Retail Category Management with Slotting Fees Supplemental File

1. Other Robustness Tests

In this section, we present the details of the robustness tests we highlight in Section 6.4 of the paper.

1.1. Presence of a Zero-Demand Product in the Retailer's Equilibrium Assortment

As Section 4.2 of the paper demonstrates, if the retailer commits to offering high product variety, the first manufacturer's product has zero demand when $\frac{v_1}{v_1+v_2} \in [0, 1-\bar{v}]$, and the second manufacturer's product has zero demand when $\frac{v_1}{v_1+v_2} \in [\bar{v}, 1]$. In Section 4.3 of the paper, we assume that $\frac{v_1}{v_1+v_2} \in (1-\bar{v}, \bar{v})$ (equivalently, $\frac{q_1}{2q_1-q_2} < \frac{q_1-c_1}{q_2-c_2} < \frac{2q_1-q_2}{q_2}$) for ease of exposition. This assumption is sufficient to ensure that the retailer does not carry a zero-demand product at equilibrium. In this section, we remove this assumption and allow $\frac{v_1}{v_1+v_2} \in [0, 1]$ to consider the possibility that the retailer's equilibrium assortment includes a zero-demand product. Revisiting Section 4.2 of the paper, the retailer may have an incentive to a carry a zero-demand product because a zero-demand product creates a price pressure on the other product when $\frac{v_1}{v_1+v_2} \in \left(\frac{q_2}{4q_1+q_2}, 1-\bar{v}\right] \cup \left[\bar{v}, \frac{4q_1}{4q_1+q_2}\right)$.

Removing the assumption that $\frac{q_1}{2q_1-q_2} < \frac{q_1-c_1}{q_2-c_2} < \frac{2q_1-q_2}{q_2}$ expands the set of feasible parameter values to from Ω (defined in Section 4.3 of the paper) to $\hat{\Omega} \equiv \{(q_1, q_2, c_1, c_2, K) \in \mathbb{R}^5 | 0 \leq K \leq \max\{\frac{(q_1-c_1)^2}{16q_1}, \frac{(q_2-c_2)^2}{16q_2}\}, q_1 > c_1 \geq 0, q_2 > c_2 \geq 0\}$. When $\omega \in \hat{\Omega}$, the retailer's subgame equilibrium profits for $|\mathbb{A}| = 1$ and $|\mathbb{A}| = 2$ are

$$\Pi_r^{|1|} = \begin{cases} 3v_2/16 - K & \text{if } \frac{v_1}{v_1+v_2} \in [0, 3/7], \\ v_1/4 - K & \text{if } \frac{v_1}{v_1+v_2} \in (3/7, 1/2), \\ v_2/4 - K & \text{if } \frac{v_1}{v_1+v_2} \in [1/2, 4/7), \\ 3v_1/16 - K & \text{if } \frac{v_1}{v_1+v_2} \in [4/7, 1], \end{cases} \tag{1}$$

and

$$\Pi_r^{|2|} = \begin{cases} \frac{v_2}{16} - 2K & \text{if } \frac{v_1}{v_1+v_2} \in \left[0, \frac{q_2}{4q_1+q_2}\right], \\ \frac{q_1 v_1}{4q_2} - 2K & \text{if } \frac{v_1}{v_1+v_2} \in \left(\frac{q_2}{4q_1+q_2}, 1-\bar{v}\right], \\ v_{12} + \frac{\min\{((2q_1-q_2)\sqrt{q_1 v_1} - q_1\sqrt{q_2 v_2})^2, ((2q_1-q_2)\sqrt{q_1 v_2} - q_1\sqrt{q_2 v_1})^2\}}{(q_1-q_2)(4q_1-q_2)^2} - 2K & \text{if } \frac{v_1}{v_1+v_2} \in (1-\bar{v}, \bar{v}), \\ \frac{q_1 v_2}{4q_2} - 2K & \text{if } \frac{v_1}{v_1+v_2} \in \left[\bar{v}, \frac{4q_1}{4q_1+q_2}\right), \\ \frac{v_1}{16} - 2K & \text{if } \frac{v_1}{v_1+v_2} \in \left[\frac{4q_1}{4q_1+q_2}, 1\right], \end{cases} \tag{2}$$

respectively. Accordingly, the retailer compares two piecewise functions, $\Pi_r^{|1|}$ and $\Pi_r^{|2|}$, and sets $|\mathbb{A}^*| = 1$ if $\Pi_r^{|1|} \geq \Pi_r^{|2|}$ and $|\mathbb{A}^*| = 2$ otherwise.

