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Less is More? The Strategic Role of Retailer's Capacity

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Retailers are often short on capacity, so a logical assumption would be that retailers could improve their profits by acquiring more. In this study, we show that this is not necessarily true, because retailer's capacity has a strategic role in channel distribution. Specifically, we consider a setting with multiple suppliers and a common retailer. Our analysis reveals that, first, when the retailer's capacity is limited, its suppliers will compete head-to-head for the retailer's capacity, thereby driving down the equilibrium wholesale prices. Second, when the number of suppliers is large, the retailer finds it optimal to limit its own capacity to induce fierce competition among the suppliers. The result also holds when the suppliers and the retailer are contracted through two-part tariffs. Third, when capacity is scarce, the retailer prefers two-part tariffs to wholesale prices, while the suppliers prefer wholesale prices to two-part tariffs. This is because two-part tariffs enhance the retailer's capacity allocation power, which is translated into retailer profit. Nonetheless, when suppliers can freely choose between two-part tariffs and wholesale prices, they always choose two-part tariffs, leading to a form of prisoner's dilemma. We also demonstrate the robustness of our findings by considering substitutable and complementary products, exclusive contracts, and positive capacity cost. Our results underscore the importance of considering the retailer's capacity in channel management.

Key words: retailer's capacity; supply chain management; two-part tariff; wholesale contract
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1. Introduction

The proliferation of products has significantly boosted retailer's demand for capacity. While demand keeps increasing, retailer's capacity often falls short. According to Brohan (2018), US retailers are suffering from shortage of warehouse space, especially "modern warehouses with features to accommodate automated supply chains, logistics management and order management." Property Council of Australia (2014) revealed that the availability of retail space was not keeping up with the demand growth and that the shortage had worsened over the years. In addition to warehouse and retail space, retailers are also short on trucking and supply chain professionals, making it difficult to meet the growing consumer demand (Culver 2018). Intuitively, it seems that such capacity shortage hurts the retailers as it limits the quantities of goods that they can sell. A natural and straight-forward question arises: should retailers try their best to build up or rent sufficient capacity to keep up with the demand growth?

Many retailers are choosing not to. The retail chain 7-Eleven has been successful in increasing the sales per square foot by limiting its retail capacity (Farber 2005). Amazon Go stores only carry a limited number of grocery categories despite their size differences, and the extra store space is filled with coffee bars or spacious dining areas instead of carrying more inventory (Buontempo 2019). Macy's is radically shrinking its retail space by "walling off entire sections" and reducing the amount of merchandise as its revival plan (Kapner 2018). The big-box retailer Walmart is aggressively promoting the concept of their limited-capacity stores, Walmart Neighborhood Markets, which are about one-fifth the size of a Walmart Supercenter. The smaller-capacity stores' comparable sales growth has outpaced Walmart's overall growth by more than 5% (Bowman 2016). While these retailers' capacity decisions are counter-intuitive, we want to investigate how retailer's capacity affects the profitability of retailers and their upstream suppliers.

To understand the strategic role of retailer's capacity in channel management, we construct a stylized model of multiple suppliers selling through a common retailer, where products from suppliers are unrelated and consumer demands are thus independent. We deviate from the existing literature by assuming that the retailer has a capacity limit for the total quantity of products that it procures and sells. We also endogenize the retailer's capacity decision to examine the long-run equilibrium of its capacity. Our results show that, even in the absence of capacity cost, the retailer may prefer to limit its capacity to induce competition among its upstream suppliers, thereby driving down wholesale prices and procurement costs. Hence, we argue that capacity shortage can be the result of a retailer's strategic choice rather than its inability to set up a larger capacity.

1.1. Preview of Findings

Based on the above model characteristics, our analysis reveals several interesting findings. First, we consider the case in which the suppliers and the retailer are contracted through wholesale prices. The standard double marginalization outcome is nested in our model when capacity is sufficient. As all products are unrelated, there is virtually no competition among the suppliers. However, we show that, when capacity is limited, capacity constraint could create competition among upstream suppliers. This arises because the retailer now gains power by making the capacity allocation decision, and the suppliers that offer better deals will secure more capacity. As such, when capacity is scarce, the suppliers will compete head-to-head for the retailer's capacity, thereby driving down the wholesale prices.

Second, we endogenize the retailer's capacity decision by allowing the retailer to choose any capacity at zero cost. We show that, when there are two suppliers, while the retailer's profit may decrease in its capacity, it still maximizes its profit by choosing a sufficient capacity. However, the result no longer holds when there are three or more suppliers. In this case, the retailer is better off limiting its capacity to create fierce competition among upstream suppliers, even in the absence of capacity cost. Nevertheless, the increase in retailer's profit is at the expense of the suppliers, consumers, and social welfare.

Third, we show that the above findings are robust when we consider an alternative supply chain contract: two-part tariffs. The conventional wisdom holds that, under two-part tariffs, suppliers can both implement the first-best solution and extract all of the residual channel profits. While this is true when the retailer has sufficient capacity, we show that this no longer holds when retailer's capacity is limited. Similar to the case of wholesale prices, the retailer gains power through managing and allocating capacity, and this power enables the retailer to make a positive profit.

Fourth, we compare the equilibrium channel outcomes under wholesale prices vs. two-part tariffs. We find that, when capacity is scarce, the retailer makes more profit under two-part tariffs. The suppliers, on the other hand, make less profit under two-part tariffs. This flies in the face of the conventional wisdom that two-part tariffs help suppliers better extract the retailer's profit through fixed fees. The underlying rationale is that the retailer's capacity allocation power is stronger under two-part tariffs, as it can easily reject a supplier's offer, skip the fixed fee, and resort completely to other suppliers. This change in balance of power allows the retailer to make a higher profit under two-part tariffs. Therefore, channel members must take the retailer's capacity into consideration when choosing the contract form.

Fifth, we investigate a case where the suppliers can offer exclusive dealing contracts to the retailer. When capacity is scarce, the suppliers aggressively offer exclusive dealing contracts to the retailer, trying to win the retailer's entire capacity. Exclusive dealing contracts further intensify the upstream competition, and as a result, the retailer is more willing to limit its capacity.

Collectively, the above results underscore the nontrivial role of retailer's capacity in supply chain management, and provide guidelines for firms in making their capacity and pricing decisions.

1.2. Organization of this Study

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 presents and analyzes the base model with $N \geq 2$ suppliers selling to a common retailer through a wholesale price contract. Section 4 considers the case where channel members are contracted through two-part tariffs, and compares the results with the case of wholesale price contract. Section 5 extends the base models by considering a scenario where the products have correlated demands, the effect of exclusive dealing contracts, and a positive capacity cost. Section 6 concludes the paper. All proofs are available in the Online Appendix.

2. Literature Review

This study contributes to the large body of literature on distribution channel management. Among all decisions that a retailer makes, price decision stands at the top of the list. It is well established that the simple wholesale price contract will cause the double marginalization problem, which is detrimental to channel efficiency (e.g., Jeuland and Shugan 1983, Li et al. 2018, 2019, Tan and Carrillo 2017). In addition to the price decision, a number of other decisions can be relevant to a retailer, and may affect channel performance. For example, Gu and Liu (2013) study how a retailer makes its shelf layout decisions. They find that the retailer obtains a higher profit by displaying competing products in distant locations (the same location) if the products' fit probabilities are low (high). Dukes and Liu (2010) study the effects of retailer in-store media (ISM) on distribution channel relationships. They suggest that ISM has an important role in coordinating a distribution channel on advertising volume and product sales, and on mitigating supplier competition. Bhargava (2012) considers a problem where a retailer decides whether or not to bundle the products of two different manufacturers, and shows that channel conflicts weaken the case for bundling. Geng et al. (2018) investigate a model where retailers choose different contracts in the presence of add-on pricing. Yao and Zhang (2012) explore the interaction between base price and shipping price using an analytical model. In our model, the retailer, faced with limited capacity, makes a capacity allocation decision in addition to the traditional price decision. We show that this capacity decision changes the balance of power between channel members and substantially affects the channel equilibrium.

