. Only a Portion of Consumers Having Access to the Retailer's Online Store

In this extension, we relax the assumption that all consumers have access to the retailer's online store. Instead, only consumers of proportion γ have online access. Among these individuals, consumers of proportion β are more skilled online shoppers and the others are less skillful. As in the main model, consumers of proportion α have access to the retailer's offline store. We then have six types of consumers as listed in Table 4.

Under this setup, the equilibrium quality in the case of brick-and-click remains qualitatively the same as in the main model, that is, the manufacturer decreases product quality when δ_h and/or s is low (increases otherwise) in order to induce the retailer to designate the new product to both channels. Nevertheless, because the retailer's offline store is relatively more attractive within this context, the manufacturer does not need to adjust the product quality to the same extent as in the main model when inducing the retailer to designate the new product to either the offline channel or both channels. Specifically, in the case of brick-and-click, when δ_h and/or s is low, the equilibrium quality is higher than that in the main model, but is still lower than that in the baseline model; when δ_h and/or s is high, the equilibrium quality is lower than that in the main model, but is still higher than that in the baseline model. Similarly, in the case of offline-exclusive, the equilibrium quality is lower than that in the main model, but still higher than that in the baseline model. In the case of online-exclusive, the equilibrium quality remains the same as in the main model.

Table 4 Consumer Types and Utilities when Not All Have Online Accessibility

Consumer Type	Proportion	U_1	U_2
More-online-skilled, offline-accessible	$\alpha\beta\gamma$	$q - p$	$\delta_h q + s - p$
Less-online-skilled, offline-accessible	$\alpha(1-\beta)\gamma$	$q - p$	$\delta_l q + s - p$
Online-inaccessible, offline-accessible	$\alpha(1-\gamma)$	$q - p$	/
More-online-skilled, offline-inaccessible	$(1-\alpha)\beta\gamma$	/	$\delta_h q + s - p$
Less-online-skilled offline-inaccessible	$(1-\alpha)(1-\beta)\gamma$	/	$\delta_l q + s - p$
Online-inaccessible, offline-inaccessible	$(1-\alpha)(1-\gamma)$	/	/

4.8. Continuous Consumer Heterogeneities

In this subsection, we relax the assumption of discrete consumer segments using models of continuous consumer heterogeneity. We first analyze a case where consumer heterogeneities are continuous in both dimensions. In the offline market, consumers are geographically uniformly distributed on a Hotelling line of unit length. A representative consumer located at $x \in [0, 1]$ gains utility $q - tx - p$ by purchasing the product from the retailer's offline store located at $x = 0$, where t is the unit transportation cost. When purchasing the product online, at each location $x \in [0, 1]$, a representative consumer $\delta \sim U[0, \delta_{\max}]$ obtains utility $\delta q + s - p$ by purchasing the product from the online store, where $\delta_{\max} q$ represents utility of the most skilled online shoppers.

Under this setup, the retailer's profit from the new product is given by $\pi^r(p, q, w) = Q_I(p) \cdot (p - w)$ and the manufacturer's profit is given by $\pi^m(p, q, w) = Q_I(p) \cdot (w - cq^2)$, with $I = \{0, 1, 2, 3\}$. In the offline-exclusive case, the offline demand is given by $Q_1(p) = \frac{q-p}{t}$. In the online-exclusive case, the online demand is given by $Q_2(p) = 1 - \frac{p-s}{q\delta_{\max}}$. In the case of brick-and-click, the demand is given by $Q_3(p) = \frac{1}{2}(2 - \frac{q-p}{t})(1 - \frac{p-s}{q\delta_{\max}}) + \frac{1}{2}\frac{q-p}{t\delta_{\max}}(\frac{p-s}{q} + \frac{q-s}{q})$, where the first term is the offline demand and the second term is online demand.

When the retailer operates offline only, the equilibrium results are below. When the marginal cost is not low, that is, $c \geq \frac{1}{16\sqrt{Rt}}$, results from our main model hold qualitatively. When $c < \frac{1}{16\sqrt{Rt}}$, the retailer's participation constraint is not binding. As a result, the retailer obtains more than R due to his added ability to fine-tune the retail price in the linear demand model.

With continuous consumer heterogeneities both offline and online, both firms' profits under offline-exclusive, online-exclusive, and brick-and-click options are functions of more than three degrees of product quality. Therefore, we employ a numerical approach to check if our major qualitative insights hold under this more generalized setting.