Expanding the parameter set from Ω to $\hat{\Omega}$ also affects the benchmark model in which the retailer does not charge slotting fees. Specifically, the retailer's subgame equilibrium profits for $|\mathbb{A}| = 1$ and $|\mathbb{A}| = 2$ in the benchmark model are

$$\bar{\Pi}_r^{|1|} = \begin{cases} v_2/16 - K & \text{if } \frac{v_1}{v_1+v_2} \in [0, 1/5], \\ v_1/4 - K & \text{if } \frac{v_1}{v_1+v_2} \in (1/5, 1/2), \\ v_2/4 - K & \text{if } \frac{v_1}{v_1+v_2} \in [1/2, 4/5), \\ v_1/16 - K & \text{if } \frac{v_1}{v_1+v_2} \in [4/5, 1], \end{cases} \tag{3}$$

and

$$\bar{\Pi}_r^{|2|} = \begin{cases} \frac{v_2}{16} - 2K & \text{if } \frac{v_1}{v_1+v_2} \in \left[0, \frac{q_2}{4q_1+q_2}\right], \\ \frac{q_1 v_1}{4q_2} - 2K & \text{if } \frac{v_1}{v_1+v_2} \in \left(\frac{q_2}{4q_1+q_2}, 1-\bar{v}\right], \\ v_{12} & \text{if } \frac{v_1}{v_1+v_2} \in (1-\bar{v}, \bar{v}), \\ \frac{q_1 v_2}{4q_2} - 2K & \text{if } \frac{v_1}{v_1+v_2} \in \left[\bar{v}, \frac{4q_1}{4q_1+q_2}\right), \\ \frac{v_1}{16} - 2K & \text{if } \frac{v_1}{v_1+v_2} \in \left[\frac{4q_1}{4q_1+q_2}, 1\right], \end{cases} \tag{4}$$

respectively. Accordingly, the retailer sets $|\bar{\mathbb{A}}| = 1$ if $\bar{\Pi}_r^{|1|} \geq \bar{\Pi}_r^{|2|}$ and $|\bar{\mathbb{A}}| = 2$ otherwise.

We numerically analyze the prevalence and impact of the cases in which the retailer carries a zero-demand product at equilibrium. We generate unique scenarios (parameter combinations) as follows: We vary q_2 between 1 and 10 in increments of 1. For a given q_2, we set $q_1 = \gamma q_2$ and vary γ between 1.1 and 2 in increments of 0.1. For a given (q_1, q_2), We vary v_1 between 0.01 and 0.99 in increments of 0.01. Furthermore, we set $v_1 + v_2 = 1$ so that v_2 also varies between $1 - \bar{v}$ and $\bar{v}$ in increments of 0.01. For a given (v_1, v_2), we vary K between 0 and $\min\{v_1/16, v_2/16\}$ in increments of 0.001. Because $v_l = (q_l - c_l)^2/q_l$ for $l = 1, 2$, a given (q_l, v_l) implies that we set $c_l = q_l - \sqrt{q_l v_l}$. These parameter combinations lead to 161,500 unique scenarios, where the ranges we pick for v_1, v_2, and K ensure that each scenario is an element of our new parameter set, $\hat{\Omega}$. The only difference between this numerical study and the one we have in Section 5.3 of the paper is that we vary v_1 and v_2 between 0.01 and 0.99 in this study, whereas we vary v_1 and v_2 between $1 - \bar{v}$ and $\bar{v}$ in Section 5.3 of the paper.

