Channel Design and OEM Growth in a Multi-market Setup

Hsiao-Hui Lee[†] • Tingkai Chang[‡] • Kevin Jean[£] •Chia-Wei Kuo[Γ,1]

Department of Management Information Systems, National Chengchi University, Taipei, Taiwan, hsiaohui@g.nccu.edu.tw[†]

Department of Business Administration, National Taiwan University, Taipei, Taiwan, clarka56b789@gmail.com[‡]*, kevinj0419@gmail.com*[£]*, cwkuo@ntu.edu.tw*[Γ]

April 2021

Abstract. We study how to design an original equipment manufacturer's (OEM's) direct selling channel in a multi-market setup such that the OEM experiences sustained business growth without sacrificing its brand customers' profits. In this paper, we consider an OEM producing for a brand customer that operates in two markets: the domestic market in which the OEM resides and the international market (i.e., other mature markets). The OEM can offer its brand customers at a discount price in exchange for using the excess capacity to produce products under the OEM's own brand and then sell these products through its channel. We build a game theoretical model in a Stackelberg setting in which the OEM is the leader and the brand is the follower, and determine their optimal pricing decisions and the associate profits under two different dual channel settings (i.e., one in which the brand cannot flexibly change its retail price and one in which it can). Contrary to the first-order intuition of market cannibalization, we find that the OEM direct selling channel can be a win-win-win strategy for the brand (gaining higher profit margin in the international market), the OEM (gaining a higher market coverage in the domestic market), and consumers in the domestic market (buying the product at a cheaper price). Such insights are generally robust, even when we consider a cost for the OEM's selling channel, and/or consider a price constraint enforced by the brand, such that the OEM avoids selling the same product at too low a price.

Keywords: Supply chain management; channel of distribution; incentives and contracting; market expansion.

[1] Corresponding Author. (T)+886-2-3366-1045, (F)+886-2-2362-5379

1 Introduction

Global sourcing has become ubiquitous in present business environments, thus leading to more and more dispersed supply chains that spread across different continents, as well as creating both challenges and opportunities for firm growth. Stan Shih, the founder of Acer, Inc., which specialized in personal computers, observed that parties at both ends of a supply chain (i.e., design and innovation as well as branding and service) received more value-added benefits than those parties in the middle (i.e., manufacturing and production). This U-shaped relationship, denoted as a smile curve (Shih 1996), suggests that original equipment manufacturers (OEMs) often receive fewer profit shares than their brand partners. One growth option for OEMs is to expand their market coverage by offering their own brand products. However, such a business expansion option is risky; because of market cannibalization, these OEMs' brand customers may suffer from lower profits and, hence, may decide not to continue their business with these OEMs. In this paper, we discuss how adding an OEM selling channel in a "multi-market" setup can help increase an OEM's market coverage and profitability, while maintaining its relationship with its brand customers by providing the same, if not more, profits to these brands via economies of scale.

As a motivating example, we use the case written by Ng et al. (2010) that illustrates the growth of Galanz Enterprises Group Co. Ltd., an OEM for major international brands' microwave ovens in China. In the mid 1990's, prices of microwave ovens with international brands (e.g., Panasonic, Toshiba) in China ranged from RMB 1,000 to 3,000; however, per capita annual income of urban households in 1995 was only around 4,200 RMB. During this period, while serving as an OEM for these international brands, Galanz started selling products carrying its own brand in China at a low price (as low as RMB 300 per unit). To achieve this low price strategy and stay competitive in the market, Galanz adopted production line transfer agreements with its international brand customers, so it could freely use its excess capacity to sell its *own brand's* low-price microwave ovens in China. In return, Galanz significantly lowered its wholesale price to these international brand customers. Using economies of scale to lower production costs, Galanz sold more than 16 million microwave ovens and earned 76% of the Chinese market (denoted as the domestic market) by October 2000. We note that this type of business model, which leverages an OEM's low cost strategy and economies of scale in setting its own brand (and/or selling channel), is not uncommon even to this day. For example, Foxconn, one of Apple's largest OEMs, produced smart phones under its new brand[2] with its partner HMD in 2019.[3] According to Neil Mawtson, wireless devices executive director at Strategy Analytics, "HMD smartphone models deliver relatively high specs at relatively reasonable price points." In 2019 Q2, HMD shipped 4.8 million Nokia smartphones, a 55% growth in shipments compared to Q1 2019 or 20% growth to Q2 2018.[4]

In ways that differ from the dual channel literature that considers OEMs and brands competing in the same market to highlight the cannibalization effect, we focus on two aspects that capture an OEM's challenges: brand-OEM relationship and market structure. First, depending on incentive terms, brand customers that had been working with the OEM (e.g., Panasonic or Toshiba in the Galanz case) may not agree with the OEM's own selling channel, as these brands often have concerns over cannibalization in the domestic market (e.g., the Chinese market in the case). Therefore, incentives to brands are needed to overcome brand customers' concerns over intensified competition. As an example, when Galanz initiated its low-price strategy, most of its customers could not follow such a low price, and they were either pushed out of the Chinese market or only focused on loyal consumers who only purchase brand products. In order to mitigate this issue, Galanz offered a very low wholesale price to its customers, who, in turn, received a higher premium for products sold outside

---

[2] Nokia has licensed Foxconn to use its brand name for ten years.

[3] https://www.forbes.com/sites/ralphjennings/2019/01/31/apple-contractor-foxconn-makes-gains-with-its-own-brand-of-phones-in-a-tough-market/68fde0f22c48

[4] https://nokiamob.net/2019/07/31/nokia-smartphone-sales-rebound-with-4-8-million-units-shipped-in-q2-2019/

China. As a result, these customers still continue their sourcing relationship with Galanz despite the market cannibalization effect within the China market.

Second, although OEMs can use a low wholesale price strategy to incentivize brand customers' agreements and reduce potential business friction, the market structure still plays an important role. In particular, we consider multiple markets: the international markets in which brands operate, and the domestic market in which both the brands and OEMs operate. For example, during Galanz's rising period, China was considered the "world's factory" but not the "world's market." These customers, even though they were pushed to give up this (small) market, did not seem to mind the intensified competition, as Galanz's wholesale price helped them obtain a heavy margin from other markets in which they operated. However, as the Chinese market grew further, some of these brands returned to this market, but no longer sourced products from Galanz, as sourcing from Galanz sustained Galanz's low cost strategy (due to increased scales) and, hence, intensified competition. As a result, in addition to the multi-market assumption, market characteristics of the domestic market play a key role with respect to both brands' and OEMs' decisions.

Motivated by the Galanz example, we model a supply chain with an OEM and a brand that can sell the product to two markets: the domestic market (where the OEM is located) and international markets (other countries). In a conventional supply chain (denoted as Channel B), the OEM sells products to the brand, and then the brand distributes the goods to consumers in both markets. In contrast, the OEM can also sell products in the domestic market with its own brand name at a lower price than the brand, and then sell products to the brand with a lower wholesale price than that in Channel B to induce the brand's agreement, so the OEM may use its excess capacity. In this case, the OEM operates a dual channel, but only competes with the brand in the domestic market.

To further model how market characteristics influence the brand and the OEM's decision, we consider three components: the size of the international market, the size of the domestic market, and the size of the brand's loyal consumers in the domestic market. As the product under the brand's name has the same quality as the one under the OEM's name, consumers will likely purchase the OEM's product, as long as the price of the OEM product is lower. However, in emerging markets, some consumers perceive brand names differently (e.g., rich consumers in an M-shaped society), and these consumers will only purchase brand products as long as they can afford these products. In this paper, we identify this group as "loyal consumers"who view a brand as an indicator of perceived quality (instead of valuing only the physical quality, which is the same as mentioned previously)[5].

Motivated by the above-mentioned issues, we pose the following research questions. How can the OEM design a direct selling channel serving different markets without objections from its brand customers? Can this direct selling channel be beneficial to the OEM, the brand, and consumers, simultaneously? To answer these questions, we first consider the situation in which a brand maintains its pricing strategy even after the OEM's direct selling channel is established (denoted as Channel C). This situation is largely consistent for brands that enter the domestic market but try to maintain their branding effect.[6] In this case, we show that Channel C always achieves a higher supply chain profit (sum of the profits of the brand and the OEM) than Channel B when the domestic market is not too small.[7] Moreover, the brand receives the same profit as that of Channel B, such that it is indifferent to such a dual channel; even though the sales from the domestic market are reduced, the high margin

---

[5] Prior research on brand effect provides supporting evidence that good brand names have a positive effect on perceived quality (e.g., see Grewal et al. 1998, Rao and Monrow 1989, and Dodd et al. 1991).

[6] For example, brands like Apple and Microsoft may likely keep their respective pricing strategies. For example, the price of an iPhone X (64 GB ROM) is 999 USD in the US, 1,023 USD in Japan, 1,215 USD in China, and 1,211 USD in Switzerland. Excluding import taxes, these prices are very compatible. We used exchange rates of 113.05 for JPY to USD, 6.9 for RMB to USD, and 1.001 for CHF to USD (accessed date November 4, 2018). Moreover, as shown in Grewal et al. (1998), price discount has a negative effect on consumers' internal reference prices; thus, some brands, though they can, may not be willing to lower their respective prices when entering a new market.

[7] When the domestic market is too small such that the brand only operates in the international market, the OEM does not want to offer its own product, as the domestic market cannot sustain its selling channel.

derived from the low wholesale price compensates for this loss.[8] The OEM receives higher profits from increased sales in the domestic market. We also show that with the additional channel, the OEM also increases total production scale (i.e., sum of both the sales under its name and sales under the brand's name). As an added benefit, the increased production scale results solely from the domestic market, and because more consumers in the domestic market can enjoy a low-price product, such a channel design improves social welfare as well.

Second, we relax the brand's fixed pricing and allow the brand to change its retail price after the entry of the OEM's direct selling channel (denoted as Channel F). Some brands can react to the OEM's low-price product by re-optimizing their respective pricing strategies. Intuitively, this additional flexibility with respect to brand pricing enables the brand's power; as a result, we expect this added flexibility to hurt the OEM's profit. Contrary to our first-order intuition and under minor conditions, when the domestic market is sufficiently large, Channel F still always outperforms Channel B with respect to OEM profit (and, hence, supply chain profit). Interestingly, for a sufficiently large domestic market and a small portion of loyal consumers, the brand also lowers its retail price in the international market and orders more from the OEM, further enabling the OEM to use scale to lower costs. As an added benefit, the OEM's production scale increment in Channel F results not only from the domestic market but also from the international market, thereby improving social welfare.

In addition to comparing the single channel (Channel B) with the dual channels (Channels C and F), we also use this paper to analyze when the flexible retail price is preferred by the OEM. In a sufficiently large domestic market, the OEM benefits more from the brand's flexible retail price due to the brand's higher sales in the international market. However, these benefits diminish in smaller domestic markets, and the supply chain prefers a fixed

[8] Our model can be easily modified to allow a brand to charge a (fixed) authorization fee. As long as the improved supply chain profit exceeds this fee, supply chain profits can be freely distributed between the brand and the OEM, and managerial insights remain with only slight changes with respect to domestic market thresholds.

brand price in equilibrium when the domestic market is sufficiently small. Furthermore, the size of the loyal consumer base in the domestic market also significantly affects equilibrium strategies. A large portion of loyal consumers makes it easier for the OEM to provide the same profit to the brand under dual channels, but it also reduces the market size for the OEM. This mixed effect complicates our analysis in ways that yield some interesting results: the profit in Channel C increases with the number of loyal consumers, whereas the profit in Channel F decreases with the number of loyal consumers.

Finally, we include two extensions. In the first, we aim to capture both the situation in which a customer can also write contract terms to limit the OEM's retail price, as well as the situation when the OEM incurs a cost by operating its own channel. Generally, adding these two constraints make it difficult for the OEM to maintain a dual channel. Hence, one can expect the entire supply chain to incline more towards Channel B in this extension. However, as we show in our numerical results, our previous insights still remain for a wide range of parameters for both the price constraint and operations costs. In the second extension, we analyze a model with a quality-embedded utility function to capture the potential vertical quality differentiation between the brand's and the OEM's respective products. In this extension, we no longer assume a fixed portion of loyal consumers but allow consumers with different valuation toward quality and prices to select the channel from which they should purchase, based on their utility comparison. We find that although Channel C is degenerated to Channel B, Channel F strictly outperforms Channel B, thus leading to a similar insight as that obtained with our main model.