Our research builds upon the existing literature of upstream competition. McGuire and Staelin (1983) consider a model with two manufacturers and two retailers, each of whom sells only one manufacturer's product exclusively. They show that, when competition between the two products is fierce, neither manufacturer will have an incentive to vertically integrate its downstream retailer. Choi (1991) first develops a model of two competing manufacturers and a common retailer that sells both manufacturers' products. Sudhir (2001) empirically investigates the price competition between two manufacturers in the presence of a common retailer. Desai et al. (2010) study a two suppliers-one retailer model where the retailers can forward buy from the suppliers. Tian et al. (2018) explore the interaction of upstream competition and order-fulfillment cost for online platforms. In all the models described above, the upstream suppliers compete with each other in the consumer market (as their products are imperfect substitutes). Our model, by contrast, assumes that the products of the suppliers are unrelated, that is, they are neither substitutes nor complements. However, they are tied together by and compete for the retailer's limited capacity. As such, the suppliers compete for capacity even if they do not compete for consumers.

Our paper is also closely related to limited capacity models. Xie and Shugan (2001) discuss extensively how a seller's capacity constraint may affect its optimal selling strategy. Lim (2009) shows that, in a duopoly with capacity constraints, both firms prefer overselling to conventional selling, which can lead to a *prisoner's dilemma* situation in which both firms are worse off overselling. Bandyopadhyay and Paul (2010) study the competition between two capacity-constrained manufacturers for shelf space with the same retailer, and show that a complete-credit returns policy is the unique equilibrium of the game.

Guo and Wu (2018) study the sharing of capacity between two competing firms that have limited capacity, and show that capacity sharing could soften the price competition. Cui and Zhang (2018) examine a supply chain with a single supplier with limited capacity and multiple retailers to predict retailers' actual ordering behaviors. They show how a retailer's strategic-reasoning capability affects its ordering decisions.

While capacity is usually exogenously given as in the above literature, several studies endogenize the firm's capacity decision. Balachander and Farquhar (1994) uncover that occasional stockouts can alleviate market competition and improve competing firms' profit. Kim et al. (2004) show how competing firms could manage their capacities through reward programs, and then analyze the firms' capacity decisions. Liu and van Ryzin (2008) find that a monopoly seller may find it optimal to intentionally "ration" its capacity to create a rationing risk, which will induce early purchases. Their mechanism hinges on consumer risk aversion. Yang et al. (2018) show that, in a dual-channel environment, compared to the case of unlimited capacity, the upstream supplier, the downstream buyer, and the end consumers may all benefit from the supplier's limited capacity at the same time.

Finally, our paper overlaps with the "exclusive dealing" literature (Bernheim and Whinston 1998, Chen and Guo 2014, Mathewson and Winter 1987). These papers consider the case where a supplier can offer the retailer an exclusive contract, prohibiting the retailer from contracting with other suppliers. In the extension, we also consider the case of exclusive dealing, and show that suppliers' ability to offer an exclusivity contract further induces the retailer to limit its capacity.

3. The Base Model

Our base model consists of N independent suppliers, each producing a single product and selling it through a common retailer. The suppliers' marginal production costs are constant, symmetric, and normalized to zero.

Market Demand. Without loss of generality, we assume that the demand for product i takes the linear form: $D_i = 1 - p_i$, where p_i is the retail price for product i (which the retailer sources exclusively from supplier i). To focus on the strategic effect of capacity on supplier competition, we assume that the two products are unrelated and thus independent in demand. For example, for a fashion retailer, the demands for men's and women's apparel are independent. In other words, the products sold are neither substitutes nor complements. This assumption helps us to isolate the suppliers' competition for retailer's capacity from competition in the consumer market.[1]

As there is no demand uncertainty in our model, the retailer's purchase of each product should be equal to the realized demand. Therefore, the retail price for product i is $p_i = 1 - q_i$, where q_i is the quantity that the retailer procures from supplier i.

Capacity. Deviating from the classical distribution channel setting, we make the critical assumption that the retailer has a limited total capacity for the quantity of products that it procures and sells, denoted by K. Here capacity can be broadly understood as the bottleneck in retail logistics. It can refer to the retail warehouse, inventory, or the retailer's service ability. For ease of exposition, let λ represent the average capacity per product, and we will use K and λ interchangeably throughout the paper. The retailer places orders before sales begin, and there is no replenishment opportunity afterward, an assumption commonly adopted in the literature (Feng et al. 2014, Liu and van Ryzin 2008). The suppliers and the retailer are contracted through wholesale contract, the most commonly used contracts in practice. The rationalization of wholesale price contracts has been thoroughly addressed in the literature (e.g., Cui et al. 2007, Li and Liu 2019, Ho and Zhang 2008) and is beyond the scope of this study. In section 4, we consider an alternative form of supply chain contract, the two-part tariff, and show that the main insights of the model can be generalized to the alternative contract.

Timing and Decisions. We conceptualize the suppliers' and the retailer's actions into three stages. In the first stage, the suppliers simultaneously decide their wholesale prices w_i. In the second stage, the retailer decides q_i, the quantity to be purchased from each supplier, subject to its capacity constraint $\sum q_i \leq K$. In the third stage, the retailer sets its retail prices p_i, and retail demands materialize.

Before solving the base model, it is useful to consider two benchmark cases: (1) the retailer has sufficient capacity and (2) there is only one supplier.

Benchmark 1: The retailer has sufficient capacity

As a benchmark, we first consider the case that the retailer has sufficient capacity. As the demand for one product is independent of the other, we can divide the problem into N separate subproblems, each consisting of a supplier and a retailer.

A simple analysis of the model yields the familiar double marginalization outcome: in equilibrium, supplier i chooses a wholesale price $w_i = \frac{1}{2}$. The retailer procures $q_i = \frac{1}{4}$ units of product i, and charges a retail price $p_i = \frac{3}{4}$. The retailer's total profit from selling the N products is $\pi = \frac{N}{16}$ and each supplier makes a profit $\Pi_i = \frac{1}{8}$. As we will see later, when the retailer's capacity is limited, the above results are no longer sustained in equilibrium.

Benchmark 2: Single supplier

Next we consider a second benchmark case with a single supplier selling to the retailer. We analyze the problem using backward induction. In stage 2, given wholesale price w, the retailer's profit maximization problem is formulated as follows:

$$\begin{aligned} \pi &= \max_q \,(1-q-w)q, \\ &\text{s.t. } q \leq K. \end{aligned} \tag{1}$$

It follows immediately that the retailer's optimal decision is $q = \min\{\frac{1-w}{2}, K\}$. In stage 1, the supplier selects w that maximizes its own profit $\Pi = wq = w \cdot \min\{\frac{1-w}{2}, K\}$. Solving the supplier's profit maximization problem, we come up with the following strategy.

(i) If $K \leq \frac{1}{4}$, the supplier charges $w = 1 - 2K$, and the retailer procures $q = K$ units.
(ii) If $K > \frac{1}{4}$, the supplier charges $w = \frac{1}{2}$, and the retailer procures $q = \frac{1}{4}$ units.

It is worth noting that, when capacity is limited ($K \leq \frac{1}{4}$), the equilibrium wholesale price decreases in K, that is, $\frac{dw}{dK} < 0$. This is because the supplier's sales are capped at K. When the wholesale price is below $1 - 2K$, sales are inelastic to the wholesale price and further cutting the wholesale price does not boost the demand. Therefore, the supplier has no incentive to offer a price below $1 - 2K$. As a retailer's capacity goes up, so does the sales cap, and the supplier can effectively cut the wholesale price to boost its sales. We refer to the above effect as the *matching effect* as the supplier sets its wholesale price to match the capped sales.

In equilibrium, the retailer's profit, π, is given by

$$\pi = \begin{cases} K^2 & \text{if } K \le \dfrac{1}{4}, \\ \dfrac{1}{16} & \text{if } K > \dfrac{1}{4}. \end{cases}$$

From the retailer's profit, Lemma 1 follows immediately.