The retailer sets $|\mathbb{A}^*| = 2$ and carries a zero-demand product in only 0.26% of the scenarios (420 scenarios) we analyze. That is, it is rare for the retailer to carry a zero-demand product to exert wholesale price pressure on the other product in its assortment. Intuitively, when $\frac{v_1}{v_1+v_2} \in [0, 1-\bar{v}]$ or $\frac{v_1}{v_1+v_2} \in [\bar{v}, 1]$, the retailer faces a tradeoff between carrying a zero-demand product to potentially create price pressure on the other product in its assortment and dropping the zero-demand product from its assortment to lower its operational cost from $2K$ to K and potentially collecting a slotting fee from the manufacturer that stays in the assortment. In most cases, dropping the zero-demand product from the assortment makes the retailer better off, which is why the retailer rarely carries a zero-demand product in its equilibrium assortment.

Slotting fees emerge in 81.31% of the scenarios we analyze, while the retailer sets $S^* = 0$ in the remaining scenarios. In addition, slotting fees continue to create a category expansion, a competition exclusion, or a rent extraction effect. Last, the average profit increases in the competitive exclusion, rent extraction, and category expansion regions are 0.0536, 0.0332, and 0.0057, respectively. That is, the retailer benefits the most (least) from slotting fees in the competitive exclusion (category expansion) region. In light of these findings, we conclude that our main insights continue to hold when we expand our parameter set from Ω to $\hat{\Omega}$ to consider the rare possibility that the retailer carries a zero-demand product in its equilibrium assortment.

1.2. Retailer's Assortment Size Announcement

We model the strategic interactions between the retailer and the two manufacturers as a three-stage game in which the retailer announces product variety, $\mathbb{A}$, and slotting, S, to the manufacturers in the first stage. In this section, we study an alternative setting in which the retailer does not commit to an assortment size in the first stage. Accordingly, we study a three-stage game in which the retailer determines the slotting fee in the first stage, the manufacturers make participation and wholesale price decisions in the second stage, and the retailer makes assortment and pricing decisions in the last stage. The benchmark model in this alternative setting is a two-stage game in which the manufacturers determine wholesale prices in the first stage and the retailer makes assortment and retail pricing decisions in the second stage.

We consider the benchmark model first for ease of exposition. When $S = 0$, both manufacturers participate because they can always ensure that they make a non-negative profit by setting their wholesale prices to their unit costs. For given wholesale prices (w_1, w_2), the retailer sets $\tilde{p}_i = (q_i + w_i)/2$ for $i \in \mathbb{A}$. Accordingly, for a given assortment $\mathbb{A}$, let $\bar{\Pi}_r^{\mathbb{A}} \equiv \sum_{i \in A}(\tilde{p}_i - w_i)\tilde{z}_i - K|\mathbb{A}|$ denote the retailer's profit in the benchmark model. In the last stage, the retailer compares $\bar{\Pi}_r^{\{1\}}(w_1)$, $\bar{\Pi}_r^{\{2\}}(w_2)$, and $\bar{\Pi}_r^{\{1,2\}}(w_1, w_2)$ to pick the assortment that maximizes its profit. In the first stage, each manufacturer sets its wholesale price in anticipation of (i) the other manufacturer's wholesale price and (ii) the retailer's optimal assortment decision. The retailer's assortment decision creates discontinuities in the manufacturers' objective functions. For example, a small increase in w_1 may force the retailer to switch its assortment from $\mathbb{A} = \{1, 2\}$ to $\mathbb{A} = \{2\}$. Consequently, a wholesale price equilibrium may not exist in the first stage of the game.

We numerically analyze this alternative setting in two steps. First, we analyze the benchmark model and identify the scenarios in which a wholesale price equilibrium exists. Then, we limit our attention to those cases and solve our main model in which the retailer sets its slotting fee in the first stage. We generate unique scenarios (parameter combinations) based on the setup we used in Section 1.1 in the appendix of this response letter. Specifically, we vary q_2 between 1 and 10 in increments of 1. For a given q_2, we set $q_1 = \gamma q_2$ and vary γ between 1.1 and 2 in increments of 0.1. For a given (q_1, q_2), We vary v_1 between 0.01 and 0.99 in increments of 0.01. Furthermore, we set $v_1 + v_2 = 1$ so that v_2 also varies between $1 - \bar{v}$ and $\bar{v}$ in increments of 0.01. For a given (v_1, v_2), we vary K between 0 and $\min\{v_1/16, v_2/16\}$ in increments of 0.001. Because $v_l = (q_l - c_l)^2/q_l$ for $l = 1, 2$, a given (q_l, v_l) implies that we set $c_l = q_l - \sqrt{q_l v_l}$. These parameter combinations lead to 161,500 unique scenarios.

