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Strategic Sourcing in the Presence of Uncertain Supply and Retail Competition

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This study develops an analytical model to evaluate competing retail firms' sourcing strategies in the presence of supply uncertainty. We consider a common supplier that sells its uncertain supply to two downstream retail firms engaging in price competition in a horizontally differentiated product market. The focal firm has a dual-sourcing option, while the rival firm can only source from the common supplier. We assess the system-wide effects of supply uncertainty on the focal firm's incentive to pursue the dual-sourcing strategy. We find that the focal firm's dual-sourcing strategy can create a win–win situation that leads to increased retail prices and expected profits for both firms. Furthermore, under certain conditions, we show that it is beneficial for the focal firm to strategically source from the common supplier, even if its alternative supplier offers a lower wholesale price. Overall, we identify two types of incentives for adopting the dual-sourcing strategy: the incentive of mitigating supply risk through supplier diversification and the incentive of strategic sourcing for more effective retail competition.

Key words: dual sourcing; supply uncertainty; uniform allocation; price competition; supply chain
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1. Introduction

With the growing trend of outsourcing, offshoring, and globalization, supply uncertainty has become an increasing concern and a major source of supply chain inefficiency. Many external causes (e.g., weather issues and natural disasters) and internal causes (e.g., machine breakdown and defective products) could result in supply fluctuations. For example, a recent explosion at the production plant of Evonik, a big supplier of a specialty resin for auto parts in Germany, led to significant inventory shortfalls (Bennett and Hromadko 2012). As a result, Ford had to delay the rollout of its new Ranger pickup truck to the Asian market (Ramsey 2012). Similarly, the flooding in Thailand hurt the supply of disk drives and related components from Intel (Clark 2012b), and the earthquake and tsunami in Japan caused a supply shortage of electronic gadgets (Fletcher 2012). Apple's iPad2 shipment was not severely affected by the supply disruption because the firm had planned production around multiple component suppliers (Clark 2012a). Sourcing from multiple suppliers clearly can minimize the supply disruption risk and enhance the firm's flexibility in the presence of supply chain uncertainty.

Dual sourcing, a form of supply diversification, has become a common procurement strategy in practice (Anupindi and Akella 1993). For example, the main supplier for HP's DeskJet printers is in Singapore. At the same time, HP has a local source of supply in Vancouver to respond faster to demand increases or supply disruptions in the North American market. Similarly, the Spanish toy manufacturer Famosa receives approximately 80% of its products from China, and the rest comes from European sources only when the Chinese production is insufficient. Although the dual-sourcing benefit of mitigating supply risks is well recognized, firms might prefer single sourcing, for instance, to streamline their supplier base or for more effective quality control and coordination (Larson and Kulchitsky 1998). As an example, over 98% of Ford's outsourced parts are supplied by single-source suppliers. Evidently, whether to choose single sourcing or dual sourcing is a firm's strategic decision, and supply uncertainty is a key factor, among others, in crafting the firm's sourcing strategy. In addition, in today's networked markets, risks resulting from supply uncertainty are often interdependent, leading to the chain effect of demand-side shortages among competing retailers. Consequently, the effect of supply uncertainty on firm profitability should be evaluated in the context of both the supply-side uncertainty and the demand-side competition. So far, previous research has shed little light on how different sourcing strategies would affect both the vertical buyer–supplier relationship and the horizontal market competition. We aim to fill this gap in the literature.

In this study, we build an analytical model to study firms' incentives to choose a dual-sourcing strategy from both risk mitigation and strategic sourcing perspectives. We examine how different sourcing strategies would affect firm performance in the presence of both supply uncertainty and retail competition. Specifically, we consider a supply chain in which one supplier, who is subject to yield uncertainty, supplies an essential input to two downstream retail producers. The two downstream firms—one of which adopts single sourcing and the other a dual-sourcing strategy—transform the essential input into differentiated products and compete in the consumer market. While the dual-sourcing firm can respond effectively to a supply shortage, the single-sourcing firm might suffer from the exclusive supplier's lock-in. This representative supply chain structure captures a class of real-world scenarios in which competing firms adopt distinct sourcing strategies. For example, Philips Electronics was a major microchip supplier for both Nokia and Ericsson cell phones. In early 2000, a fire broke out in one of Philips's chip manufacturing plants in Mexico, which caused a significant supply shortage. Nokia survived the mishap by sourcing from alternative suppliers, while Ericsson experienced substantial operating loss as a result of the component shortage.