Our work contributes to the operations literature by analyzing how a dual channel can be used to sustain firm growth in a multi-market setup. Our work focuses on how market structure (i.e., the sizes of the two markets and loyal consumers) affect dual channels and pricing decisions. Specifically, our analytical outcomes not only help explain how parties' behaviors in supply chains depend upon market characteristics, but also how OEMs can use a proper channel design to create a win-win situation for themselves and their brand customers. To enhance their profits, OEMs can persuade their brand customers (using lowered wholesale prices) to allow them to operate their own selling channels. Depending on how mature the domestic market is and how many consumers are at the top of the pyramid, these OEMs can also influence their brands' decisions in modifying their pricing strategies.

Moreover, our work offers the following managerial insights and suggested actions. When an OEM grows, it must consider the transition from an OEM business to an OBM business by setting up its own brand and/or selling channel. However, a typical challenge is whether such a move creates an internal conflict of interests between its OEM business and its OBM business, as the brands that source products from this OEM may deter the OEM's move by threatening the OEM to remove their orders. [9] Our result suggests both conditions and ways for OEMs to grow under such a challenge. Specifically, it is easier for OEMs that sell to brands with a sales focus on other developed markets than emerging ones (where the OEMs operate) to persuade their brand customers by leveraging their economies of scale and low cost strategies. By compensating brands for their losses in the domestic market, the brands gain higher profit margins and/or higher international market coverage. Moreover, supply chain profits may also be freely distributed to brands by using channel authorization and licensing fees paid by OEMs to further incentivize the brands and create a win-win situation for both parties. Finally, given different market structures, OEMs can also incentivize their brand customers to either adjust their retail prices or not to maximize their entire supply chain profits. Finally, we note that our work also has implications with respect to consumer welfare. By understanding when and how to establish OEM dual channels, consumers in emerging countries may enjoy low-cost alternatives that they could not previously afford, and policy makers might consider incentive schemes to help cultivate the growth of such OEM businesses, should doing so benefit their people.

We organize the remainder of this paper as follows. After we review the existing literature in Section 2, we use Section 3 to outline our model and present our analytical results. Section 4 compares the dual channels and consider the case in which the brand is able to offer

---

[9] This has been shown to be a great challenge for many firms, such as ASUS (Shih et al. 2010).

differential pricing for both markets and own the OEM production in our comparison. In Section 5, we provide two extensions of our model. We conclude our paper in Section 6 with a discussion and some directions for future research. We provide all proofs in the Appendix.

2 Literature Review

Our work is closely related with the channel design literature that focuses upon a supply chain comprised of a manufacturer and a retailer. By optimizing pricing and other decisions, these works generally focus on channel efficiency by comparing profits (including the supply chain as well as the players in the chain) under the traditional retail channel and under the dual channel. For example, Tsay and Agrawal (2004) consider a setting in which a manufacturer can initiate a direct sales channel, which may not hurt the retailer. They provide a thorough discussion regarding different sources of inefficiencies, such as double marginalization and channel conflicts, and how to mitigate these adverse effects in the dual channel. In addition to pricing decisions, some other studies analyze how a manufacturer or a retailer in a dual channel makes decisions with respect to the timing of pricing (Matsui 2017), product assortment (Rodríguez and Aydın 2015), and leadtime (Hua et al. 2010; Modak and Kelle 2019). Yan (2020) further extends the dual-channel setting to online finance services, and Xiao and Shi (2016) consider a dual-channel setting for which supply shortage may exist in the channel.

Most studies in the channel design literature consider cases in which a manufacturer can freely establish a direct selling channel, regardless of a retailer's preference. Indeed, in some scenarios, a dual channel can be a win-win for both the manufacturer and the retailer, and hence the manufacturer can freely operate its own channel (e.g. Chiang et al. 2003; Cattani et al. 2006; Arya et al. 2007; Cai 2010; Vinhas and Heide 2014; Xiao et al. 2014; Ha et al. 2015; Caidieraro 2016; Chen et al. 2017; Yan 2019; Matsui 2020). For example, Chiang et al. (2003) suggest that when consumers have a low preference toward a direct selling channel, such a channel design benefits both the manufacturer and the retailer. Cattani et al. (2006) find that when the manufacturer can optimally choose the wholesale and retail prices (instead of fixing either of these prices), such a channel design also benefits the retailer. Arya et al. (2007) consider a higher direct channel cost, and demonstrate that manufacturers and retailers can benefit from such a dual channel when manufacturers can lower wholesale prices offered to their retailers, thereby lowering the double marginalization issue. Although we find many cases in which both the manufacturer and retailer benefit from the direct selling channel, numerous cases also suggest that adding a new channel still incurs double marginalization that hurts all parties. For example, extending the work of Arya et al. (2007), Li et al. (2014) consider the case that only the retailer possesses information regarding market size, and this information asymmetry leads to a poor performance for not only the retailer, but also for the manufacturer under a dual channel design, especially in smaller markets.

In addition, many dual channel studies assume that consumers' utility function is purely based on the prices set by each channel (e.g., Cattani et al. 2006; Dumrongsiri et al. 2008; Mukhopadhyay et al. 2008; Ha et al. 2015; Yu et al. 2017; Chen et al. 2017), except that some explicitly model consumer channel-specific preferences (either an explicit preferences or via differential product qualities). In addition to price comparison considerations, Chiang and Monahan (2005), Geng and Mallik (2007), and Chiang (2010) also consider that a good number of consumers prefer to search for and buy products online (i.e., "direct channel" in our paper). In a two-manufacturer and two-retail channel setting, Dukes et al. (2006) consider the case that consumer preferences depend on the combination of manufacturers and retailers (i.e., a total of four channels). Considering multiple retailers, David and Adida (2015) assume that some consumers prefer each type of retailer, regardless of price. Matsui (2016) shows asymmetric product distribution may exist in equilibrium, even when both manufacturers are symmetric. Iyer (1998), following assumptions similar to ours, also models brand loyalty when consumers make their purchase decisions.

Our paper differs from those in the extant literature in two aspects: brand-OEM relationship and market structure. First, our paper considers the mitigation of channel conflicts between an OEM and a brand. Upon initiating the direct channel to serve the domestic market, the OEM makes pricing decisions (both its own retail and wholesale prices) so that the brand will earn at least the same profit that it would earn in a single channel. Second, the existing literature mainly considers a single market setup (e.g., Chiang et al. 2003; Netessine and Rudi 2006; Arya et al. 2007; Li et al. 2014; Ha et al. 2015). In our paper, the OEM only sells its products to the domestic market, whereas the brand serves the international market as well as loyal consumers in the domestic market who prefer to purchase from the brand as long as the products are affordable. This setup enables us to incorporate the channel preference captured by the prior literature, as well as the dual market setup that has not yet been explored in previous studies. We are particularly interested in how the characteristics of these two market segments (domestic and international) and loyal consumers influence channel pricing decisions and channel efficiency, so we may better understand how an OEM can design its selling channel to achieve its market expansion and firm growth.

3 Model and Analysis

We consider a model with an OEM selling a product to a brand owner, who then sells the product to two markets: a domestic market (where the OEM is located) and an international market (other countries). The OEM produces the product with unit production cost c, and sells the product to the brand at a wholesale price w. The brand then sells the product to end consumers in both markets at the same price p. Because of brand positioning concerns, we consider that the brand does not price discriminate between the two markets (see Footnote 1, for example). This assumption is generally true for brand products. However, we relax this assumption in Section 4.3 and investigate channel efficiency when the brand can price discriminate between the two markets. In this section, we consider three types of channel designs. First, as a benchmark, we consider that only the brand sells the product to both markets (denoted as Channel B). Second, we consider that the brand sells its brand products to both markets but the OEM sells its OEM products only to the domestic market, and the brand cannot adjust its retail price in response to the OEM setting up its selling channel (denoted as Channel C). Finally, we consider a channel design similar to Channel C, except that we allow for the brand's adjustment on retail prices (denoted as Channel F).

Consumers are heterogeneous in their willingness to pay. Hence, we let v be an end consumer's willingness to pay, and we assume that v is uniformly distributed in between $[0, \alpha]$ for the international market and between $[0, \beta]$ for the domestic market. We consider β to be sufficiently large (but still smaller than α) so that the brand will be profitable enough to serve the domestic market.[10] We then assume that a consumer with a willingness to pay v can receive a valuation of $v - p$ if s/he buys the product and his/her reservation value is 0. Therefore, in Channel B for which only the brand offers a selling outlet (differentiated by a subscript B), the market coverage by a product priced at price p_B is $\alpha - p_B$ in the international market and $\beta - p_B$ in the domestic market. The sum of the two then constitutes the total production scale for the OEM.

However, in the case when the OEM can sell the product directly to the domestic market, because the product quality is the same (i.e., from the same production line), the valuation function cannot differentiate consumers who have strong brand loyalty from those who do not. We model these consumers' preferences for the brand product (due to perceived better service or reputation) by a parameter Δ. That is, Δ high willingness-to-pay consumers (distributed in between $[\beta - \Delta, \beta]$) will only purchase the brand product if they can afford the product. However, if they cannot afford the brand product but can only afford the OEM product, then they can still buy the OEM product. We denote these high-valuation consumers as "loyal consumers" in our paper. We do not directly model the perceived

[10] First, we consider $\alpha > \beta$ so that the international market is the main market for the brand. Otherwise, the brand may pay more attention to the domestic market, and such a case falls outside the scope of this paper. Second, as long as $\beta - p_B > 0$, it is profitable for the brand to serve the domestic market. The inequality can be rewritten as $\beta > (3\alpha + 2c)/5$. We note that, given that $\alpha > \beta$, $\beta > (3\alpha + 2c)/5$ also implies $c < (\alpha + \beta)/2$, which guarantees the the cost will be sufficiently low enough to allow the brand to source the product.

product quality difference and allow consumers to choose which product to purchase in the main model for two reasons. First, rich consumers (especially in China, India, and many emerging economies) do not care about the price difference and only want to buy brand products. Second, our aim is to investigate how market structure influences an OEM's selling channel effectiveness, rather than investigate the effect of quality discrimination for the perceived product quality through different channels. That said, in Section 5.2, we extend our main model to consider a quality-embedded utility function that allows consumers to freely choose the channel, and we find similar insights as those we observe in our main model.

Finally, we refer to the case in which the OEM can sell the product in the domestic market as "dual channels." In particular, we consider two brand pricing strategies with respect to an OEM dual channel: a rigid pricing strategy for which the brand cannot change its retail prices easily (or at least in the short run) to maintain brand positioning, and a flexible pricing strategy for which the brand can change its retail prices easily. We denote the former as Channel C and the latter as Channel F, and differentiate them from Channel B by using subscripts C and F, respectively. With Channel C, the brand cannot adjust its original pricing strategy and, hence, its retail price is $p_C = p_B$, whereas with Channel F, the brand can adjust its original pricing strategy fairly easily from p_B to p_F.

Therefore, when the OEM sells the product in the domestic market, it charges a retail price of p_i^m, for which i can be C or F. Following the same consumer valuation logic, we know that, in the international market where the OEM does not sell its own product, the brand's market coverage is $\alpha - p_i$. In the domestic market, the brand's market coverage becomes $\min\{\Delta, \beta - p_i\}$, depending on how many loyal consumers can afford the brand product, whereas the OEM's market coverage becomes $\beta - p_i^m - \min\{\Delta, \beta - p_i\}$. As a result, the total market coverage in the domestic market becomes $\beta - p_i^m$. In Table 1, we provide a summary table of the notations in this paper. In the following subsections, we consider the case in which the OEM is the Stackelberg leader and the brand is the follower, and analyze the OEM's pricing strategies and the associated profits using this assumption.

3.1 Channel B: Brand Channel Only

Using the above model setup, we observe that the brand's profit can be expressed as:

$$\pi_B = (p_B - w_B)(\alpha + \beta - 2p_B),$$

and the OEM's profit is:

$$\Pi_B = (w_B - c)(\alpha + \beta - 2p_B).$$

Solving the two optimizations by the first-order conditions and using backward induction, we find that the optimal brand retail price is:

$$p_B = \frac{3\alpha + 3\beta + 2c}{8}.$$

We denote the optimal brand profit as π_B^* and the optimal OEM profit as Π_B^*, or,

$$\pi_B^* = \frac{(\alpha + \beta - 2c)^2}{32}, \text{ and } \quad \Pi_B^* = \frac{(\alpha + \beta - 2c)^2}{16}.$$

3.2 Dual Channels C and F

In Channel C, the brand allows the OEM to establish the OEM's selling channel, and upon its establishment, the brand maintains its original retail price $p_C = p_B$. In order for the brand to be incentivized to allow for this OEM channel, the OEM needs to give a wholesale price w_C so that the brand's profit will not be lower than its original profit, expressed as:

$$\pi_C = (p_C - w_C)\left(\alpha - p_C + \min\{\Delta, \beta - p_C\}\right) \geq \pi_B^*.$$

The OEM also needs to decide its own retail price by maximizing its own profit function, expressed as:

$$\Pi_C = (w_C - c)\left(\alpha - p_C + \min\{\Delta, \beta - p_C\}\right) + (p_C^m - c)\left(\beta - p_C^m - \min\{\Delta, \beta - p_C\}\right).$$

As a low wholesale price will increase the brand's profit but hurt the OEM's profit, the OEM sets the wholesale price such that $\pi_C = \pi_B^*$. We then can solve for the OEM retail price in Lemma 1.