A wholesale price equilibrium does not exist in 9.6% of the scenarios we analyze. Consistent with the observation Heese and Martínez-de Albéniz (2018) make, a wholesale price equilibrium exits for relatively small and relatively large K values because the retailer carries both products when K is relatively small and only one product when K is relatively large. However, an equilibrium may not exist for medium K values because the retailer goes back and forth between carrying both products vs. only one product, depending on the manufacturers' wholesale price offers, which in turn prevents the manufacturers from reaching a wholesale price equilibrium. In addition, not committing to an assortment size makes the retailer worse off by eliminating one of the levers it can use to control the intensity of manufacturer competition.

The retailer charges a slotting fee in 70.2% of the scenarios in which a wholesale price equilibrium exists in the benchmark model. In other words, the retailer sets $S^* = 0$ in the remaining 29.8% of the scenarios with a wholesale price equilibrium. Slotting fees continue to create a category expansion, a competition exclusion, or a rent extraction effect. In addition, the average profit increases in the competitive exclusion, rent extraction, and category expansion regions are 0.0301, 0.0239, and 0.0036, respectively. That is, the retailer benefits the most (least) from slotting fees in the competitive exclusion (category expansion) region. On the basis of these findings, we conclude that our main insights remain valid when the retailer does not make an assortment size commitment in the first stage of the game.

1.3. Multinomial Logit Demand Model

In our study, we use the vertical differentiation model to formulate consumer demand. In this section, we consider an alternative setting in which we use the multinomial logit (MNL) model to formulate consumer demand. This alternative setting allows us to test the robustness of our insights with respect to the way we model consumer preferences.

Let $U_i \equiv u_i - p_i + \xi_i$ denote the random utility of product i, where u_i is the expected utility, p_i is the retail price, ξ_i is a Gumbel random variable with the scale parameter μ. Accordingly, let $v_i \equiv \exp((u_i - p_i)/\mu)$ denote the attractiveness of product i. Without loss of generality, we continue to normalize the market size to one. Accordingly, when $\mathbb{A} = \{1, 2\}$, the demand for product $i = 1, 2$

is $z_i(p_1, p_2) = \frac{v_i(p_i)}{v_0 + v_1(p_1) + v_2(p_2)}$, where v_0 is the attractiveness of the no-purchase option. When the retailer carries only product i in its assortment (i.e., when $\mathbb{A} = \{i\}$), the demands for product i and $j \neq i$ are $z_i(p_i) = \frac{v_i(p_i)}{v_0 + v_i(p_i)}$ and $z_j = 0$, respectively. Let c_i, m_i, and r_i denote the unit production cost, manufacturer markup, and retailer markup for product i, respectively. Accordingly, we can write the retail price of product i as $p_i = r_i + m_i + c_i$. Hereinafter, without loss of generality, we use indices i and j such that manufacturer i has a higher *base* attractiveness (i.e., $u_i - c_i \geq u_j - c_j$).

When the retailer offers low product variety and sets $\mathbb{A} = \{i\}$, it solves $\max_{r_i \geq 0} r_i z_i(p_i(r_i)) + S - K$ in the last stage of the game. Let $\tilde{r}_i(m_i)$ denote the retailer's best response. When the retailer sets $|\mathbb{A}| = 1$, it needs to set its slotting fee, S, such that at least one manufacturer participates. If the retailer sets S such that only manufacturer i participates, manufacturer i solves $\max_{m_i \geq 0} m_i z_i(p_i(\tilde{r}_i(m_i))) - S$ in the second stage of the game. By contrast, if the retailer sets S such that both manufacturers participate, manufacturer i, which enters the retailer's assortment solves