Our model delivers several insights. First, we demonstrate the incentive of mitigating supply risk through supplier diversification, as is typically discussed in the literature. In addition, we show that the dual-sourcing firm's alternative sourcing strategy benefits not only itself but also its single-sourcing rival, creating a win–win outcome. The dual-sourcing firm directly benefits from having its alternative supplier because, in the event of a supply shortage, the firm can fulfill the residual demand that is not covered by the common supplier. Compared with its single-sourcing competitor, the dual-sourcing firm has a "monopoly" power over the residual demand, which induces the dual-sourcing firm to raise its retail price. Consequently, the increase in the retail price by the dual-sourcing firm softens the price competition with its single-sourcing rival. The single-sourcing rival, in turn, raises its retail price and indirectly benefits from the softened competition, leading to higher retail prices and profits for both firms. Under certain conditions, the total consumer utility and social welfare also increase.

Second, we find that the dual-sourcing focal firm has incentive to strategically source from the common supplier even if its alternative supplier offers a lower wholesale price. By ordering from the common supplier, the dual-sourcing firm shares the scarce supply provided by the common supplier with the rival firm in the event of a supply shortage and thus limits its rival's supply to the market. Such strategic sourcing comes with a higher procurement cost, but the benefit resulting from the end consumer market competition can outweigh the extra procurement cost paid to the common supplier. In the battle for competitive advantage, our results suggest that strategic sourcing should be considered as an integral component of a firm's overall business strategy.

The rest of the article is organized as follows. Section 2 briefly reviews related literature. Section 3 describes our basic model setup. In section 4 we derive the equilibrium market outcomes and demonstrate both the tactical benefits (i.e., risk mitigation) and strategic value (i.e., competitive advantage) of the dual-sourcing strategy. In section 5 we consider several extensions of the base setting. Section 6 concludes.

2. Related Literature

Uncertain yield is a common problem in many production systems, such as electronic fabrication and assembly, chemical processes, and procurement of raw materials from suppliers (Yano and Lee 1995). Yield uncertainty traditionally has been modeled using two general approaches: the random yield model, which assumes the output level is a random function of the input variables (Henig and Gerchak 1990, Kouvelis and Li 2013), and the total supply disruption model, which is of the "all-or-nothing" form (Hu et al. 2013, Tomlin 2006). We adopt a simplified form of the random yield model in which the output can only partially fulfill the order quantity with some probability.

With an increasing awareness of the high risks associated with single sourcing, considerable attention has been paid to multiple-sourcing operations in the presence of yield uncertainty (Agrawal and Nahmias 1997, Anupindi and Akella 1993) and supply disruption (Parlar and Perry 1996, Tomlin 2006). The benefits of multiple sourcing over single sourcing have been well documented in the literature (Federgruen and Yang 2008, Tomlin and Wang 2005). Much of the literature either focuses on a single firm's upstream supply diversification or assumes independent downstream demand to isolate the effect of supply chain competition. In the presence of both yield uncertainty and buyer competition, Tang and Kouvelis (2011) examine the benefits of supplier diversification in the context of dual-sourcing duopolies. However, they focus on the effect of supplier correlation rather than on strategic sourcing, which we consider in this study. Moreover, we assume that the yield uncertainty has an interdependent effect on competing firms' order fulfillment, which is different from their work.

When selling to multiple downstream firms, suppliers face the operational issue of quantity allocation in the presence of supply shortage. Suppliers usually map firms' orders to final order delivery based on a publicly known allocation mechanism. Cachon and Lariviere (1999) show that retailers generally have incentives to order more than they need, hoping to gain a more favorable allocation. However, a number of allocation rules can induce truth-telling, including lexicographic allocation (i.e., retailers are ranked in some manner independent of their order sizes, such as alphabetically) and uniform allocation (i.e., all orders either are completely fulfilled or receive the same allocation as all other partially fulfilled orders). It is well established in the economics literature that the uniform allocation rule satisfies a number of desirable properties, including strategy-proofness, fairness, efficiency, and anonymity (Sprumont 1991). In the supply chain management context, Cachon and Lariviere (1999) further demonstrate that uniform allocation can result in higher supply chain profits than lexicographic allocation. For these reasons, we adopt the uniform allocation rule in this study.