Lemma 1. *The optimal OEM retail price is:*

$$p_C^m = \begin{cases} \frac{\beta-\Delta+c}{2}, & \text{if } \beta \geq \frac{3\alpha+8\Delta+2c}{5} \equiv \beta_1; \\ \frac{3\alpha+3\beta+10c}{16}, & \text{if } \beta < \beta_1. \end{cases}$$

When $\beta = \beta_1$, the brand covers exactly the number of loyal consumers in the domestic market.

This lemma shows that with the dual channel, the OEM can offer a cheaper choice (i.e., $p_C^m < p_B$) to consumers in the domestic market. When $\beta \geq \beta_1$, we obtain:

$$p_B - p_C^m = \frac{3\alpha - \beta + 4\Delta - 2c}{8} > 0,$$

in which we use $\alpha > \beta$ and Footnote 10 in the inequality. When $\beta < \beta_1$, by using Footnote 10, we obtain:

$$p_B - p_C^m = \frac{3\alpha + 3\beta - 6c}{16} > 0.$$

As a result, this dual channel can successfully price discriminate between the two markets. In this case, the OEM's production scale is greatly enhanced, as the market coverage from the international market remains unchanged, but the market coverage in the domestic market increased from $\beta - p_B$ to $\beta - p_C^m$, because of the lowered OEM retail price.

In Channel F, the brand allows the OEM to offer a selling channel, but the brand can adjust its retail price in order to maximize its profit. In this case, in order for the brand to be incentivized to allow for the OEM channel, the OEM still needs to maintain the brand's profit to at least match its original profit (i.e., $\pi_F^* = \pi_B^*$).[11] The profit functions for the brand

[11] We can easily show that if the two can freely (optimally) choose their prices, then the brand earns less

and the OEM are similar to the ones in Channel C, except that we change the subscript from C to F, and p_F, the brand's retail price in Channel F, now becomes a decision variable in addition to p_F^m. The following lemma characterizes the optimal solution.

Lemma 2. *The optimal brand retail price is:*

$$p_F = \begin{cases} \frac{8\alpha+8\Delta-\sqrt{2}(\alpha+\beta-2c)}{8}, & \text{if } \beta > \frac{8\alpha+16\Delta-\sqrt{2}[\alpha-2c]}{\left(8+\sqrt{2}\right)} \equiv \beta_2, \\ \beta-\Delta, & \text{if } \beta_1 \leq \beta \leq \beta_2, \\ \frac{3\alpha+3\beta+2c}{8}, & \text{if } \beta < \beta_1. \end{cases}$$

The optimal OEM retail price is:

$$p_F^m = \begin{cases} \frac{\beta-\Delta+c}{2}, & \text{if } \beta \geq \beta_1, \\ \frac{3\alpha+3\beta+10c}{16}, & \text{if } \beta < \beta_1. \end{cases}$$

First, regardless of the brand's reaction in its pricing strategy, we observe that the OEM charges the same retail price. Similar to Channel C, this dual channel also offers a cheaper choice for the consumer as $p_F^m = p_C^m < p_B$, and we therefore know that the OEM also expands its market coverage in the domestic market in Channel F when compared with Channel B.

However, in the international market, the brand can change its retail price so that p_F is higher than p_B. That is, when $\beta < \beta_1$, $p_B = p_F$, and when $\beta_1 \leq \beta \leq \beta_2$, we obtain:

$$p_B - p_F = \Delta - \frac{5\beta - 3\alpha - 2c}{8} \leq 0,$$

because $\beta \geq \beta_1$. When β increases such that $\beta_2 < \beta \leq \beta_{CF}$, in which,

$$\beta_{CF} = \frac{(17-8\sqrt{2})\alpha + (24-8\sqrt{2})\Delta + c(8\sqrt{2}-10)}{7},$$

profit than π_B^*. As a result, the OEM still needs to maintain the brand's profit by lowering its wholesale price in exchange for the brand's agreement of the dual channel.

then $p_F \geq p_B$. As the brand's international market coverage changes from $\alpha - p_B$ to $\alpha - p_F$ in Channel F, when β is not large (i.e., $\beta_1 \leq \beta \leq \beta_{CF}$), the result, $p_F \geq p_B$, thus implies that the OEM will lose part of its sales in the international market due to the increased retail price of the brand. In this case, the brand gains from a higher profit margin in two ways: from a higher retail price and a lower OEM wholesale price. However, when β is sufficiently large (i.e., when $\beta > \beta_{CF}$), the brand is willing to reduce its retail price for larger market coverage. We use the following corollary to depict the result.

Corollary 1. *If $\beta < \beta_1$, then $p_F = p_B$. If $\beta_1 \leq \beta \leq \beta_{CF}$, then $p_F \geq p_B$. If $\beta > \beta_{CF}$, then $p_F < p_B$.*

Finally, we compare the overall market coverage of Channel F with Channel B by comparing $(\alpha+\beta) - p_F - p_F^m$ and $(\alpha+\beta) - 2p_B$. If $2p_B - p_F - p_F^m > 0$, then the overall OEM still improves its production scale, even though the brand raises its price when $\beta_1 \leq \beta \leq \beta_{CF}$. We have shown above that the inequality is valid when $\beta < \beta_1$. When $\beta_1 \leq \beta \leq \beta_2$, we obtain:

$$2p_B - p_F - p_F^m = \frac{3\alpha - 3\beta + 6\Delta}{4} > 0,$$

whereas when $\beta > \beta_2$, we obtain:

$$2p_B - p_F - p_F^m = \frac{2\beta - 2\alpha - 4\Delta + \sqrt{2}(\alpha + \beta - 2c)}{8} > 0,$$

as this value, obviously, increases with β, and when $\beta = \beta_2$, we find that it will be positive as well, based upon the continuity of this value. Following our collective analysis of these two lemmas, then, we obtain the following corollary:

Corollary 2. *Although Channel C and Channel F both enhance the overall production scale, the enhancement in Channel F is achieved at the cost of the market coverage in the international market when $\beta_1 \leq \beta \leq \beta_{CF}$.*

Next, we consider how the size of each market, α and β, respectively influences the optimal retail price decisions (i.e., p_B, p_C, p_C^m, p_F, and p_F^m) in the following lemma.

Lemma 3. *The following table shows the effects of α and β on the optimal retail price in the three channels:*

	Channel B	Channel C		Channel F	
	p_B	p_C	p_C^m	p_F	p_F^m
α	$+$	$+$	$\times$ if $\beta \geq \beta_1$ $+$ if $\beta < \beta_1$	$+$ if $\beta > \beta_2$ $\times$ if $\beta_1 \leq \beta \leq \beta_2$ $+$ if $\beta < \beta_1$	$\times$ if $\beta > \beta_1$ $+$ if $\beta < \beta_1$
β	$+$	$+$	$+$	$-$ if $\beta > \beta_2$ $\times$ if $\beta < \beta_2$	$+$

First, we observe that when the international market size increases (i.e., α increases), it is always weakly beneficial for both the brand and the OEM retail prices, as these prices are at least non-decreasing in α. We can observe a similar effect when the domestic market size increases, except when $\beta > \beta_2$ in Channel F. This exception is a result of the brand focusing more on its market coverage on the international market rather than the profit margin.

4 Effectiveness of Dual Channels

After analyzing the two dual channels (one with a rigid brand price and one with a flexible price), we next discuss the effectiveness of the two dual channels. We first investigate whether the two dual channels outperform the single selling channel in Section 4.1. We then compare the two dual channels to determine which one the OEM prefers in Section 4.2. Finally, as one benefit resulting from the dual channels is the price discrimination between the two markets and within the domestic market, we extend the comparison between the dual channels with a single channel in a centralized system that can price discriminate between domestic and international markets in Section 4.3. We note that we use supply chain profits as the key performance for the comparison, as the brand receives the same profit as before; hence, the OEM profit changes because of the OEM channels are equivalent to the profit changes in the supply chain.

4.1 Comparison between Channel B and Channels C and F

Based on the analysis of the optimal prices in Section 3, we compare the two dual channels with Channel B in the following proposition:

Proposition 1. *(1) $\Pi_C^* \geq \Pi_B^*$, and Π_C^* weakly increases with Δ. (2) $\Pi_F^* \geq \Pi_B^*$, and Π_F^* weakly decreases with Δ if α is sufficiently large (i.e., $\alpha > \max\{(29 - 14\sqrt{2})c/(8 - 5\sqrt{2}) - \Delta, (24 - 7\sqrt{2})(\Delta - c)/(9\sqrt{2} - 8)\}$).*

First, regardless of the brand's pricing flexibility, offering a dual channel always benefits the OEM while maintaining the brand's profitability, as dual channels can help price discriminate a product. Although some loyal consumers still prefer a brand's product, the vast consumers who cannot afford the brand's product now have a cheaper alternative, as p_C^m and p_F^m are both smaller than p_B as we have seen from Lemmas 1 and 2.

Second, Proposition 1 highlights the effect with respect to loyal consumers under different types of brand pricing flexibility. When the brand cannot adjust its price in the short run (i.e., Channel C), the OEM benefits from loyal consumers. The number of loyal consumers influences the OEM profit in two opposite ways. On the one hand, when Δ increases, the OEM effective market size $(\beta - \Delta)$ shrinks as more consumers in the domestic market would prefer the brand product over the OEM one. On the other hand, a higher Δ also makes it easier for the OEM to offer the same profit to the brand. As the brand has a rigid pricing strategy, the OEM benefits more from the latter rather than being harmed by the former.

When the brand can flexibly adjust its price (i.e., Channel F), then a higher Δ reduces OEM profits, which occurs when the international market size is sufficiently large. This is in an opposite direction as that demonstrated in Channel C. Flexible brand pricing increases the power of the brand, as the brand now has a pricing tool (adjusting its own retail price) to use in supply chain negotiations; moreover, this power is enhanced with a high degree of attention (i.e., loyal consumers) from the domestic market.

Finally, although we only focus upon the OEM as the Stackelberg leader in the model, improved OEM profits that result from the dual channel can be easily extracted by the brand. For example, the brand may use a (fixed) authorization fee to allow the OEM to use excess capacity to produce and sell more products. In this case, the additional profits that the OEM earned via the dual channel can be freely distributed in the supply chain. As this process involves the relative bargaining power between the two parties, we do not split the profits, but rather focus on the enhancement of the OEM's (and hence, the supply chain's) profit.

4.2 Comparison between C and F

Even though we have shown that both dual channel settings always outperform the single channel setting because of their ability to price discriminate among consumers, the two nonetheless differ in their effectiveness. More importantly, understanding the two dual channels' relative effects allows the OEM to incentivize the brand to choose the brand's pricing strategy, if possible. The difference between the two dual channels' profits thus gives an upper bound with respect to the OEM's incentive amount.

Intuitively, when a brand can adjust its retail prices based on wholesale prices that the OEM offers, we can expect this extra lever to harm the OEM's profitability, making it more difficult for the OEM to incentivize the brand and allow for a dual channel. That said, the following proposition offers a different result.

Proposition 2. $\Pi_F^* > \Pi_C^*$ *if and only if*

$$\beta > \beta_{CF} = \frac{(17 - 8\sqrt{2})\alpha + (24 - 8\sqrt{2})\Delta] + c(8\sqrt{2} - 10)}{7} > \beta_2, \tag{1}$$

and in this region, $p_C > p_F$*, whereas* $p_C \leq p_F$*, otherwise.*

First, when the domestic market is mature/large enough, the OEM, and hence the supply chain, can benefit from the brand's adjusting its global pricing strategy. This interesting result (echoing Corollary 1) is due to the improved market coverage, which stems from the international market. As the proposition shows for this region, $p_C > p_F$, implying that the brand lowers its retail prices to both markets. This move neither changes its market coverage in the domestic market (which is Δ) nor changes the OEM's market coverage, as the OEM's retail prices are the same whether or not the brand can adjust its retail price (i.e., $p_F^m = p_C^m$); rather, this move increases the brand's market coverage in the international market. Conversely, this proposition also shows that when the domestic market size is small, the brand usually raises its retail price, knowing that the OEM will offer compensation for what the brand earns in the single channel setup. Because of this rise in retail price, the OEM's profitability and, hence, the supply chain's profitability will both decrease.