Specifically, we carry out a series of numerical tests by taking different combinations of $s \in [0.01, 0.1]$ and $\delta_{\max} \in [0.8, 1]$, with $t = 0.2$, $r = 0.01$, and $c = 0.5$. Note that values of t, r, or c do not affect our qualitative results; they only influence the magnitudes of the equilibrium quality and profits. With continuous consumer heterogeneities both offline and online, we learn that the retailer's best-response function is a high degree non-polynomial, and the equilibrium can only be solved in the case of interior solutions. When equilibrium results are obtained as interior solutions, we confirm the following results: First, to induce the retailer to carry the new product both offline and online, the manufacturer may design a low quality product when $\delta_{\max}$ and/or s is low; and high quality otherwise. Second, the retailer may gain the most profit at the intermediate values of R when the product is carried both offline and online.

We further examine whether we can obtain some analytical results under a special case where consumer heterogeneity is continuous only in the offline dimension. Specifically, we consider a case where consumers are geographically uniformly distributed on a Hotelling line of unit length in the offline market. When purchasing the product online, at each location $x \in [0, 1]$, consumers of type δ_h (resp., δ_l) of proportion β (resp., $1 - \beta$) obtain utility $\delta_h q + s - p$ (resp., $\delta_l q + s - p$) by purchasing the product from the online store, where δ_h and δ_l are defined the same as in the main model. The total market size is normalized to unity.

Under this setup, in the case of online-exclusive, the equilibrium results remain the same as in the main model. In the case of offline-exclusive, the retailer is able to obtain more than R when the offline-participation constraint, R, is sufficiently low, that is, $R < \frac{1}{16^2 c^2 t}$. This is due to his added ability to fine-tune the retail price in the linear demand model. In the case of brick-and-click, our findings are summarized in the following Lemma 3.

LEMMA 3 (CONTINUOUS OFFLINE HETEROGENEITY). *When the offline and/or online heterogeneity is sufficiently large (i.e., t and/or β is sufficiently high) such that the market is not fully covered, compared with when the retailer only operates offline, the manufacturer may design a product of lower quality when δ_h and/or s is low (higher quality otherwise) to induce the retailer to carry the new product both offline and online.*

We discover that, under continuous offline heterogeneity, whether the market is fully covered when the retailer expands online plays an important role in the equilibrium outcome. Key insights from the main model remain valid as long as the offline and/or online heterogeneity is sufficiently large (i.e., t and/or β is sufficiently high). When heterogeneity is considerably small, the brick-and-click case may not arise in equilibrium because it will be dominated by either the online-exclusive or the offline-exclusive option.

4.9. Consumers Inspecting the Product Offline then Purchasing It Online

When the product is carried both offline and online, if the retailer charges a lower online price, consumers may first visit the offline store to physically inspect the new product then purchase it online. We further examine whether our main results hold if we take into account such possibilities. Consumers are uniformly distributed over a Hotelling line from 0 to 1, with the offline store located at 0 and t being the unit transportation cost. At each location x, consumers of proportion β are more skillful and obtain utility $\delta_h q + s$ towards online purchases. And consumers of proportion $1 - \beta$ are less skillful in this respect, and hence attach $\delta_l q + s$ (with $0 < \delta_l < \delta_h < 1$) towards online purchases. A representative consumer obtains a utility, $q - tx - p_2$, by first visiting the offline store and then purchasing the product online. Hence, the consumer will only engage in such behavior if (1) she obtains a higher utility than directly purchasing the new product online, that is, $q - tx - p_2 \geq \delta q + s - p_2$, and (2) she obtains a higher utility than purchasing it directly offline, that is, $p_2 < p_1$. Therefore, consumers who are located close to the retailer's offline store, $x \leq \frac{1}{t}[(1 - \delta)q - s]$, will first inspect the product in-store and then purchase it online.

In such cases, the less skillful online shoppers who locate closer to the retailer's offline store will first inspect the product offline then purchase it online. Therefore, the retailer will incur a margin loss, not only from the switch segment (i.e., more-online-skilled, close to the offline store) as in the main model, but also from some less-skilled online shoppers who are close to the retailer's offline store. Hence, the retailer incurs a higher margin loss under the brick-and-click strategy in this case than in our main model. Intuitively, the manufacturer will reduce the quality of the new product to some extent in order to discourage such behavior, as lower quality implies less offline inspection benefits. But our overall qualitative results from the main model still hold. When δ_h and/or s is low, the equilibrium quality in the case of brick-and-click will be even lower than that in our main model. When δ_h and/or s is high, as long as not all consumers engage in such behavior, the equilibrium quality in the case of brick-and-click will be reduced, but will still be higher than that in the baseline case.