As outsourcing production becomes an industry-wide practice, substantial work in the supply chain management literature studies the optimal sourcing strategies under different supply chain competition structures. Based on the Hotelling product differentiation model, Shy and Stenbacka (2003) study strategic decisions of Bertrand competitors in differentiated industries to outsource production of a key component. They show that symmetric firms outsource production to a low-cost, common subcontractor, which fully uses economies of scale. Our model differs from theirs in that we introduce an asymmetric outsourcing structure in which one firm adopts single sourcing and the other firm chooses dual sourcing. In the presence of supply risk, our enriched model offers additional insights regarding competing firms' different outsourcing and pricing decisions.

In addition, we add to the growing literature discussing strategic incentives in outsourcing practices. Building on a price competition model, we demonstrate the existence of strategic sourcing, which is similar to the cost-increasing strategy discussed in Salop and Scheffman (1983). Under the classical framework of Cournot quantity competition, Salop and Scheffman (1987) show that a firm may over-purchase inputs in an outside market even when it is more efficient to produce the input internally in order to raise the input cost of competitors. More recently, Arya et al. (2008) demonstrate the strategic benefit of purchasing from a common external supplier. They show that a firm might have incentives to outsource production even when the cost of outsourcing exceeds the firm's cost of in-house production. Although their results of strategic sourcing are similar to ours, the underlying driving forces are fundamentally different. Arya et al. (2008) find that the strategic consideration is to limit the supplier's incentive to provide the rival with favorable terms. We show that supply shortage can be another reason for the focal firm to strategically source from a common supplier.

3. The Base Model

We consider a simple supply chain model consisting of a common supplier selling an essential input at unit wholesale price w to two retail producers, as shown in Figure 1. The two retail producers, labeled as firm A and firm B, transform the essential input into differentiated retail products and sell at unit retail price p_i, for $i \in \{A, B\}$, in the end consumer market. The two firms differ in their sourcing options. While firm A relies solely on the common supplier for the essential input, firm B has an alternative supplier that can provide unlimited supply at unit price s. In other words, firm A adopts a single-sourcing strategy and firm B uses a dual-sourcing strategy.

The sequence of events is illustrated in Figure 2. First, given the price pair (w, s), both firms decide their retail prices (p_A, p_B) simultaneously. Anticipating the market demand based on the price competition, the two firms place orders (q_A, q_B) to the common supplier. Next, the common supplier fulfills the orders. The common supplier has uncertain yield. With probability α, $\alpha \in (0,1)$, the common supplier has high yield and fulfills both firms' orders in

Figure 1 Supply Chain Model

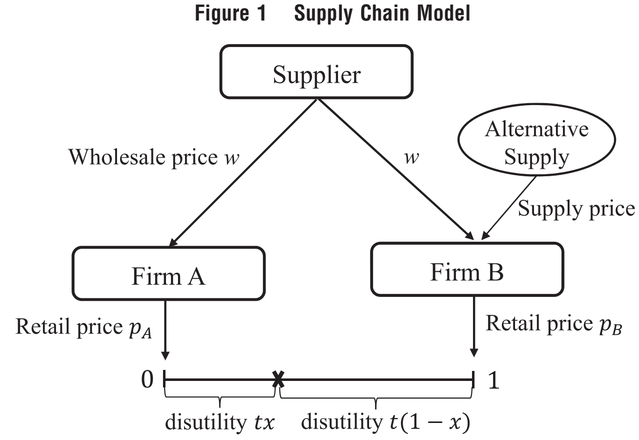
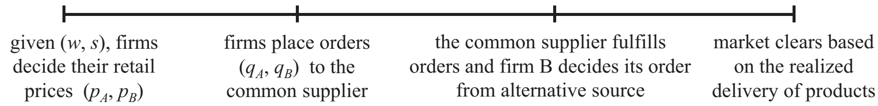


Figure 2 Sequence of Events



full; with probability $1 - \alpha$, the common supplier's realized yield is Q, $Q \in [0,1)$. In the latter, the common supplier experiences supply shortage and it rations the orders from the two firms according to a pre-announced allocation rule, and firm B can acquire additional supply from its alternative source. Finally, the market clears, based on the realized delivery of products from the two firms. Note that here we assume price commitment, implying that firms determine the retail prices before the supply uncertainty is realized and are committed to the chosen prices afterwords. For example, Apple commits to the retail price for its iPad before the start of the selling season, and supply shortage does not affect the product price. We further assume that firms are risk neutral and that the supply chain structure is common knowledge. Each firm optimally chooses its retail price and order quantity, anticipating its rival's action. In the following paragraphs, we describe the two retail firms' competition and the common supplier's allocation rule in detail.