Second, this proposition also shows the effect of loyal consumers in deciding whether to incentivize the brand to adjust its retail prices. From Equation (1), we see that, when Δ increases, β_{CF} also increases, implying that Channel F will become less preferred than Channel C. This result can also be seen from Lemmas 1 and 2: when Δ increases, Π_C^* weakly increases, but Π_F^* weakly decreases.

4.3 Comparison between Dual Channels and A Centralized Price-Discriminated Channel

As we have shown in Section 4.1, because they can price discriminate in the domestic market, the two dual channels can outperform the single channel model. In this subsection, we investigate the case in which the brand can engage in differential pricing for the two markets and own the OEM production (denoted as Channel DP), as well as investigate the effectiveness of the dual channels by comparing them with this centralized channel.

First, we denote the supply chain profit of Channel DP as Π_{DP}. If the brand can engage in price discrimination for both markets and own the OEM production, then the optimal prices are:

$$P_I = \frac{\alpha + c}{2} \text{ and } P_D = \frac{\beta + c}{2},$$

respectively, for the international market and domestic market. Thus, the optimal supply chain profit is:

$$\Pi_{DP}^{*} = \frac{(\alpha - c)^2}{4} + \frac{(\beta - c)^2}{4}.$$

Intuitively, when the brand can engage in differential pricing and eliminate friction due to sourcing (i.e., a centralized system), this case should always dominate the decentralized system, which also engages in differential pricing for the two markets. Our next proposition, however, shows that this intuition is not always true.

Proposition 3. *(1) The profit difference,* $\Pi_{DP} - (\Pi_C + \pi_B)$*, decreases with* β *when* $\beta < \beta_1$*, but increases with* β *when* $\beta \geq \beta_1$*.*

(2) Under minor conditions with respect to Δ *and* c *(i.e., both cannot be too large)*[12]*, the profit difference,* $\Pi_{DP} - (\Pi_F + \pi_B)$*, decreases with* β *when* $\beta < \beta_1$*, increases with* β *when* $\beta_1 \leq \beta \leq \beta_2$*, and decreases with* β *again when* $\beta > \beta_2$*.*

(3) When $\beta < \beta_1$ *and* $(\alpha - c)(\beta - c) > 31(\alpha - \beta)^2/4$*, then* $\Pi_{DP} < \Pi_C + \pi_B = \Pi_F + \pi_B$*.*

Parts (1) and (2) of Proposition 3 imply that having the brand price discriminate between the two markets is not necessarily better than the dual channel from the supply chain perspective around $\beta = \beta_1$, as the profit difference between Channel DP and the two dual channels is decreasing and then increasing around $\beta = \beta_1$. We illustrate this case numerically in Figure 1. In this numerical example, we normalize α to 1, $c = 0.1$, and $\Delta = 0.1\beta$ (10% of consumers in the domestic market are loyal consumers). In this case, $\beta_1 = 0.76$. Therefore, we plot the profits for Channel DP, Channel C, and Channel F around $\beta = 0.76$ (see Figure 1), which shows that around $\beta = 0.76$, the two decentralized channels can outperform the centralized one.

The degree of price discrimination helps explain this result. Even when the brand can

12 Specifically, we require that $c < (13/18)\alpha$ and $\sqrt{2}\left(3 + \sqrt{2}\right)\Delta + 2c < \alpha$. The former condition requires that the production cost cannot be too high, which is reasonable, and the latter can be viewed such that the portion of loyal consumers cannot be too high too, so that the OEM can earn sufficient consumers in the domestic market to sustain its own channel. Alternatively, the latter condition requires that the international market size must be sufficiently large, which coincides with that in Proposition 1

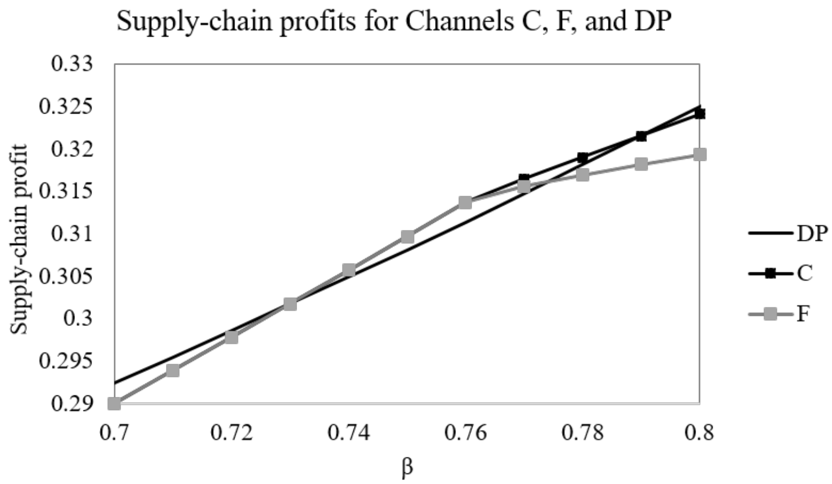


Figure 1: Profit comparisons for Channel DP, Channel C, and Channel F

price discriminate between the two markets and eliminate the friction of sourcing, the OEM's second selling channel not only allows the supply chain to price discriminate between two markets, but also allows the supply chain to charge two prices within the domestic market. Therefore, a dual channel can be useful when the domestic market is of a particular size (i.e., when the brand can at most cover the loyal consumers using its retail price).

5 Extensions

In this section, we consider two extensions, relaxing assumptions to ensure that the robustness of the insights derived from the base model are not challenged by these assumptions. Specifically, in Section 5.1, we relax two assumptions of the negligible OEM retail cost and OEM retail price by incorporating these two parameters in the OEM decision making process. In Section 5.2, instead of assuming a group of loyal consumers and identical product qualities regardless of selling channels, we consider quality difference between the brand and OEM products, and allow consumers to choose the channel based on their utilities.

5.1 Additional Retail Cost and Price Constraint for OEM

We assumed in the previous section that the OEM does not incur any cost when it sells product through its own selling channel. However, when compared to the brand that has extensive experience in operating the brand's selling channel, the OEM needs to incur a higher retail cost in its channel; sometimes, this cost may impede the OEM from providing a direct selling channel as a distribution outlet. To capture this effect, we normalize the brand retail cost to zero, but model the OEM retail cost by a unit cost $s \geq 0$. When $s = 0$, the model is the same as in the previous sections.

Moreover, we have considered an OEM that can freely determine its own retail price when it sells the product in the domestic market. This was the case for Galanz: the brand microwave oven was priced from \$1,000 to \$3,000 RMB, but Galanz's microwave often was priced at only \$300. That said, our model can be extended to other situations in which the brand can influence the OEM's pricing strategy. As one example, although the OEM produces the product, it may demand use of the brand's core technology. Therefore, the brand can exercise its technology right to push the OEM to raise the product price. As another example, the OEM can sell the brand products via its own channel; as the product is still under the brand's name, the brand can demand that the OEM maintains the price in ways that help preserve brand image. For example, Foxconn launched its own e-commerce platform–flnet.com–in China in 2015 to sell the products it manufactured, but these products were still under the brand's name (Luk 2015). We capture this situation by enforcing the OEM to price the product that sells through the OEM channel to be $L \in [0, 1]$ times larger than the brand's price.

Thus, in this section we consider the extension that incorporates the OEM retail cost, s, and retail price constraint, L, and denote the channel as Channel LC if the brand does not change its price after the launch of the OEM channel, and denote the channel as Channel LF if the brand can change its price. In Channel LC, the OEM is subject to the price constraint of Lp_B if $p_C^m < Lp_B$, whereas in Channel LF, the price is constrained by Lp_F if $p_F^m < Lp_F$.

We next show how relaxing these two assumptions affects the OEM's channel strategy and total production scale.

The following lemma characterizes the optimal prices for Channel LC and Channel LF, respectively.

Lemma 4. *For Channel LC, the optimal price is:*

$$p_C^m = \begin{cases} \frac{(\beta-\Delta)+(c+s)}{2}, & \text{if } \beta \geq \max\{\beta_1, \beta_{LC+}\}; \\ Lp_B, & \text{if } \min\{\beta_1, \beta_{LC-}\} \leq \beta < \max\{\beta_1, \beta_{LC+}\}; \\ \frac{3\alpha+3\beta+10c+8s}{16}, & \text{if } \beta < \min\{\beta_1, \beta_{LC-}\}, \end{cases}$$

in which

$$\beta_{LC+} \equiv \frac{3\alpha L + 4\Delta - 2c(2-L) - 4s}{4-3L}, \text{ and } \beta_{LC-} \equiv \frac{2c(5-2L) - 3\alpha(2L-1) + 8s}{6L-3}.$$

For Channel LF, consider only the case where $L > 1/2$, the optimal price is:

$$p_F^m = \begin{cases} \frac{\beta-\Delta+c+s}{2}, & \text{if } \beta > \max\{\beta_2, \beta_{LF+}\}; \\ Lp_F, & \text{if } \underline{\beta}_{LF-} \leq \beta \leq \max\{\beta_2, \beta_{LF+}\}; \\ \frac{3\alpha+3\beta+10c+8s}{16}, & \text{if } \beta < \underline{\beta}_{LF-}, \end{cases}$$

in which

$$\begin{aligned} \beta_{LF+} &= \frac{L(8\Delta + 2\sqrt{2}c + 8\alpha - \sqrt{2}\alpha) + 4\Delta - 4c - 4s}{4 + \sqrt{2}L}, \\ \beta_{LF-} &= \frac{c+s}{2L-1+\Delta}, \text{ and} \\ \underline{\beta}_{LF-} &= \begin{cases} \beta_{LF-}, & \text{if } \beta_{LF-} > \beta_1; \\ \min\{\beta_1, \beta_{LC-}\} & \text{if } \beta_{LF-} \leq \beta_1; \end{cases}. \end{aligned}$$

Lemma 4 shows that the impact of the OEM retail price constraint will be effective only when the domestic market is moderately sized. When the domestic market size is small, the brand cannot charge a high price (as $p_C = p_F = [3\alpha + 3\beta) + 2c]/8$), and hence the restriction on the OEM retail price is not too strict. When the domestic market size is large, the OEM will already charge a sufficiently high price. Therefore, only when the domestic market size is moderate will the OEM pricing decision be affected. For Channel LF, we impose a minor, sufficient condition on L: $L > 1/2$. Not only is this condition a sufficient one, but it also is generally not very strict (i.e., asking the OEM to give less than 50% discount to the product).

Second, the impact of the OEM retail price constraint will be effective even when L is as small as 1/2. To illustrate, let $s = 0$. For Channel LC to have a non-empty region, we require that $\beta_{LC-} < \beta_1$ and $\beta_{LC+} > \beta_1$. Substituting these threshold definitions into the two inequalities, we obtain the necessary condition, $L > (3\alpha + 3\Delta + 7c)/(6\alpha + 6\Delta + 4c)$, in which the right-hand side is less than 1/2. Therefore, we assume that once this price constraint is in effect, the OEM and supply chain profit will suffer. In turn, the total production scale achieved from the OEM direct selling channel will also be harmed.

However, when we use the next proposition to compare the profits of the OEM, and hence that of the supply chain, across Channels, B, LC, and LF, we show that for a reasonable range of parameters on L, dual channels can still be useful, as long as the price constraint is not too high.

Proposition 4. *Assume* $c \leq (3L(\alpha + \beta) - 8s)/(8 - 2L)$.

(1) $\Pi^*_{LC} \geq \Pi^*_B$, *except when* $\beta_1 \leq \beta \leq \beta_{LC+}$ *and* L *is sufficiently larger than* L_C.

(2) $\Pi^*_{LF} \geq \Pi^*_B$, *except when* $\beta_{LF-} \leq \beta \leq \beta_{LF+}$ *and* L *is sufficiently larger than* $\overline{L}_F$ *and* $\underline{L}_F$.