LEMMA 1. *Consider the case of a supplier selling to a retailer at a wholesale price. The retailer's profit is non-decreasing in its capacity.*

Consistent with one's intuition, when there is a single supplier, the retailer cannot be worse off having a larger capacity. Moreover, when $K \le \frac{1}{4}$, $\pi' > 0$, $\pi'' > 0$, indicating increasing returns to scale. Within this regime, an increase in K has two effects on the retailer's profit. First, the retailer is able to satisfy more consumer demand that would otherwise be lost, and we refer to this effect as the *demand satisfaction effect*. Second, the *matching effect* suggests that the wholesale price decreases in K. As K increases, both effects work to the benefit of the retailer.

3.1. Model Analysis

We now analyze the channel equilibrium with $N \ge 2$ suppliers. We assume that each supplier produces a single product whose end demand is, independent of each other, $D_i = 1 - p_i$. All marginal production costs are symmetric, constant, and zero. For ease of exposition, we focus on the average capacity per product, $\lambda = \frac{K}{N}$, in the following analysis.

Equilibrium Characterization

In a symmetric equilibrium, each supplier will quote the same wholesale price w. The retailer orders the same quantity q from each supplier and charges the same retail price p.

The model is solved using backward induction. In stage 2, given wholesale prices w_i, the retailer procures q_i units from supplier i to maximize its total profit, π. The retailer's total order quantity, $\sum q_i$, shall not exceed its capacity. Subsequently, the corresponding retail prices are $p_i = 1 - q_i$.

The suppliers anticipate how their prices will directly affect the retailer's procurement decisions and the allocation of retailer's capacity. Specifically, supplier i chooses its wholesale price w_i to maximize its profit $\Pi_i = w_i q_i$. A formal analysis of the suppliers' problem leads to the optimal wholesale prices which are summarized in the following lemma.

LEMMA 2. *Consider the case of $N \ge 2$ suppliers selling through a common retailer at wholesale prices. There exists a unique symmetric equilibrium for wholesale prices, which is summarized below.*

$$w = \begin{cases} \dfrac{2N}{N-1}\lambda & \text{if } \lambda \le \dfrac{N-1}{2(2N-1)}, \\ 1 - 2\lambda & \text{if } \dfrac{N-1}{2(2N-1)} \le \lambda \le \dfrac{1}{4}, \\ \dfrac{1}{2} & \text{if } \dfrac{1}{4} \le \lambda. \end{cases}$$

Lemma 2 shows how the retailer's capacity constraint affects the equilibrium wholesale prices. Specifically, the equilibrium wholesale prices first increase, then decrease, and are finally constant in λ. For example, when $N = 2$, wholesale prices increase in λ when $\lambda \le \frac{1}{6}$, decrease in λ when $\frac{1}{6} \le \lambda \le \frac{1}{4}$, and become constant in λ otherwise. Why are the equilibrium wholesale prices not monotonic in λ?

When λ is small, that is, $\lambda \le \frac{N-1}{2(2N-1)}$, capacity is very tight. The N products compete for the retailer's capacity even though they do not compete for consumers. An increase in capacity will alleviate the competition between the suppliers, leading to higher equilibrium wholesale prices. We refer to this effect as the *competition dampening effect*.

When λ is intermediate, that is, $\frac{N-1}{2(2N-1)} \le \lambda \le \frac{1}{4}$, capacity is mildly tight. The suppliers no longer need to compete head-to-head for the retailer's capacity. In this region, the *matching effect* emerges: As λ increases, the suppliers cut their wholesale prices to match the increased demand cap. As a result, the equilibrium wholesale prices are decreasing in λ.

Finally, when $\lambda \ge \frac{1}{4}$, the retailer's capacity is sufficient. Both the competition dampening effect and the matching effect vanish, and the equilibrium wholesale prices are independent of λ. The model reverts to the standard double marginalization case.

As discussed above, at different values, the retailer's capacity affects the suppliers' wholesale prices through different channels. This result is in sharp contrast to the single supplier case, where the equilibrium wholesale price is non-decreasing in the retailer's capacity. The reason is simple: With a single supplier, there is no upstream competition, the competition dampening effect dissipates, and the wholesale price is affected by retailer's capacity solely through the matching effect.

It is worth noting that the region for wholesale prices to decrease in capacity vanishes as the number of suppliers grows. This is because, as the number of suppliers increases, the competition between upstream suppliers also becomes fiercer.

3.2. Retailer's Profit

Using the equilibrium wholesale prices and back substituting yield the equilibrium outcome, which is summarized in Proposition 1.

PROPOSITION 1. *Consider the case of $N \geq 2$ suppliers selling through a common retailer at wholesale prices. Given λ, the retailer's total profit is*

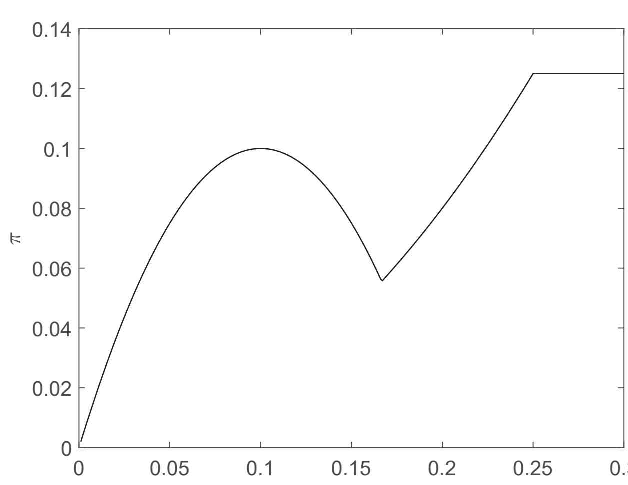
$$\pi = \begin{cases} N\left(\lambda - \dfrac{3N-1}{N-1}\lambda^2\right) & \text{if } \lambda \leq \dfrac{N-1}{2(2N-1)}, \\ N\lambda^2 & \text{if } \dfrac{N-1}{2(2N-1)} \leq \lambda \leq \dfrac{1}{4}, \\ \dfrac{N}{16} & \text{if } \dfrac{1}{4} \leq \lambda. \end{cases}$$

The retailer's profit is increasing in λ when $\lambda \leq \frac{N-1}{2(3N-1)}$, decreasing in λ when $\frac{N-1}{2(3N-1)} \leq \lambda \leq \frac{N-1}{2(2N-1)}$, and increasing in λ again when $\frac{N-1}{2(2N-1)} \leq \lambda \leq \frac{1}{4}$.

We illustrate the result with the case of $N = 2$ suppliers. The similar intuition will carry over for the case when $N > 2$. Figure 1 plots the retailer's profit in λ. The retailer's profit first increases in λ when $\lambda \in [0, \frac{1}{10}]$, then decreases in λ when $\lambda \in [\frac{1}{10}, \frac{1}{6}]$, and then increases in λ again when $\lambda \in [\frac{1}{6}, \frac{1}{4}]$. This non-monotonic result suggests that, the retailer benefits from an increase in capacity if and only if its initial capacity is sufficiently small or sufficiently large. If its initial capacity is intermediate, then the retailer can get hurt when its capacity increases. It is worth noting that while the retailer's profit is non-monotonic in its capacity, both the suppliers' profit and total channel profit increase with capacity.

To gain insight into the above results, recall that an increase in capacity has three effects on the retailer:

Figure 1 The Retailer's Equilibrium Profit when There are Two Suppliers



A demand satisfaction effect that expands the market, a matching effect that lowers the equilibrium wholesale prices, and a competition dampening effect that raises the equilibrium wholesale prices, as summarized in Table 1. With an increase in the retailer's capacity, the demand satisfaction effect and the matching effect benefit the retailer, whereas the competition dampening effect hurts the retailer.

First, consider the case $\lambda \leq \frac{1}{10}$. Within this regime, capacity is extremely tight and the retailer cannot satisfy much consumer demand. While the increase in the scarce capacity pushes up the equilibrium wholesale prices through the competition dampening effect, the shortage of capacity is the strongest tension here. Therefore, the demand satisfaction effect dominates, and an increase in capacity helps the retailer satisfy more demand, thereby raising its profit.