To simplify our exposition, we assume that one unit of the input from the supplier is required to produce each unit of the retail product. The marginal production costs for both retail producers are normalized to be zero. We further assume that products produced by the two firms are horizontally differentiated in that consumers have heterogeneous preferences toward consuming the two firms' products. Following Hotelling's horizontal product differentiation model to capture consumer preference (Hotelling 1929), we assume that products A and B are located at positions 0 and 1, respectively, of a line of length 1 (i.e., at the two ends of the line). A continuum of consumers of measure 1 is uniformly distributed along the line, and each consumer has unit demand. Therefore, the total market demand is 1. Consumer utility for a product is the reservation value of the product v, net the disutility from the mismatch between the product and the consumer's need, measured by the distance between the product's and the consumer's locations on the line. We denote t as the marginal disutility. A consumer who is located at $x \in [0,1]$ incurs disutility tx if purchasing from firm A and $t(1 - x)$ if purchasing from firm B. Therefore, the net surplus purchasing from firm A is $v - tx - p_A$ and from firm B is $v - t(1 - x) - p_B$. To focus on market competition, we assume that v is large enough for each consumer to derive positive utility from both products and for the market to be fully covered. A consumer purchases the product that gives her higher net surplus. We can easily derive the location of the indifferent consumer as $\hat{x} = 1/2 + (p_B - p_A)/2t$. Thus, consumers located between 0 and $\hat{x}$ on the Hotelling line buy from firm A, and the remaining consumers buy from firm B. Accordingly, the demand for the two firms can be expressed as

$$\begin{cases} D_A = \dfrac{1}{2} + \dfrac{p_B - p_A}{2t} \\ D_B = \dfrac{1}{2} + \dfrac{p_A - p_B}{2t}. \end{cases} \quad (1)$$

Following Sprumont (1991) and Cachon and Lariviere (1999), we assume that the common supplier adopts a uniform allocation rule because of its desirable properties, which include its being both fair and strategy-proof. Under the uniform allocation, both firms are equally likely to receive each unit produced by the supplier until one firm's order is completely fulfilled or all produced units are allocated. Denote q_i, $i \in \{A, B\}$, as firm i's order quantity to the common supplier. Mathematically, the uniform allocation rule allocates $g_i(q_i, q_{\bar{i}})$ to firm i, where $\{i, \bar{i}\} = \{A, B\}$, as follows:

$$g_i(q_i, q_{\bar{i}}) = \begin{cases} q_i & \text{if } q_i < \frac{Q}{2} \text{ or } q_i + q_{\bar{i}} < Q \\ Q - q_{\bar{i}} & \text{if } q_{\bar{i}} < \frac{Q}{2} \le q_i \text{ and } q_i + q_{\bar{i}} \ge Q \\ \frac{Q}{2} & \text{if } \min\{q_i, q_{\bar{i}}\} \ge \frac{Q}{2}. \end{cases} \quad (2)$$

More specifically, if the sum of the two firms' order quantities is smaller than the supplier's realized capacity Q, or if a firm's order quantity is smaller than $\frac{Q}{2}$, the latter firm's order can be completely fulfilled without being affected by the supply uncertainty. If both firms' order quantities are higher than $\frac{Q}{2}$, then the two firms share the limited capacity and each firm gets $\frac{Q}{2}$. If one firm's order amount is greater than $\frac{Q}{2}$, but the other firm's order amount is smaller than $\frac{Q}{2}$, then the smaller size order gets fulfilled in full, and the remaining units are allocated to the larger size order. To ease exposition without causing any confusion, we suppress the arguments and use g_A and g_B to denote firm A's allocation and firm B's allocation, respectively.

To deliver key managerial insights, we focus on the most interesting cases, where the common supplier's reliability is not too low (e.g., $\alpha \ge \frac{1}{2}$; otherwise, firm A needs to consider an alternative supplier or the common supplier should expand its capacity), and where the wholesale price from the common supplier is not significantly different from firm B's alternative supply price (otherwise firm B might simply choose the low-cost source, and the dual-sourcing strategy degenerates to single sourcing). Analysis of other scenarios is available from the authors upon request.