(3) Given the price constraint L, *Channel LC outperforms Channel LF when* β *is not too large (i.e.,* $\Pi^*_{LC} \geq \Pi^*_{LF}$ *when* $\beta \leq \beta_{CF}$*).*

The thresholds are defined as:

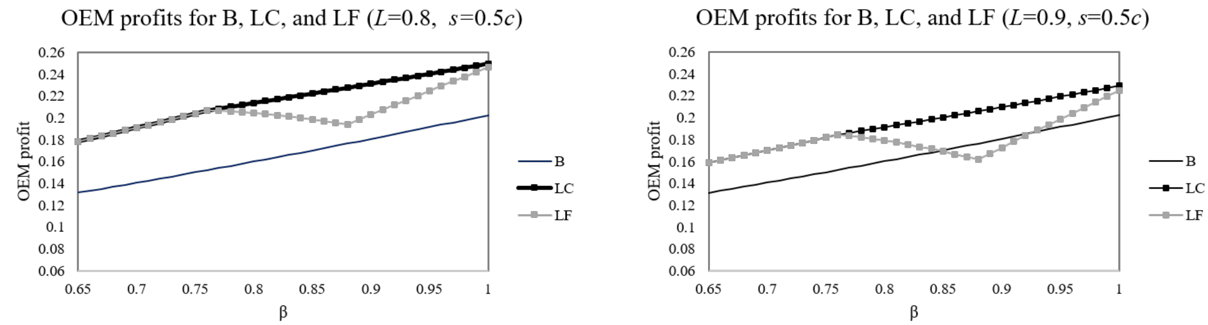
$$
\begin{aligned}
L_C &= 4\frac{\beta-\Delta+c+s}{3\alpha+\beta+2c},\\
\overline{L}_F &= 4\frac{\beta-\Delta+c+s}{(8-1/\sqrt{2})\alpha-1/\sqrt{2}\beta+4\Delta+\sqrt{2}c},\ \textit{and}\\
\underline{L}_F &= \frac{\beta-\Delta+c+s}{2\beta-\Delta}.
\end{aligned}
$$

Parts (1) and (2) of this proposition show that for a reasonable range of parameters on L, the dual channels still outperform the single channel for both the OEM and the supply chain. The profit difference of $\Pi^*_{LC}-\Pi^*_B$ ($\Pi^*_{LF}-\Pi^*_B$) when $\beta_1 \leq \beta \leq \beta_{LC+}$ ($\beta_{LF-} \leq \beta \leq \beta_{LF+}$) is a concave function of L, and the optimum occurs at $L = L_C$ ($L = \overline{L}_F$ or $L = \underline{L}_F$). Therefore, there exists a threshold of L sufficiently higher than L_C ($\min\{\overline{L}_F, \underline{L}_F\}$), such that $\Pi^*_{LC} \geq \Pi^*_B$ ($\Pi^*_{LF} \geq \Pi^*_B$). Finally, Part (3) of this proposition shows that $\Pi^*_{LC} > \Pi^*_{LF}$ if $\beta < \beta_{CF}$, which is the same threshold as in Proposition 2; this finding indicates that our insight on the choice with respect to brand pricing remains.

To numerically show the range of L that will still yield similar insights to those in our previous sections, we use the same setup in Section 4.3 and let $s = 0.5$ and $c = 0.05$. Figure 2 shows the profit comparisons between Channels B, LC, and LF, for $L = 0.8$ and $L = 0.9$. We observe that, when $L = 0.8$, the two dual channels still outperform Channel B for any valid β; however, when $L = 0.9$, the OEM profits that result from the dual channels can be smaller than those that result from Channel B, when β is moderately sized. We have tried other cases with $s = 0$ and $s = c$, and the results are qualitatively the same. Thus, we conclude that although the additional retail cost and retail price constraint can reduce the OEM's incentive to operate a dual channel, our insight still remains for a wide range of parameter sets.

5.2 Quality-embedded Utility Function

In our main model, we consider consumer preferences toward the brand's selling channel using loyal consumers (i.e., Δ), and assume identical product qualities, regardless of the selling channels. Although in some markets, there exists consumers who will only purchase



(a) $L = 0.8$

(b) $L = 0.9$

Figure 2: Profit comparisons for Channel B, Channel LC, and Channel LF

products from the brand's channel regardless of its high prices, in other markets, consumers may take both price and perceived quality into account when they make their purchasing decisions. In this section, we relax the identical product quality assumption and incorporate the valuation for such quality difference (e.g., attribute differences, perception differences in quality) in the consumer utility function instead of assuming loyal consumers.

Specifically, we denote the product quality for the product sold from the OEM direct channel as q_L and that from the brand's selling channel as q_H. To be consistent with our main model, we normalize $q_H = 1$. By doing so, we then assume that a consumer with a willingness to pay, v, will receive a valuation of $vq_H - p = v - p$ for purchasing the product from the brand's channel, and will receive only $vq_L - p$ for purchasing from the OEM channel. The rest of our assumptions remain the same as in the main model in Section 3, except that we remove the segment modeled by loyal consumers.

We again consider three channels: Channel B in which only the brand can sell the product, Channel C that considers both the brand and OEM selling channels in which the brand cannot flexibly change its retail prices, and Channel F that considers dual selling channels in which the brand can change its retail prices in the two markets. In Channel B, as the consumer utility function does not change and only the brand can sell the product, we have identical optimal prices and profits as shown in Section 3.1.

For Channel C, we first illustrate how consumers make their purchasing decision. Consumers will receive a value of zero if they do not purchase, receive a value of $v - p_B$ if they purchase the product from the brand, and receive a value of $vq_L - p_C^m$ if they purchase from the OEM channel. Comparing these utilities, we find that consumers with $v \geq (p_B - p_C^m)/(1 - q_L)$ will purchase from the brand, and $p_C^m/q_L \leq v < (p_B - p_C^m)/(1 - q_L)$ will purchase from the OEM.[13] For Channel F, we follow the same procedure and identify that consumers with $v \geq (p_F - p_F^m)/(1 - q_L)$ will purchase from the brand, whereas consumers with $p_F^m/q_L \leq v < (p_F - p_F^m)/(1 - q_L)$ will purchase from the OEM.

With these market segments, we next find the optimal pricing strategies and the associated profits (see the Appendix for the proof) and compare the profits between the dual channels with Channel B (similar to Proposition 1), and compare the profits between the two dual channels (similar to Proposition 2) in the following proposition.

Proposition 5. *Using the quality-embedded utility function, we find that* $\Pi_C^* = \Pi_B^*$*, implying that Channel C is reduced to Channel B, and* $\Pi_F^* > \Pi_B^*$*, implying that Channel F always dominates Channels B and C.*

This extension is useful in two ways. On the one hand, we still obtain a similar insight that the dual channels weakly dominate the single channel even after we relax the assumption of a fixed portion of loyal consumers to segmenting consumers by both product qualities and prices. On the other hand, using this model setting, we find that the OEM dual channel can strictly dominate the single channel only when the brand can flexibly adjust its retail price. This is because, as in Channel C, the OEM needs to balance (1) the market size it can cover in the domestic market due to the price and quality competition against the brand (which

13 To start, consumers with $v \geq \max\{P_B, (p_B - p_C^m)/(1 - q_L)\}$ will purchase from the OEM (i.e., their willingness to pay is sufficiently large so that they will purchase the product, and their valuation of purchasing from the brand channel is larger than that from the OEM channel). It is easy to show that when $p_C^m/q_L < p_B$, we have $P_B < (p_B - p_C^m)/(1 - q_L)$. Moreover, when $p_C^m/q_L \geq p_B$, then $P_B > (p_B - p_C^m)/(1 - q_L)$ and thus, no consumers will purchase from the OEM; we do not consider this trivial case, as it reduces to the single channel setting. Similarly, we can find the OEM's market coverage

limits its retail price range), (2) the wholesale price to the brand to offer sufficient incentives (i.e., at least the same profit as before), and (3) a rigid brand's pricing strategy. These three tight constraints result in an optimal solution of not offering its own channel. That said, in Channel F, the added lever from relaxing (3) enables the OEM to gain more profits, which makes it profitable for the OEM to set up its own selling channel.

6 Conclusion

In this paper, we study the OEM's dual channel strategy in a supply chain, in which the OEM initiates its own channel and sells its product to the domestic market in addition to having a brand selling channel. First, we take the single channel (Channel B) as the benchmark and consider two dual channels, C and F. Whether or not the brand adjusts the retail price due to the new channel, we find that retail prices set by the OEM in the domestic market under both channels are the same; moreover, these retail prices are set downward, so that the OEM is able to price discriminate and target relatively low-end consumers in the domestic market. This outcome directly explains how Galanz used its ample capacity to offer products to consumers in the Chinese market. Due to the effect of price discrimination, the OEM can successfully incentivize the brand to allow for a dual channel, enhance the OEM and supply chain profit, and greatly improve the OEM's production scale. We further find that when the domestic market is moderately sized, the two decentralized dual channels can even outperform a centralized, price-discriminated single channel, as the two dual channels allow for both price discrimination between the two markets and market segmentation within the domestic market. Moreover, we extend our model to the case in which the OEM incurs a retail cost, and the OEM retail price is subject to some constraint. Even with these additional assumptions, our results are still robust, and all our managerial insights remain the same for a wide range of parameter sets; that said, dual channels are less preferred by the OEM, and thus by the entire supply chain, with this extension.

In addition, we analyze which type of dual channels the OEM prefers in the supply chain, and find that the OEM always prefers the one with higher production scale. We find that when the domestic market is mature enough (i.e., sufficiently large β), the OEM benefits from a brand that can adjust the brand's retail price freely and prefers Channel F. Knowing the brand would adjust the retail price, the OEM's best strategy, although contrary to our initial intuition, is to reduce the wholesale price, leading to a lower retail price for the brand as well as a higher production scale.

Our paper contributes to the operations and dual channel literature in the following ways. First, we incorporate in our model the market structure and the OEM consideration of brand reactions, including pricing and willingness concerns for a dual channel. Second, instead of making a single market assumption and thus following the traditional dual channel literature, we use a unique setting of the two separate markets, both international and domestic, to capture OEMs in emerging countries fighting for both profit and scale growth. In this type of situation, a dual channel may serve as an effective instrument to promote corporate growth and create a win-win situation for OEMs that earn higher profit and production scale, for brands that could extract some of the improved profits using a channel authorization fee, and for consumers in emerging markets who can gain access to a lower-priced alternative product. Finally, our model also highlights how OEMs can establish their direct selling channel and offer incentives to influence their brand customers' pricing practice. Given different market structures, more flexible brand pricing may be preferred over constant brand pricing practices.

Our work also offers practical values to OEMs. While China may lead the trend of transitioning from an OEM to an OBM, the trade war between the US and China, the rising labor costs in China, and gradually growing labor markets in southeast Asia and Africa countries drive a redistribution of global supply chains. Those new OEMs emerging from developing countries will need to consider their future growth and expansion. Our work offers a guideline to these OEMs facing various market maturities (either their own operating countries or their brand customers' markets) with different brand pricing power (i.e., Channel C or Channel F). Such a guideline is extremely valuable, as it is often challenging to balance an OEM's customer relationships with its brand building efforts (e.g., see Shih et al. 2010 for the transition of ASUS).

Although we completed a few extensions to ensure the robustness of our model insights, there are several possibilities for future research that can enrich the understanding of how OEMs may benefit/hurt themselves and their brand customers from establishing their own selling channels. First, there could be a co-branding effect that benefits the OEM, thereby enhancing economies of scale and lowering the sourcing costs for the brand. For example, consumers who cannot afford a brand product may be attracted to the OEM product, as they know that this OEM also produces the brand products that they like. This setting can be further enriched when there are multiple brands and multiple OEMs. Second, as the domestic market keeps increasing as the economy grows, the dynamics of such (potentially stochastic) growth affects how consumers value a brand product. Taking the future growth in mind, brands may face future challenges when they want to return to and exert marketing efforts in domestic markets. How such stochastic growth changes the dynamics between the OEM and the brand offers another interesting direction for future research.

References

Arya, A., B. Mittendorf, D. E. M. Sappington. 2007. The bright side of supplier encroachment. *Marketing Science* 26(5) 651-659.

Berg, A., S. Hedrich, B. Russo. 2015. East Africa: The next hub for apparel sourcing? McKinsey&Co article. https://www.mckinsey.com/industries/retail/our-insights/east-africa-the-next-hub-for-apparel-sourcing

Cai, G. G. 2010. Channel selection and coordination in dual-channel supply chains. *Journal of Retailing* 86(1) 22-36.

Caidieraro, F. 2016. The role of brand image and product characteristics on firms' entry and OEM decisions. *Management Science* 62(11) 3327-3350.