Second, consider the case $\frac{1}{10} \leq \lambda \leq \frac{1}{6}$. Within this regime, the retailer is worse off having a larger capacity. When capacity increases, the above two effects—the demand satisfaction effect and the competition dampening effect—still exist. As capacity is mildly tight, the demand satisfaction effect is attenuated and the competition dampening effect starts to take over. Overall, the retailer is worse off with an increase in capacity owing to the competition dampening effect.

Third, consider the case where $\frac{1}{6} \leq \lambda \leq \frac{1}{4}$. Within this regime, the competition dampening effect vanishes, and the matching effect starts to take over. Moreover, the demand satisfaction effect persists here. As the retailer's capacity increases, both the matching effect and the demand satisfaction effect positively affect the retailer's profit, and unsurprisingly, the retailer's profit is again increasing in λ.

Finally, when $\lambda \geq \frac{1}{4}$, capacity is sufficient and all three effects disappear. The model reverts to the standard double marginalization setting with two suppliers. The retailer makes a profit of $\frac{1}{16}$ from each product and its total profit is $\pi = \frac{1}{8}$.

3.3. Endogenizing the Retailer's Capacity

Now, we expand the strategy space of the retailer by allowing the retailer to choose its own capacity. To analyze this issue, we added a new stage (Stage 0) at the beginning of the game. In this stage, the retailer chooses its capacity. After observing the retailer's

Table 1 The Effects of Capacity on Retailer's Profit

Effect	Implication
Demand satisfaction effect	Sales volume q_i increases in λ
Matching effect	Wholesale price w_i decreases in λ when λ is intermediate
Competition dampening effect	Wholesale price w_i increases in λ when λ is small

capacity, the manufacturers set prices, and the retailer procures from the manufacturers and sells to consumers. This time sequence reflects that capacity choice is a long-term decision and is made before the short-term pricing decisions.

To eliminate standard reasons of limiting capacity, we assume the marginal cost of capacity is zero. We intend to show that, even in the absence of concern for capacity cost, the retailer may strategically limit its capacity to induce upstream competition among suppliers. Later, in section 5.3, we will discuss the results under a commonly assumed positive and linear capacity cost.

When $N = 2$, according to Figure 1, although the retailer's profit is non-monotonic in its capacity, it is still maximized when capacity is sufficient, Nonetheless, the following proposition suggests that the retailer may prefer to limit its capacity when N is large.

PROPOSITION 2. *Consider the case of $N \geq 3$ suppliers selling to a common retailer at wholesale prices.*

(i) *The retailer's profit is maximized when $\lambda^* = \frac{N-1}{2(3N-1)} < \frac{1}{4}$. At this point, the retailer's profit is $\pi = \frac{(N-1)N}{12N-4}$.*
(ii) *The optimal capacity, λ^*, is increasing in N.*

Proposition 2 defies the common wisdom that the retailer cannot be worse off having a large capacity by showing that the value of capacity constraint can be positive. That is, even if capacity is completely free, the retailer prefers a limited capacity $\lambda^* < \frac{1}{4}$ (see Figure 2). This result is surprising because building a larger capacity can increase the retailer's ability to store and sell more products without incurring any additional costs. Why does the retailer want to forgo the free capacity and the ability to store and sell more products?

A careful examination of the results indicates that the retailer may prefer a limited capacity to induce fierce competition among its upstream suppliers, which consequently drives down the equilibrium wholesale prices. While the retailer loses some potential demand, it is compensated by significantly lower procurement costs and thus higher profit margins. When the number of suppliers is not too small, the latter gain outweighs the former loss. Thus, overall, the retailer is better off by limiting its capacity.

A typical retailer carries a wide assortment of products provided by different suppliers. According to the Food Marketing Institute, a supermarket carries an average of 33,055 different products (https://www.fmi.org/our-research/supermarket-facts). Therefore, in practice, it is likely that a retailer can benefit from limited capacity. Table 2 compares the equilibrium strategies when the retailer has optimal capacity vs. sufficient capacity, as $N \to \infty$. From Table 2, we can see that, compared to the case of sufficient capacity (i.e., $\lambda \geq \frac{1}{4}$), when the retailer optimally limits its capacity to $\lambda^* = \frac{1}{6}$, its profit from each product increases from $\frac{1}{16}$ to $\frac{1}{12}$ (see Figure 3 for a graphic illustration). A careful examination shows that, compared to the case of sufficient capacity ($\lambda \geq \frac{1}{4}$), when $\lambda = \lambda^*$, the retailer's total sales decrease by 33.3%, whereas the retailer's unit cost (i.e., the equilibrium wholesale price w_i) drops from $\frac{1}{2}$ to $\frac{1}{3}$, a 33.3% decrease, and the retail margin increases from $\frac{1}{4}$ to $\frac{1}{2}$, a 100% improvement. Overall, the capacity constraint benefits the retailer through the cost reduction caused by the fierce upstream competition.

A further analysis of the equilibrium outcome reveals that the retailer's profit improvement from capacity constraint is at the expense of the suppliers and consumers. From the viewpoint of the suppliers, the retailer's capacity constraint is purely detrimental:

Figure 2 The Retailer's Optimal Capacity

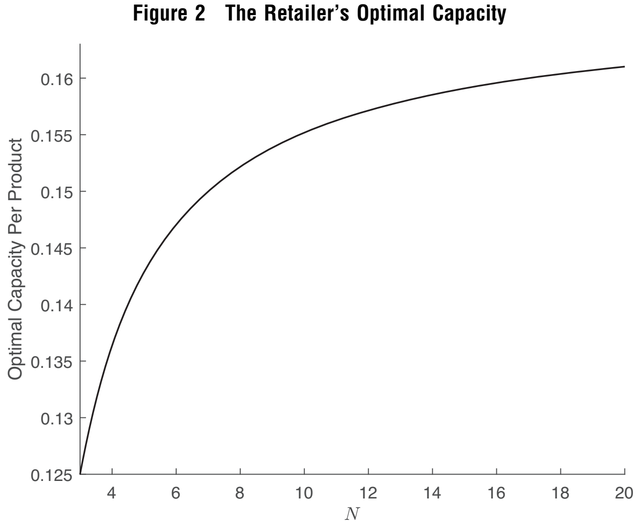


Figure 3 The Retailer Profit per Product in the Presence of a Large Number of Suppliers

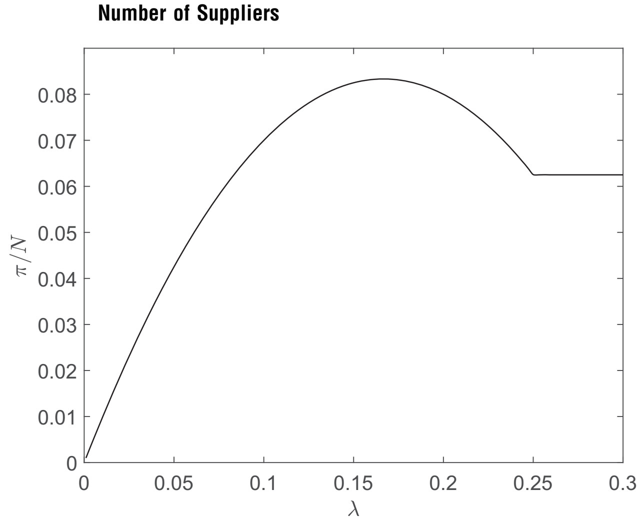


Table 2 Equilibrium Strategies with a Large Number of Suppliers

	$\lambda \geq \frac{1}{4}$ (sufficient)	$\lambda = \frac{1}{6}$ (optimal)
Wholesale price (w_i)	1/2	1/3
Retail price (p_i)	3/4	5/6
Retail margin ($p_i - w_i$)	1/4	1/2
Sales of each product (q_i)	1/4	1/6
Supplier profit (Π_i)	1/8	1/18
Retailer profit per product ($\frac{\pi}{N}$)	1/16	1/12
Channel profit per product	3/16	5/36
Social welfare per product	7/32	11/72

It not only reduces their sales volume, but also induces fierce competition. As $N \to \infty$, compared to the case in which the retailer has sufficient capacity, each supplier suffers a 55.6% profit loss when the retailer limits its capacity. Combining the retailer's and the suppliers' profit, the entire channel also suffers a 25.9% profit loss compared to the case of sufficient capacity, and a 44.4% profit loss compared to the case of a vertically integrated supply chain. Consumers suffer from higher retail prices and less demand is satisfied. Overall, compared to the case in which the retailer has sufficient capacity, limiting capacity is also detrimental to social efficiency and leads to a 30.2% loss in social welfare. However, we will show in section 5.3, the effect of upstream competition on the suppliers' profit and social welfare changes when capacity is no longer free to build.