4. Equilibrium Market Outcomes

In this section, we first formulate firms' optimization problems and derive their ordering strategies. Based on a benchmark case that no alternative sourcing is available, we consider the benefit of dual sourcing as a tactical hedge against a supply shortage in section 4.1. We further identify conditions under which dual sourcing becomes a strategic consideration in section 4.2.

Because of the competition for scarce resources, both firms might strategically manipulate their orders from the common supplier, hoping to gain a favorable share of allocation in the event of a supply shortage. In the context of single sourcing and independent demand from retailers, Cachon and Lariviere (1999) show that uniform allocation can induce truth-telling. In our setting with dual sourcing and retail competition, Lemma 1 shows that firms' equilibrium order strategies must satisfy the following properties.

LEMMA 1. *In equilibrium,* $q_A = D_A$ *and* $q_B \le max\{D_B, \frac{Q}{2}\}$.

PROOF. Notice that g_i is weakly increasing in q_i. For firm A, ordering less than D_A is not optimal because the only effect of ordering less than D_A is to curtail its own demand. Next, we show that firm A has no incentive to order more than D_A. According to Equation (2), if $D_A \le \frac{Q}{2}$ or if $D_A > \frac{Q}{2}$ and $D_A + q_B < Q$, ordering D_A leads to $g_A = D_A$. So the demand can be fully satisfied even in the event of a supply shortage. Ordering more than D_A might entail the risk of overstock if the order can be completely fulfilled. Therefore, firm A has no incentive to order more than D_A in this case. If $D_A > \frac{Q}{2}$ and $D_A + q_B \ge Q$, ordering more than D_A gets the same allocation as ordering D_A in the event of shortage, but it leads to overstock if the supply is sufficient. Therefore, firm A has no incentive to order more than D_A in this case as well. For firm B, when $D_B > \frac{Q}{2}$, ordering more than D_B leads to that $g_A = g_B = \frac{Q}{2}$ if $D_A > \frac{Q}{2}$ and $g_A = D_A$ and $g_B = Q - D_A$ if $D_A \le \frac{Q}{2}$. So firm B does not have incentive to order more than D_B from the common supplier because doing so gets the same allocation as ordering exactly D_B, but with the risk of overstocking. When $D_B \le \frac{Q}{2}$, ordering more than D_B may affect firm A's fulfillment $g_A = Q - q_B$ and thus firm B's sales in the event of a supply shortage. However, firm B does not have incentive to order more than $\frac{Q}{2}$, as doing so does not affect firm A's allocation but increases its own overstocking cost. Meanwhile, because it has the alternative supplier, firm B might have incentive to order from the alternative supplier in some cases. Therefore, $q_B \le max\{D_B, \frac{Q}{2}\}$. □

An important property of the uniform allocation rule is its robustness against strategic manipulations (Sprumont 1991). In the context of dual sourcing, Lemma 1 confirms that firm A will order truthfully according to the anticipated market demand; that is, $q_A = D_A$ where D_A is defined in Equation (1). However, firm B does not always have incentive to order exactly D_B from the common supplier. In particular, in the special case when $D_B < \frac{Q}{2}$, because of the competition in the end consumer market, firm B might consider ordering more than D_B from the common supplier. On the one hand, this strategic consideration can limit firm A's supply to the market, thus increasing firm B's sales in the event of a supply shortage. On the other hand, it incurs a cost of overstocking if the supply from the common supplier is sufficient. Firm B has to trade off the potential benefit against the inherent cost. For ease of exposition, we simply assume that the overstocking cost is relatively high such that firm B has no incentive to inflate its order more than it needs, and thus $q_B \le D_B$ (As we shall show later, in the equilibria we study, D_B is no less than $Q/2$, so relaxing the above assumption does not affect our results.)