Cattani, K., W. Gilland, H.S. Heese, J. Swaminathan. 2006. Boiling frogs: pricing strategies for a manufacturer adding a direct channel that competes with the traditional channel. *Production and Operations Management* 15(1) 40-56.

Chen, J., L. Liang, D.-Q. Yao, S. Sun. 2017. Price and quality decisions in dual-channel supply chains *European Journal of Operational Research* 259(3) 935-948.

Chiang, W.-Y.K. 2010. Product availability in competitive and cooperative dual-channel distribution with stock-out based substitution. *European Journal of Operational Research* 200(1) 111-126.

Chiang, W.-Y.K., G. Chhajed, J.D. Hess. 2003. Direct marketing, indirect profits: A strategic analysis of dual-channel supply-chain design. *Management Science* 49(1) 1-20.

Chiang, W.-Y.K., G.E. Monahan. 2005. Managing inventories in a two-echelon dual-channel supply chain. *European Journal of Operational Research* 162(2) 325-341.

David, A., E. Adida. 2015. Competition and coordination in a two-channel supply chain. *Production and Operations Management* 24(8) 1358-1370.

Dodds, W. B., K.B. Monroe, D. Grewal. 1991. Effects of price, brand, and store information on buyers' product evaluations. *Journal of marketing research* 28(3) 307-319.

Dukes, A. J., E. Gal-Or, K. Srinivasan. 2006. Channel bargaining with retailer asymmetry. *Journal of Marketing Research* 43(1) 84-97.

Dumrongsiri, A., M. Fan, A. Jain, K. Moinzadeh. 2008. A supply chain model with direct and retail channels. *European Journal of Operational Research* 187(3) 691-718.

Grewal, D., R. Krishnan, J. Baker, N. Borin. 1998. The effect of store name, brand name and price discounts on consumers' evaluations and purchase intentions. *Journal of retailing* 74(3) 331-352.

Geng, Q., S. Mallik. 2007. Inventory competition and allocation in a multi-channel distribution system. *European Journal of Operational Research* 182(2) 704-729.

Ha, A., X. Long, J. Nasiry. 2015. Quality in supply chain encroachment. *Manufacturing and Service Operations Management* 18(2) 280-298.

Hua, G., S. Wang, T. C. E. Cheng. 2010. Price and lead time decisions in dual-channel supply chains. *European Journal of Operational Research* 205 113-126.

Huang, W., J.M. Swaminathan. 2009. Introduction of a second channel: implications for pricing and profits. *European Journal of Operational Research* 194(1) 258-79.

Iyer, G. 1998. Coordinating channels under price and non-price competition. *Marketing Science* 17(4) 338-355.

Li, Z., S.M. Gilbert, G. Lai. 2014. Supplier encroachment under asymmetric information. *Management Science* 60(2) 449-462.

Luk, L. 2015. Foxconn launches new E-commerce platform in China. *Wall Street Journal* (March 4). http://www.wsj.com/articles/foxconn-launches-new-e-commerce-platform-in-china-1425447691

Matsui, K. 2016. Asymmetric product distribution between symmetric manufacturers using dual-channel supply chains. *European Journal of Operational Research* 248(2) 646–657.

Matsui, K. 2017. When should a manufacturer set its direct price and wholesale price in dual-channel supply chains? *European Journal of Operational Research* 258(2) 501–511.

Matsui, K. 2020. Optimal bargaining timing of a wholesale price for a manufacturer with a retailer in a dual-channel supply chain. *European Journal of Operational Research* 287(1) 225–236.

Modak, N. M., P. Kelle. 2019. Managing a dual-channel supply chain under price and delivery-time dependent stochastic demand. *European Journal of Operational Research* 272(1) 147–161.

Mukhopadhyay, S. K. , X. Zhu, X. Yue. 2008. Optimal contract design for mixed channels under information asymmetry. *Production and Operations Management* 17(6) 641-650.

Netessine, S., N. Rudi. 2006. Supply chain choice on the internet. *Management Science* 52(6) 844-864.

Ng, S.C.H., B. Li, X. Zhao, X. Xu, Y. Lei. 2010. Operations strategy at galanz. Richard Ivey School of Business Case.

Rao, A. R., K.B. Monroe. 1989. The effect of price, brand name, and store name on buyers' perceptions of product quality: An integrative review. *Journal of marketing Research* 26(3) 351-357.

Rodríguez, B., G. Aydın. 2015. Pricing and assortment decisions for a manufacturer selling through dual channels. *European Journal of Operational Research* 242(3) 901–909.

Shih, S. 1996. *Me-Too is Not My Style: Challenge Difficulties, Break through Bottlenecks, Create Values.* The Acer Foundation.

Shih, W. C., H. H. Yu, H. C. Chiù. 2010. Transforming ASUSTek: Breaking from the Past. Harvard Business School Case.

Tsay, A. A., N. Agrawal. 2004. Channel conflict and coordination in the e-commerce age. *Production and Operations Management* 13(1) 93-110.

Vinhas, A. S., J.B. Heide. 2014. Forms of competition and outcomes in dual distribution channels: The distributor's perspective. *Marketing Science* 34(1) 160-175.

Xiao, T., J. J. Shi. 2016. Pricing and supply priority in a dual-channel supply chain. *European Journal of Operational Research* 254(3) 813–823.

Xiao, T., T.-M. Choi, T. C. E. Cheng. 2014. Product variety and channel structure strategy for a retailer-Stackelberg supply chain. *European Journal of Operational Research* 233(1) 114–124.

Yan, Y., R. Zhao, T. Xing. 2019. Strategic introduction of the marketplace channel under dual upstream disadvantages in sales efficiency and demand information. *European Journal of Operational Research* 273(3) 968–982.

Yan, N., Y. Liu, X. Xu, X. He. 2020. Strategic dual-channel pricing games with e-retailer finance. *European Journal of Operational Research* 283(1) 138–151.

Yang, Z., X. Hu, H. Gurnani, H. Guan. 2017. Multichannel distribution strategy: Selling to a competing buyer with limited supplier capacity. *Management Science* 64(5) 2199-2218.

Yu, D. Z., T. Cheong, D. Sun. 2017. Impact of supply chain power and drop-shipping on a manufacturer's optimal distribution channel strategy. *European Journal of Operational Research* 259(2) 554-563.

Appendix: Proofs and Table of Notations

Table 1. Notations

α	The size of the international market
β	The size of the domestic market
Δ	The number of loyal consumers
c	The OEM's unit production cost
v	A consumer's willingness to pay for the OEM product
L	The retail price constraint (only in extension)
s	The OEM's unit retail cost (only in extension)
π_i	The brand's profit in Channel i, i=B, C, F, LC, LF
Π_i	The OEM's profit in Channel i, i=B, C, F, LC, LF, and the supply chain profit if i=DP
p_i	The brand's retail price in Channel i, i=B, C, F, and the brand's retail price in the domestic market($i = D$) and international market ($i = I$) in Channel DP
p_i^m	The OEM's retail price in Channel i, i=C,F
w_i	The OEM's wholesale price in Channel i, i=B, C, F
β_1	The size of the domestic market so that the brand covers exactly the loyal consumers in Channel C, in which $\beta_1 = (3\alpha + 8\Delta + 2c)/(5)$
β_2	The maximum size of the domestic market so that the brand covers exactly the loyal consumer in Channel F, in which $\beta_2 = (8\alpha + 16\Delta - \sqrt{2}[\alpha - 2c])/(8 + \sqrt{2})$
β_{CF}	The size of the domestic market so that Channel C yields the same OEM profit as Channel F, and $\beta_{CF} = (17\alpha + 24\Delta - 8\sqrt{2}\alpha - 8\sqrt{2}\Delta + 8\sqrt{2}c - 10c)/(7)$

Proof of Lemma 1: Because $p_C = p_B$ and $\pi_C^* = \pi_B^*$, we can solve for the wholesale price directly, which is:

$$w_C = \begin{cases} \frac{24\Delta\alpha+24\Delta\beta+16\Delta c+2\alpha\beta+12\alpha c+13\alpha^2-11\beta^2-12c^2}{64\Delta+40\alpha-24\beta-16c}, & \text{if } \beta \geq \beta_1; \\ \frac{\alpha+\beta+2c}{4} & \text{if } \beta < \beta_1. \end{cases}$$

By substituting w_C into the OEM's profit function, we can find the optimal OEM retail pricing, p_C^m, in this lemma by the first-order condition.■

Proof of Lemma 2: The brand will determine its retail price p_F based on the wholesale price w_F, which is determined by making $\pi_F = \pi_B^*$, and the OEM optimizes its own profit to determine its retail price p_m^F. We note that allowing the OEM to optimally determine its wholesale price and retail price simultaneously will always result in a lower brand profit than π_B^*, causing the brand to refuse to agree to a dual channel. Therefore, the sequence described above for determining the decision variables is indeed optimal.

Next, we separate β into three regions: (1) $p_F < \beta - \Delta$, (2) $p_F = \beta - \Delta$, and (3) $p_F > \beta - \Delta$. The first (third) region means that the domestic market is large (small) enough so that there are more (less) people who can afford the brand product (i.e., $\beta - p_F$) than the number of loyal consumers (i.e., Δ). The second region means that the brand always prices the product at such a level that it covers exactly the loyal consumers.

When $p_F < \beta - \Delta$, although the brand prices the product in a way that although more people can afford the product, only loyal consumers will buy from the brand, and the rest will buy the cheaper (but same quality) substitute from the OEM. Therefore, the profit functions are:

$$\begin{aligned} \pi_{F1} &= (p_F - w_F)(\alpha + \Delta - p_F), \text{ and} \\ \Pi_{F1} &= (w_F - c)(\alpha + \Delta - p_F) + (p_m^F - c)\left(\beta - \Delta - p_m^F\right), \end{aligned}$$

respectively, for the brand and OEM. We add a subscript 1 to differentiate the case. Therefore, following the aforementioned decision sequence, we can solve the optimum as:

$$p_F = \frac{8\alpha + 8\Delta - \sqrt{2}[\alpha + \beta - 2c]}{8}, \text{ and } p_m^F = \frac{\beta - \Delta + c}{2}.$$

Finally, based on the value of p_F, we can thus find the range of β that satisfies the condition, $p_F < \beta - \Delta$, which is $\beta > \beta_2 > \beta_1$.

In Case 3 when $p_F > \beta - \Delta$, because the brand prices the product such that fewer than Δ loyal consumers can afford the product, some of these loyal consumers must buy from the OEM. Therefore, the profit functions become:

$$\begin{aligned}
\pi_{F3} &= (p_F - w_F)(\alpha + \beta - 2p_F), \text{ and} \\
\Pi_{F3} &= (w_F - c)(\alpha + \beta - 2p_F) + (p_F^m - c)(p_F - p_F^m),
\end{aligned}$$

respectively, for the brand and OEM. We add a subscript 3 to differentiate the case. Therefore, following the aforementioned decision sequence, we can solve the optimum:

$$p_F = \frac{3\alpha + 3\beta + 2c}{8} = p_B, \text{ and } p_m^F = \frac{3\alpha + 3\beta + 10c}{16}.$$

Finally, based on the value of p_F, we can thus find the range of β that satisfies the condition, $p_F > \beta - \Delta$, which is $\beta < \beta_1$.

Finally, in Case 2, we consider $p_F = \beta - \Delta$, and thus the range of $\beta_1 \leq \beta \leq \beta_2$. We add a subscript 2 to differentiate the case. Because $p_F = \beta - \Delta$, which is a fixed value, we can easily find w_F such that the brand's profit will be the same as π_B^*. Given the two values, we thus can find the optimal OEM retail price p_m^F using the first-order condition, which is $p_m^F = (\beta - \Delta + c)/2$. ■

Proof of Lemma 3: The results directly follow from Section 3.1, Lemmas 1 and 2 and the first-order conditions. ■

Proof of Proposition 1: First, we compare Channel B with Channel C. By substituting the optimal prices, we can obtain the optimal OEM profit of Channel C as:

$$\Pi_C^* = \begin{cases} \Pi_B^* + \frac{(3\alpha-\beta+4\Delta-2c)^2}{64}, & \text{if } \beta \geq \beta_1; \\ \frac{25}{16}\Pi_B^*, & \text{if } \beta < \beta_1.; \end{cases},$$

which is always larger than Π_B^*. Finally, Π_C^* weakly increases with Δ, as can be seen directly from the profit function.

Next, we compare Channel B with Channel F. We again separate β into three regions: (1) $\beta < \beta_1$, (2) $\beta_1 \leq \beta \leq \beta_2$, and (3) $\beta > \beta_2$. By substituting the optimal prices in Lemma 2, we can find the optimal profits in each region.