Part (ii) of Proposition 2 suggests that the retailer's optimal capacity per product, λ^*, is increasing in N. Note that the retailer always distorts its capacity downwards from the sufficient level $\lambda \geq \frac{1}{4}$ to $\lambda^* < \frac{1}{4}$; an increase in λ^* implies that the retailer distorts the capacity less severely. The intuition of this result is as follows. The retailer distorts its capacity downwards to induce upstream competition; as N increases, the retailer can flexibly reallocate the capacity among various manufacturers, making it easier to induce upstream competition. As a result, the retailer can induce desirable competition without having to distort its capacity too much.

From the above analysis, we can also see that the retailer's profit from each product as well as its total profit are increasing in N, suggesting that the retailer prefers to carry as many products as possible. Nonetheless, in practice, a retailer only carries a limited number of products. This discrepancy arises because we abstract away from certain forces that are not our focus. For example, suppose that the retailer incurs a management cost βN^2 managing N products; the cost is convex because the retailer has limited attention and ability.[2] It follows that, when the retailer optimally chooses its capacity, it will make a profit of $\frac{N(N-1)}{12N-4} - \beta N^2$; and if the retailer has sufficient capacity, it will make a profit of $\frac{N}{16} - \beta N^2$ when carrying N products. Therefore, the retailer will carry $N^* \approx \frac{1}{24\beta}$ products when it chooses capacity optimally, compared to $N^* \approx \frac{1}{32\beta}$ when it has sufficient capacity. This result suggests that, after taking the upstream competition into account, the retailer is willing to carry more products to intensify the competition.

4. Two-Part Tariffs

In this section, we study the effect of capacity constraint on the channel equilibrium when the suppliers and the retailer are contracted through two-part tariffs. A two-part tariff is an affine pricing schedule of the form $P(q) = F + w \cdot q$, where F is the fixed fee and w is the marginal wholesale price. The two-part tariff reverts to a linear pricing schedule on setting $F = 0$. The common wisdom holds that, under two-part tariffs, the suppliers can both implement the first-best solution and extract all of the residual channel profits. Indeed, this also holds in our setting when the retailer has sufficient capacity. In this case, each supplier will quote a pricing scheme $(F_i, w_i) = (\frac{1}{4}, 0)$. In equilibrium, each supplier makes a profit $\Pi_i = \frac{1}{4}$ and the retailer makes zero profit. However, as we will show later, the channel equilibrium changes completely when the retailer has limited capacity.

4.1. Model Analysis

This section considers a general case with $N \geq 2$ suppliers that sell to a single retailer through two-part tariffs. Consistent with the base model, the demand for the product i is, independent of anything else, $1 - p_i$. The timing of the game is as follows. In stage 1, the suppliers simultaneously quote their pricing schemes (F_i, w_i). In stage 2, the retailer decides whether or not to accept the contract from each supplier, and if so, the quantities to procure, subject to its capacity constraint. Finally, in stage 3, retail demands materialize. We solve the game using backward induction and characterize the result below.

PROPOSITION 3. *Consider the case of $N \geq 2$ suppliers selling through a common retailer under two-part tariff contracts. The following is an equilibrium pricing strategy for the suppliers.*

(i) *When $\lambda \leq \frac{1}{2} - \frac{1}{2N}$, each supplier quotes a pricing scheme $(F_i, w_i) = (\frac{N}{N-1}\lambda^2, 0)$.*
(ii) *When $\frac{1}{2} - \frac{1}{2N} \leq \lambda \leq \frac{1}{2}$, each supplier quotes a pricing scheme $(F_i, w_i) = (\frac{1}{4} + N(\lambda - \lambda^2 - \frac{1}{4}), 0)$.*
(iii) *When $\frac{1}{2} \leq \lambda$, each supplier quotes a pricing scheme $(F_i, w_i) = (\frac{1}{4}, 0)$.*

Proposition 3 suggests that, in equilibrium, the marginal wholesale prices w_i are constant and zero.

This result is consistent with conventional findings. The fixed fee (which is also the supplier's profit), F_i, is increasing in capacity whenever $\lambda \le \frac{1}{2}$. In equilibrium, each supplier extracts a profit exactly equal to the incremental value of its product. When λ is small, adding a new product does not increase the total value much (the demand expansion effect of the new product is eliminated). If one supplier quotes an overly high pricing scheme, the retailer simply rejects its offer, skips the fixed fee and resorts completely to other suppliers.

4.2. Retailer's Profit

The following proposition speaks to the retailer's equilibrium profit.

Proposition 4. *Consider the case of N suppliers selling through a common retailer under two-part tariff contracts. In equilibrium, the retailer's profit is*

$$\pi = \begin{cases} \frac{N}{N-1}\left((N-1)\lambda - (2N-1)\lambda^2\right) & \text{if } \lambda \le \frac{1}{2} - \frac{1}{2N}, \\ N(N-1)\frac{(1-2\lambda)^2}{4} & \text{if } \frac{1}{2} - \frac{1}{2N} \le \lambda \le \frac{1}{2}, \\ 0 & \text{if } \frac{1}{2} \le \lambda. \end{cases}$$

The retailer's profit is increasing in λ when $\lambda \le \frac{N-1}{2(2N-1)}$, and decreasing in λ when $\frac{N-1}{2(2N-1)} \le \lambda \le \frac{1}{2}$.

Proposition 4 establishes that the retailer always makes a positive profit when $\lambda < \frac{1}{2}$. This is in contrast to the case of sufficient capacity ($\lambda \ge \frac{1}{2}$) where the suppliers extract the entire channel profit. The rationale is that, capacity constraint changes the balance of power among channel members. Under the capacity constraint, the retailer gains power through making the capacity allocation decision, and can translate this power into its own profit. More specifically, with a limited capacity, if supplier i quotes a high fixed fee, the retailer can skip that supplier and allocate the capacity to other suppliers. When capacity is scarce, this becomes a realistic option to the retailer, and the retailer can easily reject the offer from the supplier who charges a higher price. This realistic threat forces all suppliers to cut their fixed fees to induce the retailer to accept their offers.

Proposition 4 also indicates that the retailer's profit is increasing in λ when $\lambda \le \frac{N-1}{2(2N-1)}$, and decreasing in λ when $\frac{N-1}{2(2N-1)} \le \lambda \le \frac{1}{2}$. To gain insight into this result, note that an increase in λ has two effects on the retailer's profit: (1) The retailer is able to satisfy more consumer demand that is lost otherwise, and (2) the retailer loses some capacity allocation power in the channel relationship. When capacity is very tight, the former effect dominates the latter and the retailer's profit is increasing in λ, whereas when capacity is mildly tight, the latter effect backfires and overshadows the former effect. Therefore, the retailer maximizes its profit when λ is intermediate, as shown in Figure 4.

4.3. Endogenizing the Retailer's Capacity

In this section we allow the retailer to choose its own capacity. Again, we assume away capacity cost here. We summarize the results in the following corollary.