$$\max_{m_i \geq 0} \quad m_i z_i(\tilde{r}_i(m_i) + m_i + c_i) - S \tag{5}$$

$$\text{s.t.} \quad \tilde{r}_i(m_i) z_i(\tilde{r}_i(m_i) + m_i + c_i) \geq \tilde{r}_j(m_j) z_j(\tilde{r}_j(m_j) + m_j + c_j) \tag{6}$$

$$m_j z_j(\tilde{r}_j(m_j) + m_j + c_j) - S = 0, \tag{7}$$

where Equation (6) ensures that the retailer sets $\mathbb{A} = \{i\}$ in the last stage, and Equation (7) ensures that manufacturer j, which cannot enter the retailer's assortment sets its markup based on its zero-profit condition. Note that when $S = 0$, manufacturer j sets its markup to zero and attempts to sell its product to the retailer at cost (i.e., sets $w_j = c_j$). This result is analogous to its counterpart in a study of Heese and Martínez-de Albéniz (2018), where the retailer announces its assortment size but does not charge a slotting fee. In the first stage of the game, the retailer sets its slotting fee to maximize its expected profit.

When the retailer offers high product variety (i.e., sets $|\mathbb{A}| = 2$), it needs to set S to ensure participation from both manufacturers. In the last stage of the game, the retailer solves $\max_{(r_1, r_2)} r_1 z_1(r_1 + m_1 + c_1, r_2 + m_2 + c_2) + r_2 z_2(r_1 + m_1 + c_1, r_2 + m_2 + c_2) + 2S - 2K$. In the MNL model, it is optimal for the retailer to set the same margin for all products (e.g., Heese and Martínez-de Albéniz 2018). Let $\tilde{r}^{|2|}(m_1, m_2)$ denote the retailer's best response. Accordingly, in the second stage of the game, the manufacturers simultaneously solve

$$\max_{m_1 \geq 0} \quad m_1 z_1(\tilde{r}^{|2|} + m_1 + c_1, \tilde{r}^{|2|} + m_2 + c_2) - S, \tag{8}$$

$$\max_{m_2 \geq 0} \quad m_2 z_2(\tilde{r}^{|2|} + m_1 + c_1, \tilde{r}^{|2|} + m_2 + c_2) - S. \tag{9}$$

In the first stage of the game, the retailer sets its slotting fee such that it extracts the full surplus from manufacturer j.

Given the analytical complexity of strategic retail and wholesale price optimization in this setting, we numerically characterize the equilibrium outcomes. Specifically, we set $c_1 = c_2 = 0$, $\mu = 1$, $u_2 = 1$, and $v_0 = 1$, and vary u_1 between 1 and 3 in increments of 0.1 and K between 0 and 0.4 in increments of 0.025. Because $u_1 - c_1 \geq u_2 - c_2$ in our numerical study, the retailer carries either $\mathbb{A} = \{1\}$ or $\mathbb{A} = \{1, 2\}$ at equilibrium. Slotting fees emerge in 83.64% of the scenarios we analyze, while the retailer sets $S^* = 0$ in the remaining scenarios. Indeed, the retailer foregoes slotting fees in cases when there is intense wholesale price competition for the single slot in its assortment. Such cases emerge when (i) u_1 is relatively small so that the first product is only slightly more attractive than the second one and (ii) K is relatively high so that the retailer carries only one product in its assortment. Comparing our main model with a benchmark model, which is a special case of the model studied by Heese and Martínez-de Albéniz (2018) with two products, reveals that slotting fees create a category expansion, a competitive exclusion, or a rent extraction effect. Indeed, the average increases in the retailer's profit in the competitive exclusion, rent extraction, and category expansion regions are 0.4929, 0.3380, and 0.1464, respectively. That is, slotting fees are most (least) beneficial for the retailer in the competitive exclusion (category expansion) region. Based on these findings, we conclude that our main insights continue to hold when we use the MNL model to formulate consumer demand.

References

Heese H, Martínez-de Albéniz V (2018) Effects of assortment breadth announcements on manufacturer competition. *Manufacturing & Service Operations Management* 20(2):302–316.