4.10. Uncertain Demand

In this extension, we examine a scenario where the actual demand may be less or greater than the quantity Q ordered by the retailer. Given that the retailer plays a gatekeeper role in our context, we follow the norm in industry practice by having the manufacturer bear holding and stockout costs. The retailer, on the other hand, incurs a profit reduction when the actual demand exceeds or is less than the quantity he has ordered. Following a simplified approach to model supply shortage in the literature (e.g., Cachon 2003), we assume that the actual demand is a factor, either $(1 - \lambda)$ or $(1 + \lambda)$, of the quantity Q the retailer orders from the manufacturer. Therefore, we have,

$$\tilde{Q} = \begin{cases} (1-\lambda)Q & \text{with probability } \rho \\ (1+\lambda)Q & \text{with probability } 1-\rho. \end{cases} \quad (7)$$

In the case of demand overage, the manufacturer incurs a unit holding cost h for unsold quantity λQ. In the case of stockouts, the manufacturer incurs a unit stockout cost l for lost demand λQ. Therefore, the manufacturer's and retailer's profit functions become

$$\begin{aligned} \pi^m(q,w) &= \begin{Bmatrix} [\rho(1-\lambda)+(1-\rho)]w - \\ [\rho\lambda h + (1-\rho)\lambda l] - cq^2 \end{Bmatrix} \cdot Q \\ \pi^r(q,w) &= [\rho(1-\lambda)+(1-\rho)]\cdot(p-w)\cdot Q. \end{aligned} \quad (8)$$

In regions where the retailer gains a profit of $R + r$, the manufacturer has to decrease her wholesale price more than in the main model to ensure the retailer's willingness to carry her product. By doing so, the manufacturer absorbs the retailer's potential profit reduction due to the uncertain demand so that the retailer still gets $R + r$.

When the retailer gains a positive surplus (in an intermediate region of R), the manufacturer and the retailer share the profit reduction due to uncertain demand. The manufacturer offers a lower wholesale price in order to partially compensate for the retailer's profit decrease. Consequently, the retailer gains a lower but still positive surplus. This in turn implies that the retailer's incentive for carrying the product both offline and online decreases, that is, the size of the intermediate region of R where the retailer gains a positive surplus decreases. Moreover, the higher uncertainty measured by λ, the smaller the region where the retailer gains a positive surplus.

To summarize, with uncertain market demand, the profits of both firms decrease, with the manufacturer absorbing more profit loss than the retailer. The higher uncertainty measured by λ, the more profit losses both firms will face. It is also worth noting that, to keep our analytical model tractable, we use a simplified approach to model demand shortage and overage. Under this setup, the uncertain demand is not a function of product quality. Therefore, the manufacturer only adjusts the wholesale price in order to compensate for the retailer's profit loss and the equilibrium quality remains the same as in the main model. If the uncertain demand is a more general function of product quality, we expect that the demand uncertainty may also incentivize the manufacturer to increase the product quality (compared with the main model) as a second avenue to compensate for the retailer's potential profit loss.

5. Managerial Implications and Conclusions

With the emerging trend of brick-and-mortar retailers entering the new brick-and-click era, new product manufacturers face new opportunities as well as new challenges. When a manufacturer presents a new product offering to a dual-channel retailer, the ultimate decision is made by the retailer regarding (1) whether to stock the new product; and (2) whether to designate the new product to his brick-and-mortar store, online store only, or both. Consequently, the manufacturer may greatly enhance the success of her new product introduction if she takes into account the retailer's channel outlet designation decisions early on. To our knowledge, this study is the first effort in examining how a manufacturer can strategically use product design to influence the retailer's channel outlet designation decision. Among others, our results provide the following managerial insights:

First, we demonstrate that, to induce the retailer to carry a new product both offline and online, it may not always be optimal for the manufacturer to enhance product quality (compared with when the retailer only operates offline). Indeed, when the online storefront is relatively less appealing to the consumer (e.g., in product categories such as apparel, furniture, and jewelry), a strategic manufacturer may intentionally lower the quality of her new product so that the retailer will opt to carry the product both offline and online (rather than offline-exclusive). We also illustrate that, when targeting the retailer's brick-and-click option, the manufacturer's adjusted quality levels may reduce market cannibalization.