Corollary 1. *Consider the case of $N \ge 2$ suppliers selling through a common retailer under two-part tariff contracts. The retailer's profit is maximized when $\lambda = \frac{N-1}{2(2N-1)}$.*

Under two-part tariffs, the retailer still benefits from limiting its capacity, that is, $\lambda^* = \frac{N-1}{2(2N-1)} < \frac{1}{2}$. In Table 3, we compare the channel equilibrium under the (retailer's) optimal capacity to that under sufficient capacity, when $N \to \infty$. From Table 3, we can see that, when capacity drops from $\lambda \ge \frac{1}{2}$ to $\lambda^* = \frac{1}{4}$, the retailer's profit per product increases from 0 to $\frac{1}{8}$, whereas each supplier suffers a striking 75% profit loss. This arises because, as the number of suppliers increases, the competition also becomes fiercer, and the suppliers make a lower profit in equilibrium. The channel also becomes less efficient: Channel profit decreases by 25%, social efficiency decreases by 41.7%, and demand shrinks by half. Again, the retailer's profit improvement is at the expense of all other members in the market.

4.4. Two-Part Tariff vs. Wholesale Price

It is well established that, when capacity is sufficient, the retailer makes more profit when contracted through wholesale price, whereas supplier profit,

Figure 4 The Retailer's Equilibrium Profit under Alternative Contracts (*N* = 2)

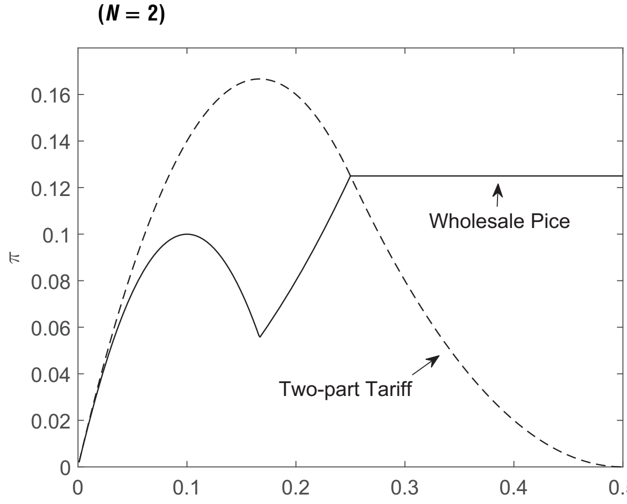


Table 3 Equilibrium Strategies with a Large Number of Suppliers (Two-part Tariff)

	$\lambda \geq \frac{1}{2}$ (sufficient)	$\lambda = \frac{1}{4}$ (optimal)
Supplier contract (F_i, w_i)	($\frac{1}{4}$, 0)	($\frac{1}{16}$, 0)
Retail price (p_i)	1/2	3/4
Retail margin ($p_i - w_i$)	1/2	3/4
Sales of each product (q_i)	1/2	1/4
Manufacturer profit (Π_i)	1/4	1/16
Retailer profit per product ($\frac{\pi}{N}$)	0	1/8
Channel profit per product	1/4	3/16
Social welfare per product	3/8	7/32

channel profit, and social welfare are all higher when contracted through two-part tariffs. Will these results continue to hold when the retailer has limited capacity?

To address the above question, we consider two scenarios: (1) the capacity is exogenously given and (2) the retailer chooses its capacity at zero cost. For the former case, we have the following corollary.

COROLLARY 2. *Consider the case of $N \geq 2$ suppliers selling through a common retailer. The retailer (reps., suppliers) makes more (resp., less) profit under two-part tariffs when $\lambda \leq \frac{1}{6}$, and less (resp., more) profit otherwise.*

Corollary 2 indicates that the retailer makes *more* profit under two-part tariffs when capacity is scarce, defying the established findings that the retailer is worse off under two-part tariffs. Consider the case of $N = 2$ suppliers, with the results illustrated in Figure 4. The retailer's profit improvement from two-part tariffs is most significant when $\lambda = \frac{1}{6}$. At this point, under wholesale prices, the retailer's profit is $\frac{1}{18}$, whereas under two-part tariffs, the retailer's profit is $\frac{1}{6}$, a 200% profit improvement over wholesale prices (see Figure 4).

Why is the retailer better off under two-part tariffs when capacity is scarce? The rationale is as follows. Under either type of contract, the retailer gains some capacity allocation power in the presence of capacity constraint, and it could translate this power into its own profit. This power becomes stronger under two-part tariffs, as the retailer could threaten to reject a high pricing scheme, skip the fixed fees, and completely resort to other suppliers. In other words, charging a higher two-part tariff price yields the supplier a payoff of zero. Under wholesale prices, however, the retailer only threatens to order less, but not nothing, from a supplier that offers a high price. In other words, charging a higher wholesale price means the supplier will get less (but not zero) demand from the retailer. Therefore, under two-part tariffs, a supplier's sales are more sensitive to price, and the retailer's capacity allocation power is stronger.

Finally, consider the case where the retailer makes its capacity decision at zero cost. That is, given the contract form (wholesale prices or two-part tariffs), the retailer then chooses the capacity that maximizes its own profit. After observing the retailer's capacity decision, the suppliers offer their contracts. The following corollary summarizes the results.

COROLLARY 3. *Consider the case of $N \geq 3$ suppliers selling through a common retailer. The retailer's optimal capacity per product is $\lambda = \frac{N-1}{2(2N-1)}$ and $\lambda = \frac{N-1}{2(3N-1)}$ under two-part tariffs and wholesale prices, respectively. The retailer profit, supplier profit, total channel profit and consumer surplus are all higher under two-part tariffs as opposed to wholesale prices.*

Corollary 3 shows that, in comparison with the wholesale price contract, a two-part tariff can benefit all firms when the retailer can choose its capacity. This is because upstream competition, as discussed above, is fiercer under two-part tariffs. In this way, the retailer does not need to cut capacity too much to induce the desirable upstream competition; as a result, it sets a larger capacity under two-part tariffs, that is, $\frac{N-1}{2(2N-1)} > \frac{N-1}{2(3N-1)}$. The retailer is better off because upstream competition is fiercer and it can serve more demand. As for suppliers, even though the competition is fiercer under two-part tariffs (for a fixed capacity), they can still make a higher profit because the retailer increases its capacity. Total channel profit and consumer surplus are also higher because of the increase in retailer's capacity.

4.5. Suppliers' Contract Choices

As discussed above, with exogenous capacity, the suppliers can be worse off offering two-part tariffs. Would the suppliers prefer a wholesale price contract to a two-part tariff contract? To answer this question, we cannot directly compare the two systems (two-part tariffs vs. wholesale prices) because we must allow each supplier to determine whether it should adopt a two-part tariff or wholesale contract. Formally, consider a game in which the retailer is endowed with a capacity K, which is observed by the suppliers. The suppliers simultaneously choose between a two-part tariff contract and a wholesale price contract. For tractability, we focus on the case of $N = 2$ suppliers. We have the following proposition.

PROPOSITION 5. *Consider the case of two suppliers. For any capacity K, when suppliers choose between a two-part tariff contract and a wholesale price contract, they always choose the two-part tariff contract.*

Proposition 5 shows that for any retailer's capacity, in equilibrium, the suppliers strictly prefer a two-part tariff contract to a wholesale price contract. This leads to a *prisoner's dilemma* whenever capacity is scarce: The suppliers are better off with wholesale price contract, yet they cannot help choosing a two-part tariff contract in equilibrium.

The intuition for the prisoner's dilemma is as follows. A two-part tariff contract is more flexible than a wholesale price contract: A wholesale price contract with $w = w_0$ can be perfectly mimicked by a two-part tariff contract with $(F, w) = (0, w_0)$. Choosing a two-part tariff contract allows a supplier to gain a competitive advantage over the other supplier. Nonetheless, when both suppliers choose two-part tariff contracts, both suppliers gain competitive power, resulting in fiercer competition and lower profits.

5. Extensions

In this section, we extend our base model in three directions. To begin with, we consider a scenario where the products of the manufacturers are substitutes or complements. In the second extension, we investigate the equilibrium strategies when the suppliers can offer exclusive contracts to the retailer. In the third extension, we examine whether a positive capacity cost would alter the retailer's optimal capacity decision. We illustrate that our main results from the base model are robust to these alternative model specifications.

5.1. Correlated Products

The base model assumes that all products are independent. In practice, the retailer often carries products that are substitutes or complements. In this section, we generalize the analysis and consider the case where the demands for the products are correlated.