When $\beta < \beta_1$, the optimal profit is $\Pi_{F3}^* = \Pi_C^*$, which is always higher than the profit in Channel B. When $\beta > \beta_2$, the optimal profit is:

$$\begin{aligned} \Pi_{F1}^* &= \Pi_B^* + \frac{\sqrt{2}(\alpha+\beta)(\alpha+\Delta) + 2(\beta-\Delta)^2 - (\alpha+\beta)^2}{32} \\ &\quad + \frac{c[(4-2\sqrt{2})(\alpha+\Delta) - \sqrt{2}(\alpha+\beta)] + (2\sqrt{2}-2)c^2}{8}. \end{aligned}$$

If the sum of the latter two terms is positive, then $\Pi_{F1}^* > \Pi_B^*$, which indicates that a dual channel effectively improves the OEM profit. To prove this, we start with the profit difference, $\Pi_{F1}^* - \Pi_B^*$, which is obviously a convex function. Thus, we can use the first-order condition to find its minimum:

$$\beta^* = \frac{\Delta(4-\sqrt{2}) + \alpha(2-\sqrt{2}) + \sqrt{2}c}{2}.$$

However, because $\beta_2 > \beta^*$, we obtain:

$$\beta_2 - \beta^* = \frac{\sqrt{2}(4+\sqrt{2})(\alpha+\Delta-c)}{16+2\sqrt{2}} > 0.$$

Given the feasible range of $\beta(> \beta_2)$, the minimum of $\Pi^*_{F1} - \Pi^*_B$ happens at $\beta = \beta_2$, which is:

$$\Pi^*_{F1} - \Pi^*_B = \frac{(48\sqrt{2} - 64 + 9c)((\alpha + \Delta) - c)^2}{(16 + 2\sqrt{2})^2} > 0.$$

Therefore, we can conclude that Π^*_{F1} will always outperform Π^*_B.

Finally, when $\beta_1 \leq \beta \leq \beta_2$, the optimal profit is:

$$\Pi^*_{F2} = \Pi^*_B + \frac{-56\Delta^2 - 32\alpha\Delta + 80\beta\Delta - 3\alpha^2 + 26\alpha\beta - 27\beta^2 + 4c(7\beta - 5\alpha - 12\Delta) - 4c^2}{32}.$$

First, we find that the numerator of $\Pi^*_{F2} - \Pi^*_B$ is a concave function of β, and hence the minimum happens on the two boundaries:

$$\beta = \frac{3\alpha + 8\Delta + 2c}{5} \text{ or } \frac{8\alpha + 16\Delta - \sqrt{2}(\alpha - 2c)}{8 + \sqrt{2}}.$$

Therefore, if we can find that the value is higher than 0 on both boundaries, then $\Pi^*_{F2} > \Pi^*_B$. By substituting $\beta = \beta_1$ into $\Pi^*_{F2} - \Pi^*_B$, the numerator becomes $(72/25)(\alpha + \Delta - c)^2 > 0$. By substituting $\beta = \beta_2$, we have $16(24\sqrt{2} - 23)(\alpha + \Delta - c)^2/(8 + \sqrt{2})^2 > 0$. As a result, $\Pi^*_{F2} > \Pi^*_B$. Together with the previous two cases, we obtain that $\Pi^*_F \geq \Pi^*_B$.

Finally, we discuss the profit functions in the three regions with respect to the number of loyal consumers. Because $\beta > \beta_2$ (used in the first inequality), we find that:

$$\frac{\partial \Pi^*_{F1}}{\partial \Delta} = \frac{\sqrt{2}(\alpha + \beta) - 4(\beta - \Delta) + 4c(4 - 2\sqrt{2})}{32} < \frac{-\left(8 - 5\sqrt{2}\right)(\alpha + \Delta) + \left(29 - 14\sqrt{2}\right)c}{8\left(8 + \sqrt{2}\right)},$$

which will be negative if α is large:

$$\alpha > \frac{(24 - 7\sqrt{2})(\Delta - c)}{9\sqrt{2} - 8}.$$

Next, because $\beta_1 \leq \beta \leq \beta_2$, we find that $\partial \Pi^*_{F2}/\partial \Delta$ increases with β. Thus, the upper bound of this first derivative happens at $\beta = \beta_2$:

$$-\frac{\left(24-7\sqrt{2}\right)c+\left(9\sqrt{2}-8\right)\alpha-\left(24-7\sqrt{2}\right)\Delta}{2\left(8+\sqrt{2}\right)},$$

which is negative if α is large:

$$\alpha > \frac{(29-14\sqrt{2})c}{8-5\sqrt{2}} - \Delta.$$

Finally, because $\beta < \beta_1$, Π^*_{F3} is independent of Δ.■

Proof of Proposition 2: Using Lemmas 1 and 2, we prove this part by separating the domestic market size, β, into three regions: (1) $\beta < \beta_1$, (2) $\beta_1 \leq \beta \leq \beta_2$, and (3) $\beta > \beta_2$. When $\beta < \beta_1$, as p_F is the same as p_B, which is the same as p_C, and $p_F^m = p_C^m$, the two dual channels are the same.

When $\beta_1 \leq \beta \leq \beta_2$, the profit difference between the two is:

$$\Pi^*_C - \Pi^*_{F2} = \frac{[3\alpha - 5\beta + 8\Delta + 2c][5\alpha - 11\beta + 16\Delta + 6c]}{64} > 0,$$

as $\beta > \beta_1$ implies that $3\alpha - 5\beta + 8\Delta + 2c > 0$ and $5\alpha - 11\beta + 16\Delta + 6c > 0$.

When $\beta \geq \beta_2$, the profit difference becomes:

$$\Pi^*_{F1} - \Pi^*_C = \frac{(\alpha+\beta-2c)(10c-24\Delta-8\sqrt{2}c-17\alpha+8\sqrt{2}\Delta+8\sqrt{2}\alpha)}{64}.$$

As $\alpha + \beta > 2c$, when $\beta > \beta_{CF}$, then $\Pi_{F1} > \Pi_C$. This threshold is higher than β_2, such that:

$$\beta_{CF} - \beta_2 = \frac{8(8-5\sqrt{2})((\alpha+\Delta)-c)}{56+7\sqrt{2}} > 0.$$

Moreover, in this region where $\beta > \beta_{CF}$, $p_F < p_C$. This is because (1) p_C increases with

β whereas p_F decreases with β, and (2) when $\beta = \beta_{CF}$, the two are the same:

$$p_C|_{\beta=\beta_{CF}} = \frac{(9-3\sqrt{2})(\alpha+\Delta)+c(3\sqrt{2}-2)}{7} = p_F|_{\beta=\beta_{CF}}.$$

As a result, when $\beta \leq \beta_1$, p_F is the same as p_B; when $\beta_1 < \beta \leq \beta_2$, p_F increases faster than p_C, and thus $p_C < p_F$ in this region; when $\beta_2 < \beta < \beta_{CF}$, p_C increases with β whereas p_F decreases with β, and $p_C < p_F$; and finally, when $\beta > \beta_{CF}$, $p_F < p_C$, and this result leads to the second half of the proof. ■

Proof of Proposition 3: When $\beta < \beta_1$, the supply chain profit difference is:

$$\Pi^*_{DP} - (\Pi^*_C + \pi^*_B) = \Pi^*_{DP} - (\Pi^*_{F3} + \pi^*_B) = \frac{31(\alpha-\beta)^2 - 4(\alpha-c)(\beta-c)}{256}.$$

As β increases, the difference decreases (the first derivative is negative), indicating that when β increases (but is still smaller than α), we obtain $\Pi^*_C + \pi^*_B = \Pi^*_{F3} + \pi^*_B > \Pi^*_{DS}$. This result shows that having the brand price discriminate is not necessarily better than the dual channel offering from a supply chain perspective. Specifically, when $(\alpha-c)(\beta-c) > 31(\alpha-\beta)^2/4$, then Channels C and F can achieve a higher profit than Channel DP.

However, for Channel C, when $\beta \geq \beta_1$, we obtain:

$$\Pi^*_{DP} - (\Pi^*_C + \pi^*_B) = \frac{\alpha^2 + 9\beta^2 - 6\alpha\beta + 8\beta\Delta - 24\alpha\Delta - 16\Delta^2 + 4c(4\Delta + 7\alpha + 3\beta) + 8c^2}{64},$$

which increases with β, as the numerator of its first derivative is $(18\beta - 6\alpha + 8\Delta) + 12c > 0$ because $\beta > \beta_1 > 1/3\alpha$. On the other hand, for Channel F, when $\beta_1 \leq \beta \leq \beta_2$, we obtain:

$$\Pi^*_{DP} - (\Pi^*_{F2} + \pi^*_B) = \frac{(56\Delta^2 + 32\alpha\Delta - 80\beta\Delta + 8\alpha^2 - 32\alpha\beta + 31\beta^2) - 16c(2\beta - \alpha - 3\Delta) + 16c^2}{32},$$

which is an increasing function of β, as the numerator of the first derivative is $(-80\Delta - 32\alpha + 62\beta) - 32c$, which is positive because $\beta > \beta_1$. That is, as long as $c < (13/18)\alpha$ (which is often true, as there would otherwise not be much profit left for production), then:

$$-80\Delta - 32\alpha + 62\beta - 32c > \frac{2}{5}\left[13\alpha + 48\Delta - 18c\right] > 0.$$

When $\beta > \beta_2$, however, we find an opposite direction, such that:

$$\begin{aligned}\Pi^*_{DP} - (\Pi^*_{F1} + \pi^*_B) \quad = \quad & \frac{\left[\left(9-4\sqrt{2}\right)\alpha^2 + \beta^2 - 4\sqrt{2}\Delta\alpha + \left(2-4\sqrt{2}\right)\alpha\beta + \left(16-4\sqrt{2}\right)\beta\Delta - 8\Delta^2\right]}{32} \\ & + \frac{4c[(3\sqrt{2}-6)\alpha + (2\sqrt{2}-4)\Delta + (\sqrt{2}-1)\beta)] + \left(8\sqrt{2}+12\right)c^2}{32},\end{aligned}$$

which is a decreasing function of β when Δ and c are not too high (i.e., $\sqrt{2}\left(3+\sqrt{2}\right)\Delta + 2c < \alpha$), as the numerator of its first derivative is:

$$\frac{\left[\beta - \left(2\sqrt{2}-1\right)\alpha + \left(8-2\sqrt{2}\right)\Delta\right] + 4(\sqrt{2}-1)c}{16} < \frac{\left[-\alpha + \sqrt{2}\left(3+\sqrt{2}\right)\Delta\right] + 2c}{8\left(\sqrt{2}+1\right)},$$

thus completing the proof.■

Proof of Lemma 4: We first start with Channel LC by considering the two regions of β as shown in Lemma 1: (1) $\beta \geq \beta_1$ and (2) $\beta < \beta_1$. When $\beta \geq \beta_1$, if there is no constraint on the OEM retail price, the optimal price will be:

$$p^m_C = \frac{\beta - \Delta + (c+s)}{2}. \tag{A1}$$

Therefore, if $\beta \leq \beta_{LC+}$, then $p^m_C < Lp_B$, and hence the OEM must set its price at Lp_B. When $\beta < \beta_1$, if there is no OEM retail price constraint, the optimal price becomes:

$$p^m_C = \frac{10c + 3\alpha + 3\beta + 8s}{16}. \tag{A2}$$

Therefore, if $\beta \geq \beta_{LC-}$, the OEM must set its price at Lp_B.

Next, we discuss Channel LF using a similar procedure. Similar to the proof of Lemma 2, we consider three regions: (1) $\beta_2 < \beta$, (2) $\beta_1 \leq \beta \leq \beta_2$, and (3) $\beta < \beta_1$. When $\beta_2 < \beta$, the unconstrained OEM price is the same as (A1); however, when $\beta \leq \beta_{LF+}$, then the price is affected. When $\beta_1 \leq \beta \leq \beta_2$, the unconstrained OEM price is again the same as in (A1), but p_F has changed to $\beta - \Delta$. By using simple algebra, we find that only when $\beta \geq \beta_{LF-}$ is the OEM retail price affected by L. Finally, when $\beta < \beta_1$, the unconstrained OEM price is the same as in (A2). As a result, we can find that if $\beta \geq \beta_{LC-}$, then the OEM retail price is affected.