Second, our results also reveal that dual-channel outlets are one possible effective lever that a retailer could use to influence the manufacturer's product design decisions and hence improve his profit. When carefully used, the addition of an online storefront will give the retailer additional leverage in accepting the manufacturer's new product offering and may even bring in an additional profit above and beyond what is determined by the sum of his outside options from the two channel outlets. As a result, the retailer may be incentivized to adjust his participation criterion to a level lower than what is determined by his outside option.

Our study is also subject to limitations that suggest promising avenues for future research. First, although the price setting scheme adopted in our main model is applicable to a large number of industry practices, our key findings do not hold when the retailer determines both wholesale and retail prices. Future research may further investigate how manufacturers can incentivize such retailers to accept their new product offerings. Second, while we use a simplified approach to model demand shortage and overage in our model extension, future research may obtain a more refined understanding of impacts from demand uncertainty by incorporating a stochastic market demand term into a linear demand function. Third, although we emphasize the manufacturer's quality choices around the tipping points where her best strategy is to switch from offering a single product (either offline or online) to offering two different qualities intended for the two different channels, future research may extend our approach to formally examine the manufacturer's product design decisions in all regions of retailer's offline participation constraint. Lastly, we suppress strategic reactions from incumbent manufacturers as well as retail competition. Future research may build upon our approach to study how reactions from competing manufacturers and/or retailers play a role in a focal manufacturer's new product design decision.

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Notes

[1]Our conversations with industry executives also suggest that this operationalization is consistent with actual practice in many product categories, such as power tools, toys, and apparel. Given the large number of new product offerings and the minimal time devoted to any specific product (e.g., *Wall Street Journal*, September 19, 2005, *Wall Street Journal*, March 21, 2006), a minimum profit threshold is probably many retailers' most effective way of contracting in attempts to minimize transaction costs (e.g., Luo et al. 2007). As a result, there is ordinarily no negotiation between the manufacturer and the retailer on wholesale price or product design (e.g., Luo et al. 2007, *Wall Street Journal*, September 15, 2005). Due to the large number of new product offerings, the retailer also typically avoids making any commitment on product acceptance or channel outlet designation prior to the manufacturers' new product introductions (e.g., Luo et al. 2007).

[2]The physical shelf-space constraint determines that the retailer is often highly selective about any new product he allows in his physical store (*Wall Street Journal*, September 19, 2005). As reported by *Hoover's Company* (2011), due to shelf-space limitation, product offerings at Wal-Mart stores are only a fraction of those at Wal-Mart.com. For example, in contrast to the less than a dozen shoulder bags available at a typical Wal-Mart store, Wal-Mart.com offers more than 400 different shoulder bags. Similarly, up to 85% of Costco's online assortment is not found in its club locations (Warehouse Club Focus 2011).

[3]For product categories that do not rely much on physical inspection but enjoy considerable benefits from online purchases (e.g., digital music), we may have $\delta = 1$. In such cases, it is always more profitable to sell the product as an online-exclusive. As a result, over a period of time, the traditional store would disappear and only the online store would remain. Thus the dual-channel retailers would eventually become obsolete in such markets. In this paper, we focus on the vast majority of markets where the business model of dual-channel retailers is sustainable in the long run.

[4]Some retailers offer easy or free returns for products sold from their online stores. In such cases, some less skilled online consumers may consider online purchases a viable option. Nevertheless, with free returns, as long as the consumers' heterogeneity in online shopping skills is sufficiently large such that some consumers still prefer making purchases offline even with free returns, our qualitative results hold.

[5]Because online shelf space is always ample and its opportunity cost r is hence less crucial for the retailer, we emphasize how the equilibrium outcomes change with R. Because the retailer's offline and online participation criteria measure the relative attractiveness of the two channel outlets, varying the online participation criterion r leads to similar results. More details are available from authors upon request.

[6]Our analytical results suggest that $\overline{R} < \hat{R}$ holds with the only exception of considerably high online shopping benefit s.

[7]We have also considered the possibility that, in the case of brick-and-click, the retailer's participation criterion may be greater or lower than the sum of R and r. Under such scenarios, the brick-and-click option will become either less or more attractive relative to the offline/online-exclusive options (i.e., the region of brick-

and-click in equilibrium will shrink or enlarge), but the qualitative results still hold. To save spaces, the equilibrium wholesale price is illustrated in Figure B1 in Appendix S2.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1: Empirical Study on Consumers' Willingness-to-Pay for New Product Purchases from Offline Vs. Online

Appendix S2: Proofs