Notice that, by Lemma 1 and D_A derived in Equation (1), firm A's order decision is completely determined by the two firms' retail prices. When the supply is sufficient, firm A's entire order can be fulfilled. When the supply is short, firm A's order is rationed according to the allocation rule specified in Equation (2). Therefore, the expected sales for firm A is $\alpha q_A + (1-\alpha)g_A$, and firm A's optimization problem is to choose the optimal price to maximize expected profit:

$$\max_{p_A} E\pi_A = [\alpha q_A + (1-\alpha)g_A](p_A - w). \tag{3}$$

When the two suppliers' prices are comparable (i.e., w and s are not significantly different from each other), firm B orders q_B, $q_B \in [0, D_B]$, from the common supplier and uses the alternative supplier to fulfill the remaining demand, if necessary. In this case, firm B needs to decide the optimal order quantity from the common supplier, along with its pricing. Subject to the condition $q_B \le D_B$, firm B's optimization problem can be formulated as

$$\max_{p_B, q_B} E\pi_B = [\alpha q_B + (1-\alpha)g_B](p_B - w) + [\alpha(D_B - q_B) + (1-\alpha)(1 - g_A - g_B)](p_B - s). \tag{4}$$

The first and second parts in this objective function are the expected profit from the common supplier and the expected profit from the alternative supplier, respectively. When no supply shortage occurs, firm B gets q_B from the common supplier and orders the remaining amount $D_B - q_B$ from the alternative supplier. When a supply shortage occurs, firm B gets allocation g_B and secures the remaining market demand $1 - g_A - g_B$ from the alternative supplier.

To examine the effects of the dual-sourcing strategy on firms' pricing strategies and expected profits, we use single sourcing as a benchmark. In the single-sourcing environment, the two firms are symmetric. Firm B's decision problem is the same as that of firm A. Solving the two firms' decision problems simultaneously, we have the following equilibrium retail prices and expected profits.

PROPOSITION 1. *If both firms use a single-sourcing strategy, the equilibrium retail prices and the expected profits are*

$$p_A^{s*} = p_B^{s*} = w + \frac{t}{\alpha}[\alpha + (1-\alpha)Q] \tag{5}$$

$$E\pi_A^{s*} = E\pi_B^{s*} = \frac{t}{2\alpha}[\alpha + (1-\alpha)Q]^2. \tag{6}$$

PROOF. All proofs are in the Supporting Information appendix unless otherwise indicated. □

We see that both firms charge the same equilibrium retail price. As a result, the expected demand for each firm is $D_i = \frac{1}{2}$ by Equation (1). That is, each firm serves half of the end consumer market, and both firms earn the same expected profit.

Next, we examine the equilibrium outcome when firm B has the dual-sourcing option. We first consider the case in which the wholesale price of the common supplier is no higher than that of the alternative supplier (i.e., $w \le s$), and then we consider the reverse case (i.e., $w > s$). In each case, we compare the equilibrium outcome with the single-sourcing benchmark.

4.1. The Wholesale Price Is Lower than the Alternative Supply Price ($w \le s$)

When the wholesale price of the common supplier is not higher than that of the alternative supplier, firm B orders all the supply it needs from the common supplier; that is, $q_B = D_B$. When no supply shortage occurs, ordering any lesser amount from the common supplier would only increase firm B's procurement cost from w to s for the rest of its supply needs when $w < s$ (or doing so has no effect when $w = s$). In the event of a supply shortage, by the uniform allocation rule, ordering any amount less than its demand (weakly) decreases firm B's own order fulfillment from the common supplier and (weakly) increases the order fulfillment of firm A. Therefore, ordering less than D_B is never optimal for firm B. Thus, by Lemma 1, we have $q_B = D_B$, and by Equation (1), $q_A + q_B = D_A + D_B = 1$, which is greater than Q. Hence, the uniform allocation rule in Equation (2) can be simplified to

$$g_A = \begin{cases} q_A & \text{if } q_A < \frac{Q}{2} \\ Q - q_B & \text{if } q_B < \frac{Q}{2} \\ \frac{Q}{2} & \text{if } \min\{q_A, q_B\} \ge \frac{Q}{2}, \end{cases} \tag{7}$$

and $g_B = Q - g_A$. Based on this allocation, solving the two firms' constrained optimization problems in Equations (3) and (4) simultaneously, we have the following equilibrium outcome.