To model the demands for $N \geq 2$ products, we assume that the inverse demand for product i is given by

$$p_i = 1 - q_i - \gamma \sum_{j \neq i} q_j,$$

where $-\frac{1}{N-1} < \gamma < 1$ captures the extent of competition among the products: when $\gamma > 0$, the products are substitutes; when $\gamma < 0$, the products are complements. Note that the assumption $-\frac{1}{N-1} < \gamma$ guarantees that price does not increase with production quantity.[3] Given wholesale prices $w_1, \ldots, w_N$, the retailer chooses $q_1, \ldots, q_N$ that maximize

$$\begin{aligned} \pi &= \sum_i (p_i - w_i) q_i, \\ &\text{s.t. } \sum_i q_i \leq N\lambda, \end{aligned}$$

where $\lambda = K/N$ is the average capacity per product. Supplier i chooses w_i that maximizes $\Pi_i = w_i \cdot q_i$. We solve the game using backward induction and present the result in the following lemma.

Lemma 3. *Consider the case of $N \geq 2$ suppliers selling products with correlated demands through a common retailer at wholesale prices. There exists a unique symmetric equilibrium for wholesale prices, which is summarized below.*

$$w = \begin{cases} \dfrac{2N}{N-1}(1-\gamma)\lambda & \text{if } \lambda \leq \lambda_1, \\ 1 - 2\lambda - 2(N-1)\gamma\lambda & \text{if } \lambda_1 \leq \lambda \leq \lambda_2, \\ \dfrac{1-\gamma}{2+(N-3)\gamma} & \text{if } \lambda_2 \leq \lambda. \end{cases}$$

where $\lambda_1 = \frac{N-1}{2(2N-1+\gamma-3N\gamma+N^2\gamma)}$ and $\lambda_2 = \frac{1-2\gamma+N\gamma}{2(2-3\gamma+N\gamma)(1-\gamma+N\gamma)}$.

Note that Lemma 3 applies to both substitutes and complements. The proof is provided in the Online Appendix. Again, the equilibrium wholesale price is increasing in capacity when capacity is small, decreasing in capacity when capacity is moderate, and constant in capacity when capacity is sufficient. Does the retailer benefit from limiting its capacity? The following proposition summarizes the result.

Proposition 6. *Consider the case of N suppliers selling substitutes through a common retailer at wholesale prices. When $N \geq 3$ and $\gamma \geq \frac{3-N}{5-4N+N^2}$, the retailer benefits from limiting its capacity, and its optimal capacity is*

$$\lambda^* = \frac{N-1}{2(3N-1+\gamma-4N\gamma+N^2\gamma)}.$$

Proposition 6 shows that, when the products are substitutes or when the complementarily between products is small enough, the retailer still benefits from limiting its capacity when the number of suppliers is greater than 3. Again, by limiting its capacity, the retailer intensifies the competition between its upstream suppliers, which substantially lowers the equilibrium wholesale prices.

Nonetheless, compared to the case of independent products or substitutes, the retailer is reluctant to limit its capacity when the products are complements. For example, when $N = 4$, the retailer prefers to limit its capacity only when $\gamma > -0.2$. The intuition is as follows. When the products are complements, there are positive externalities between the products: the more units the retailer sells for one product, the higher the price the retailer can charge on other products. If the retailer limits its capacity, it sells fewer products and cannot fully enjoy the positive externalities between the products. Due to this downside of capacity constraint, the retailer is less willing to limit its capacity.

5.2. Exclusive Dealing

A supplier may engage in exclusive dealing, which prohibits a retailer from selling the products of other suppliers (Bernheim and Whinston 1998, Chen and Guo 2014, Mathewson and Winter 1987). In this section, we investigate the retailer's optimal capacity decision when the suppliers could offer exclusive contracts to the retailer. In the analysis, we focus on the case of $N = 2$ suppliers, then discuss the case of many suppliers.

The timing of the game is as follows. In stage 1, the retailer chooses its capacity K. In stage 2, the suppliers make contract offers to the retailer. The contract offered by supplier i takes the form (w_i^e, w_i^c), where w_i^e, the exclusive wholesale price, applies when the retailer contracts only with supplier i, and w_i^c, the common wholesale price, applies when the retailer contracts with both suppliers. If the retailer chooses an exclusive contract, it cannot order from the other retailer. In stage 3, the retailer decides which supplier(s) to contract with and the q_i, the quantity to order from supplier i, subject to its capacity constraint $q_i + q_j \le K$ and the exclusivity constraint.

We solve the game and present the equilibrium contract offers in the following lemma.

Lemma 4. *Suppose that the suppliers can offer exclusive wholesale contracts to the retailer. The equilibrium wholesale prices are as follows.*

$$(w^e, w^c) = \begin{cases} (\lambda, 2\lambda) & \text{if } \lambda \le \frac{1}{5}, \\ \left(\frac{1-2\sqrt{1-6\lambda+6\lambda^2}}{3}, \frac{-1+12\lambda-12\lambda^2-\sqrt{1-6\lambda+6\lambda^2}}{9\lambda}\right) & \text{if } \frac{1}{5} \le \lambda \le \frac{\sqrt{2}-1}{2}, \\ (\varnothing, 1-2\lambda) & \text{if } \frac{\sqrt{2}-1}{2} \le \lambda \le \frac{1}{4}, \\ \left(\varnothing, \frac{1}{2}\right) & \text{if } \frac{1}{4} \le \lambda, \end{cases}$$

where $\varnothing$ denotes no contract offers.

Unlike the case where the suppliers are not allowed to offer exclusive contracts, now the suppliers lower their wholesale prices (in the common contract) when $\lambda < \frac{\sqrt{2}-1}{2}$. This is because, when capacity is limited, each supplier has an incentive to offer an exclusive deal to the retailer to win the scarce capacity. Such an ability substantially intensifies the upstream competition, and as a result, the suppliers have to lower their prices in response.

When the suppliers offer exclusive wholesale contracts, would the retailer benefit from limiting its capacity? The following proposition summarizes the result.

Proposition 7. *Suppose that the suppliers can offer exclusive wholesale contracts to the retailer. In equilibrium, the retailer chooses a capacity $\lambda = \frac{1}{6}$ and makes a profit $\pi = \frac{1}{6}$. Each supplier makes a profit $\Pi_i = \frac{1}{18}$.*

Recall that, when the two suppliers cannot offer exclusive wholesale contracts, the retailer always prefers a sufficient capacity $\lambda \ge \frac{1}{4}$. However, Proposition 7 suggests that the retailer prefers a limited capacity when the suppliers can offer exclusive contracts. That is, *exclusive contracts make it more profitable to limit capacity*. The intuition is that when the suppliers are able to offer exclusive contracts, they compete more fiercely for the limited capacity by making exclusive offers, which further drives down the equilibrium wholesale prices. As a result, the retailer benefits more from the competition and is more willing to limit its capacity.

It is worthwhile to point out that exclusive contracts become unappealing when the number of suppliers is large. Although the retailer can still use exclusive contracts to intensify upstream competition, under exclusive dealing, its profit is bounded above by $\frac{1}{4}$, the maximum profit from selling a single product. Such a profit is immaterial compared to its profit when serving all suppliers. Therefore, in equilibrium, no suppliers will offer exclusive bids and the model degenerates to the basic model discussed above.

5.3. Capacity Cost

In the base models, when endogenizing the retailer's capacity, we intentionally assume away the consideration of capacity cost. This assumption enables us to isolate the strategic effect of capacity from cost concerns. In reality, however, capacity is never free. The retailer must purchase or rent retail stores, build up warehouses, and hire workforce to manage its capacity. Would the results change qualitatively if capacity were no longer free for the retailer?

To examine the above issue, we make the following changes to the base models. First, we assume that the marginal cost for increasing capacity (e.g., by renting additional space and hiring extra workers) will cost the same, which implies that the capacity cost function is increasing and linear. Let $\alpha \geq 0$ denote the marginal cost per unit of capacity. Second, we assume that the capacity decision is made prior to the (short-term) pricing decisions. In light of this, we add a stage 0 to the base models. In stage 0, the retailer chooses its capacity $K \geq 0$ and incurs the capacity cost $\alpha \cdot K$. Then, as before, the suppliers choose their wholesale prices in stage 1, and the retailer procures from the suppliers in stage 2. Demands materialize in stage 3.