Finally, we need to show that when $\beta_{LF-} > \beta_1$, then $\beta_{LC-} > \beta_1$. Otherwise, a discontinuity of affected regions may exist (i.e., when $\beta_1 < \beta_{LF-} < \beta \leq \max\{\beta_{LF+}, \beta_2\}$ and $\beta_{LC-} < \beta < \beta_1$, the OEM retail price is affected). The condition, $\beta_{LF-} > \beta_1$ implies that:

$$s > \frac{(3\alpha + 8\Delta)(2L-1) + \Delta(3\alpha + 8\Delta) - c(7 - 4L - 2\Delta)}{5}.$$

With this condition and $L > 1/2$, we substitute:

$$\begin{aligned} \beta_{LC-} - \beta_1 &= \frac{2c(5-2L) - 3\alpha(2L-1) + 8s}{6L-3)} - \frac{3\alpha + 8\Delta + 2c}{5} \\ &> \frac{\Delta(3\alpha + 8\Delta) + 40\Delta(2L-1) + c(49 - 28L + 2\Delta)}{30L-15)} > 0. \blacksquare \end{aligned}$$

Proof of Proposition 4: (1) As shown in Proposition 1, when the price constraint does not affect the OEM profit, $\Pi^*_{LC} = \Pi^*_C \geq \Pi^*_B$. Therefore, we only need to consider the two regions that will be affected: $\beta_1 \leq \beta \leq \beta_{LC+}$ and $\beta_{LC-} \leq \beta < \beta_1$. By substituting the pricing decisions into the OEM profit, we obtain:

$$\Pi^*_{LC} = \begin{cases} \Pi^*_B + A, & \text{if } \beta_1 \leq \beta \leq \beta_{LC+}; \\ \Pi^*_{LC2}, & \text{if } \beta_{LC-} \leq \beta < \beta_1; \end{cases},$$

in which

$$
\begin{aligned}
A &= \frac{(1-L)(3(\alpha+\beta)+2c)[3\alpha-5\beta+8\Delta+3L(\alpha+\beta)-2c(3-L)]}{64} \\
&\quad +s(\Delta-\beta)+\frac{sL(2c+3\alpha+3\beta)}{8}, \text{ and} \\
\Pi^*_{LC2} &= \Pi^*_B+(Lp_B-c-s)(1-L)p_B.
\end{aligned}
$$

For $\beta_1 \le \beta \le \beta_{LC+}$, $\Pi^*_{LC}-\Pi^*_B = A$ is a concave function of L, and the optimal happens at $L = L_C = 4(\beta-\Delta+c+s)/(2c+3\alpha+3\beta)$. Moreover, for the region $\beta_1 \le \beta \le \beta_{LC+}$ to even exist, we also need $L > L_C$. As a result, A only decreases with L in the region of feasible β. Therefore, there exists a threshold of L such that $\Pi^*_{LC} > \Pi^*_B$, only when L is higher than the threshold.

For $\beta_{LC-} \le \beta < \beta_1$, since $0 \le L \le 1$, if $c < (3L(\alpha+\beta)-8s)/(8-2L)$, we obtain $(Lp^*_B-c-s)(1-L)(p_B) \ge 0$, and thus $\Pi^*_{LC2} \ge \Pi^*_B$.

(2) Similarly, we only need to consider the three regions that will be affected:

$$
\Pi^*_{LF} = \begin{cases} \Pi^*_B + AF1, & \text{if } \beta_2 \le \beta \le \beta_{LF+}; \\ \Pi^*_B + AF2, & \text{if } \beta_{LF-} \le \beta < \beta_2; \\ \Pi^*_{LC2}, & \text{if } \beta_{LC-} \le \beta < \beta_1; \end{cases} ,
$$

in which

$$
\begin{aligned}
AF1 &= \frac{[8(c+s+\Delta)+\sqrt{2}L(\beta-c)-8L\alpha][8(\Delta-\beta+\Delta L)+2\sqrt{2}Lc+8L\alpha+\sqrt{2}L(\beta-\alpha)]}{64} \\
&\quad -\frac{(\alpha-2c+\beta)^2}{16}-\frac{(\sqrt{2}(\alpha-2c+\beta))(4c-4\Delta-2\sqrt{2}c-4\alpha+\sqrt{\alpha}+\sqrt{2}\beta)}{32}, \text{ and} \\
AF2 &= (\alpha-\beta+2\Delta)\left[(\beta-\Delta)-c-\frac{(\alpha-2c+\beta)^2}{32(2\Delta+\alpha-\beta)}\right] \\
&\quad +(\beta-\Delta)(1-L)(L(\beta-\Delta)-(c+s))-\frac{(\alpha+\beta-2c)^2}{16}.
\end{aligned}
$$

When $\beta_2 < \beta \le \beta_{LF+}$, we will prove that the profit difference, $\Pi^*_{LF1}-\Pi^*_B$, decreases with L, and hence there exists a threshold that $\Pi^*_{LF1} = \Pi^*_B$. First, the condition $\beta \le \beta_{LF+}$

requires that $L \geq \overline{L}_F$. For L in this range, we know that $\Pi^*_{LF} - \Pi^*_B = AF1$ decreases with L, as $AF1$ is a concave function of L, and the optimal solution happens at $L = \overline{L}_F$. From Proposition 1, we know that $\Pi^*_{LF} \geq \Pi^*_B$ at $L = \overline{L}_F$ (as in this case, the constraint L yields the same profit as the case without the constraint), and hence when L is sufficiently small, $\Pi^*_{LF} \geq \Pi^*_B$.

When $\beta_{LF-} \leq \beta \leq \beta_2$, we follow the same procedure. The condition, $\beta \geq \beta_{LF-}$, will be satisfied only when $L \geq \underline{L}_F$. In this case, we can obtain the concave property of $\Pi^*_{LF} - \Pi^*_B = AF2$, and the first-order condition that implies the optimal solution at $L = \underline{L}_F$ together show that $\Pi^*_{LF} - \Pi^*_B$ decreases with L. Therefore, there exists a threshold that $\Pi^*_{LF} \geq \Pi^*_B$.

Finally, when $\beta_{LC-} \leq \beta < \beta_1$, Channel LF degenerates to Channel LC, which we previously proved.

(3) To prove the result, we consider three cases: $\beta_2 < \beta$, $\beta_1 \leq \beta \leq \beta_2$, and $\beta < \beta_1$.For simplicity's sake, we denote cases similar to the ones in the proofs of Lemmas 1 and 2, and add L for the price constrained case. For the last case, when $\beta < \beta_1$, Channel F and LF degenerated to C and LC, respectively, and hence $\Pi^*_{LC} = \Pi^*_{LF}$.

When $\beta_2 < \beta$, three scenarios can happen: (i) C1 compares with F1, (ii) LC1 compares with LF1, and (iii) C1 compares with LF1. As $L_C > \overline{L}_F$, the F1 and LC1 will not coexist. For (i), we have proved it in Proposition 2, for when $\beta < \beta_{CF}$, $\Pi^*_{LC} \geq \Pi^*_{LF}$. For (iii), since the cases without the constraint L are always better than the cases with L (i.e., $\Pi^*_{F1} \geq \Pi^*_{LF1}$) and from (i) above that $\Pi^*_{C1} > \Pi^*_{F1}$ if $\beta < \beta_{CF}$, we obtain that $\Pi^*_{C1} > \Pi^*_{F1} \geq \Pi^*_{LF1}$ when $\beta < \beta_{CF}$. For (ii), we discuss it using Proposition 2. When $\beta < \beta_{CF}$, $p_C < p_F$, and hence when there is a price constraint, it will affect Case LF1 more than LC1, and hence $\Pi^*_{LC1} \geq \Pi^*_{LF1}$, regardless of the value of L.

When $\beta_1 \leq \beta \leq \beta_2$, we consider three scenarios: (i) C1 compares with F2, (ii) LC1 compares with LF2, and (iii) C1 compares with LF2, as $L_C > \underline{L}_F$ (because $\beta > \beta_1$), Case F2 and Case LC1 will not coexist. For (i) and (iii), $\Pi^*_C \geq \Pi^*_F$ always holds. For (ii), the profit difference is:

$$\begin{aligned}
&\Pi^*_{LC1} - \Pi^*_{LF2} \\
= \quad &\frac{(3\alpha + 8\Delta - 5\beta + 2c)[(\beta - \Delta)(8L - 11L^2 - 11) + (5 - 3L^2)(\alpha + \Delta) + 2c(4L - L^2 + 3) + 8Ls]}{64}.
\end{aligned}$$

Because $\beta \geq \beta_1$, $3\alpha + 8\Delta - 5\beta + 2c \geq 0$. To prove the second term of the numerator is non-negative, we note that this term decreases in β and when $\beta = \beta_{LC+}$ (the upper bound where $\Pi^*_{LC} = \Pi^*_{LC1}$), this term is positive, which allows us to conclude that $\Pi^*_{LC1} \geq \Pi^*_{LF2}$.■

Proof of Proposition 5: We start with Channel C. Following the segments in Section 5.2, we can express the profit functions for the two parties as:

$$\begin{aligned}
\pi_C &= (p_B - w_C)\left(\alpha + \beta - p_B - \frac{p_B - p^m_C}{1 - q_l}\right), \\
\Pi_C &= (w_C - c)\left(\alpha + \beta - p_B - \frac{p_B - p^m_C}{1 - q_l}\right) + (p^m_C - c)\left(\frac{p_B - p^m_C}{1 - q_l} - \frac{p^m_C}{q_l}\right).
\end{aligned}$$

As w_C is set so that $\pi_C = \pi^*_B$, we then can substitute w_C into Π_C, which is reduced to:

$$\Pi_C = \Pi^*_B + (P_B - c)\left(p_B - \frac{p_B - p^m_C}{1 - q_l}\right) + (p^m_C - c)\left(\frac{p_B - p^m_C}{1 - q_l} - \frac{p^m_C}{q_l}\right).$$

As the profit function is concave in p^m_C, the the OEM's optimal retail price satisfies the first-order condition if $p_B < (p_B - p^m_C)/(1 - q_l)$ at the first-order solution, and satisfies $p_B = (p_B - p^m_C)/(1 - q_l)$ (or equivalently, $p^m_C = p_B q_l$), otherwise. We know that the first-order condition yields the following solution:

$$p^m_C = \frac{3q_l(\alpha + \beta) + 4c - 2cq_l}{8},$$

but it is obvious that this p^m_C does not satisfy the condition, which means we then have $p^m_C = p_B q_l$. In other words, although we consider a dual channel, it is optimal for the OEM *not* to operate its own selling channel, as it will not cover any of the consumers in the domestic market, and we thus have $\Pi_C^* = \Pi_B^*$

We follow a similar procedure for Channel F. Given the segments identified in Section 5.2, we can formulate the two parties' profit functions as:

$$\pi_F = (p_F - w_F) * \left(\alpha + \beta - p_F - \frac{p_F - p_F^m}{1 - q_l}\right)$$
$$\Pi_F = (w_F - c) * \left(\alpha + \beta - p_F - \frac{p_F - p_F^m}{1 - q_l}\right) + (p_F^m - c) * \left(\frac{p_F - p_F^m}{1 - q_l} - \frac{p_F^m}{q_l}\right)$$

The brand's optimal retail price, a function of w_F and p_F^m, can be derived from the first-order condition of $\partial \pi_F / \partial p_F = 0$. The OEM's wholesale price, w_F to the brand is maintained at the level so that $\pi_F = \pi_B^*$. Substituting the two into Π_F, we thus have a concave function of Π_F with respect to p_F^m. As a result, solving the first-order condition that $\partial \Pi_F / \partial p_F^m = 0$, we then have the following optimal price:

$$p_F^m = \frac{\alpha q_l + \beta q_l + 2c}{4}.$$

We note that this solution will not violate the constraint that $p_F < (p_F - p_F^m)/(1 - q_l)$, and hence, this solution is indeed optimal.

By substituting this optimal price back into the profit function to obtain Π_F^*, we next prove that $\Pi_F^* > \Pi_B^*$ using the following steps. First, it is easy to show that $\partial^2(\Pi_F^* - \Pi_B^*)/\partial c^2 > 0$ for all positive c, and $\partial(\Pi_F^* - \Pi_B^*)/\partial c > 0$ and $\Pi_F^* > \Pi_B^*$ at $c = 0$. The former condition shows that Π_F^* increases faster than Π_B^* for $c \geq 0$, and the later conditions show that even when c is 0, $\Pi_F^* > \Pi_B^*$. Combining these two together, we conclude that $\Pi_F^* > \Pi_B^*$ for all feasible $c \geq 0$. ■