In the analysis, we consider the case of a single supplier (no upstream competition) and two suppliers (upstream competition), and compare the results. The model is sufficient to capture the main effect of capacity cost on the retailer's capacity decision. We analyze the model under both wholesale prices and two-part tariffs.

Wholesale Price

First consider the case where the suppliers and the retailer are contracted through wholesale prices. Before tackling the model, we consider the benchmark case of a single supplier, that is, $N = 1$. The retailer's optimal capacity decision is summarized in the following lemma.

LEMMA 5. *Consider the case of a single supplier selling to a retailer at a wholesale price. The retailer's optimal capacity is* $K^* = \frac{1}{4}$ *when* $\alpha \leq \frac{1}{4}$, *and* $K^* = 0$ *otherwise.*

In the case of a single supplier, the retailer chooses either to have sufficient capacity, that is, $K = \frac{1}{4}$, or to have zero capacity. This is because the retailer's profit is convex in K and the retailer has no incentive to choose any capacity in between.

Next, consider the case of two suppliers. The following lemma characterizes the retailer's equilibrium capacity decision.

LEMMA 6. *Consider the case of two suppliers selling to a common retailer at wholesale prices. The retailer's optimal capacity is* $K^* = \frac{1}{2}$ *when* $\alpha \leq \frac{1}{2}(\sqrt{10} - 3) \approx 0.081$, $K^* = \frac{1-\alpha}{5}$ *when* $\frac{1}{2}(\sqrt{10} - 3) < \alpha \leq 1$, *and* $K^* = 0$ *otherwise.*

A comparison of Lemmas 5 and 6 reveals that, first, when $\alpha \leq \frac{1}{2}(\sqrt{10} - 3)$, the retailer chooses sufficient capacity, that is, $\lambda = \frac{K}{N} = \frac{1}{4}$ in both cases.

Interestingly, within the regime $\frac{1}{2}(\sqrt{10} - 3) < \alpha \leq \frac{1}{4}$, the retailer sets up less capacity when there are two suppliers than when there is a single supplier, that is, $\frac{1-\alpha}{5} < \frac{1}{4}$. Within the regime $\frac{1}{4} < \alpha \leq 1$, the retailer sets up more capacity when there are two suppliers than when there is a single supplier, that is, $0 < \frac{1-\alpha}{5}$. The intuition behind the above results is as follows. The two suppliers case differs from the single supplier case in two ways: (1) Additional consumer demand arises when the retailer carries two products, and (2) the retailer can benefit from limiting the capacity and subsequent upstream competition when there are two suppliers. While the former effect induces the retailer to set up a higher capacity, the latter effect encourages the retailer to cut back on its capacity.

When $\frac{1}{2}(\sqrt{10} - 3) < \alpha \leq \frac{1}{4}$, the low capacity cost induces the retailer to set up a high capacity when there is a single supplier. When there are two suppliers, however, the second effect dominates the first effect and the retailer chooses to reduce its capacity. When $\frac{1}{4} < \alpha \leq 1$, the high capacity cost induces the retailer to set up zero capacity when there is a single supplier. When there are two suppliers, however, the retailer can benefit from both the first and second effects and enjoy both a higher demand and a higher margin. Collectively, the retailer is willing to set up a positive capacity (even though the retailer still limits its capacity).

It is noteworthy that, when $\frac{1}{4} < \alpha \leq 1$, absent upstream competition, the retailer builds no capacity. By contrast, in the presence of upstream competition, the retailer builds positive capacity and both channel profit and social welfare are positive. As such, upstream competition improves the channel profit and social welfare through the increased capacity investment, which is contrary to the findings in the case of zero capacity cost (where upstream competition always reduces channel profit and social welfare).

Two-Part Tariff

Now consider the case where the suppliers and the retailer are contracted through two-part tariffs. Again, consider first the case of a single supplier. The retailer does not have any incentive to invest in capacity: After capacity investment is sunk, the supplier will extract the entire retailer profit through the fixed fee, and the retailer always makes zero profit. In stage 0, the retailer correctly anticipates the supplier's move and chooses zero capacity. This hold-up problem fully eliminates the market.

Consider now the case of two suppliers. Will the retailer choose positive capacity? The following proposition characterizes the equilibrium capacity decision when the supply chain is contracted under two-part tariffs.

LEMMA 7. *Consider the case of two suppliers selling through a common retailer under two-part tariff contracts. The retailer's optimal capacity is* $K^* = \frac{1-\alpha}{3}$ *when* $\alpha \le 1$, *and* $K^* = 0$ *otherwise.*

Lemma 7 shows that, when there are two suppliers, as long as unit capacity cost is not too high, the retailer always chooses positive capacity in equilibrium, which is in stark contrast to the single supplier case where the retailer does not build any capacity.

This result arises because upstream competition guarantees that the retailer makes a positive profit after capacity investment is sunk, whereas absent upstream competition, the suppliers would fully extract the retailer's profit through the fixed fees. Therefore, upstream competition solves the hold-up problem and improves supplier profit, retailer profit, and social welfare alike.

6. Conclusions

This paper studies a supply chain with multiple suppliers selling independent products to consumers through a common retailer. The retailer has a limited capacity, which restricts the total quantity of products that it can procure and sell. Our study reveals that a retailer's capacity has substantial effects on equilibrium channel strategies. To begin with, retailer's capacity can distort the equilibrium wholesale prices. When the retailer's capacity is scarce, it has to carefully allocate the capacity among its suppliers. The retailer allocates more capacity to the suppliers that offer better prices. In anticipation of this, the suppliers compete head-to-head for the retailer's capacity, thereby driving down the equilibrium wholesale prices and the retailer's costs.

Second, in equilibrium, the retailer can prefer a limited capacity. When the retailer decides its own capacity, it may intentionally distort its capacity downward, even in the absence of capacity cost. When the number of suppliers is not too small, by limiting its capacity, the retailer can induce fierce competition among the upstream suppliers. However, the retailer's profit improvement through limiting capacity is at the expense of both the suppliers and consumers. We find that the intuition holds when the channel is contracted through two-part tariffs.

Finally, a retailer's capacity may affect the channel members' preference for contract forms in a channel. When the retailer's capacity is large, consistent with conventional wisdom, by using two-part tariffs the suppliers can better extract the retailer profit through fixed fees. However, this finding does not hold when the retailer's capacity is scarce. In this case, under two-part tariffs, the retailer can easily turn down the offer from one supplier and allocate its entire capacity to another supplier. The retailer's strong capacity allocation power forces the suppliers to cut their prices deeply. As a result, the retailer (suppliers) makes a higher (lower) profit under two-part tariffs. Nevertheless, when the suppliers have the power to dictate the contract type, they always prefer two-part tariffs to the wholesale contract, leading to a form of the prisoner's dilemma.

Our study also has some limitations and restrictions. To begin with, there is no competition at the retailer level. Similar to Tan et al. (2016), future research can examine the retailer's capacity decision in the presence of downstream competition. In addition, the paper considers wholesale price contracts and two-part tariffs. Under both contracts, the retailer has an incentive to limit its capacity, leading to a loss in channel profit. It would be of interest to design contracts that better align the interests of channel members and restore market efficiency in future studies. Finally, it would be useful to formally consider a model of exclusive dealing with N suppliers, while the retailer only chooses $M < N$ from them. Notwithstanding these limitations, the current study presents an important explanation of why some retailers strategically limit their capacity even if they can acquire or build it up easily.

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Notes

[1]In the base model, products from different suppliers are noncompetitive, which allows us to focus on the strategic role of retailer's capacity. In section 5.1, we show that our qualitative insights still hold when products from different suppliers are substitutes or complements.
[2]We thank the anonymous Senior Editor who suggested this interesting point.
[3]To see this, suppose that $q_i = q$, we have $p_i = 1 - (1 + \gamma (N-1))q$, which increases with q when $\gamma \le -\frac{1}{N-1}$.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Online Appendix.