PROPOSITION 2. *When* $(s - w) \in \left[0, \frac{t[5+\alpha+(1-\alpha)Q]}{6\alpha}\right]$, *the equilibrium prices are*

$$\begin{cases} p_A^* = w + \dfrac{t[2+\alpha+(1-\alpha)Q]}{3\alpha} \\ p_B^* = w + \dfrac{t[4-\alpha-(1-\alpha)Q]}{3\alpha}, \end{cases} \tag{8}$$

and equilibrium orders are $q_i^* = D_i^* > \frac{Q}{2}$, *where* D_i^* *is defined in Equation (1) with the above equilibrium* p_i^*, $i \in \{A, B\}$. *The expected profits are*

$$\begin{cases} E\pi_A^* = \dfrac{t[2+\alpha+(1-\alpha)Q]^2}{18\alpha} \\ E\pi_B^* = \dfrac{t[4-\alpha-(1-\alpha)Q]^2 - 18\alpha(1-\alpha)(s-w)(1-Q)}{18\alpha}. \end{cases} \tag{9}$$

The upper bound in the condition $(s - w)$ implies that, to make the dual-sourcing strategy a viable choice for firm B, the alternative supply price cannot be prohibitively higher than the common supplier's price. Intuitively, if the alternative source of supply is too expensive, firm B will forgo the opportunity of ordering from the alternative supplier.

Note that the supply uncertainty is what makes the alternative sourcing play a role in the price competition. If no supply uncertainty exists (i.e., if $\alpha = 1$), firm B does not order from the alternative supplier, and the equilibrium pricing strategies are the same for the two firms, regardless of the alternative sourcing opportunity.

Intuitively, given the additional sourcing option, firm B enjoys a competitive advantage over firm A in the retail market. The following proposition compares the two firms' equilibrium prices and profits under the single-sourcing and dual-sourcing scenarios.

PROPOSITION 3. *Compared with the single-sourcing benchmark, when* $(s - w) \in \left[0, \frac{t[5+\alpha+(1-\alpha)Q]}{6\alpha}\right]$, *and in the presence of firm B's alternative sourcing, (a) both firms increase their prices in equilibrium, with firm B increasing its price more than firm A does; that is,* $p_B^* > p_A^* > p_A^{s*} = p_B^{s*}$; *and (b) both firms' expected profits increase; that is,* $E\pi_A^* > E\pi_A^{s*}$ *and* $E\pi_B^* > E\pi_B^{s*}$.

Compared with the single-sourcing benchmark, Proposition 3(a) shows that both firms charge higher prices in the dual-sourcing environment. The intuition is as follows. The uncertain supply leads to an asymmetric demand structure for the two firms. In the event of a supply shortage, there is residual demand $1 - Q$ that is not covered by the common supplier but can be fulfilled by firm B's alternative supplier. With the option of dual sourcing, firm B thus has a "monopoly" power over the residual demand, which induces it to raise its retail price. Consequently, this price increase by firm B reduces the pressure on firm A's pricing. Firm A thus raises its retail price as well, but not to the extent that firm B does because of firm B's competitive advantage over the residual demand.

Proposition 3(b) further shows that one firm's pursuit of the dual-sourcing strategy can benefit both itself and its rival. Because firm A charges a relatively lower price than firm B, it has higher demand and thus higher expected sales, compared to the single-source benchmark case. The increased price and sales lead to a higher expected profit for firm A. Because firm B, in the event of a supply shortage from the common supplier, can secure an alternative supply to satisfy the residual demand, firm B's expected profit is also higher than it is in the single-source benchmark case. Contrary to conventional wisdom, the seemingly vulnerable, single-sourcing firm's performance is not necessarily hurt by its more flexible and responsive dual-sourcing competitor. Instead, we find that the presence of alternative sourcing for one firm creates a positive externality for the other. The positive externality arises because of softened competition at the downstream level, which comes from the residual demand—fulfilled by firm B as a result of the alternative supply—that otherwise would be lost because of the supply shortage.

Note also that the expected overall consumer utility and social welfare can increase in the presence of dual sourcing. The realized utility for each consumer is affected by two factors: whether the consumer is served by the market and, if so, which product the consumer consumes. When a consumer is not served by either firm, the consumer derives zero utility. When served, the consumer derives utility $v - tx$, where x is the distance between the consumer and product consumed. In the benchmark case with single sourcing, $p_A^{s*} = p_B^{s*}$. When no supply shortage occurs, consumers located at $[0, \frac{1}{2})$ consume product A, and consumers located at $(\frac{1}{2}, 1]$ consume product B. When a supply shortage occurs, $1 - Q$ consumers are not served by the market. In contrast, in the presence of dual sourcing, $\hat{x} = \frac{1}{2} + \frac{p_B^* - p_A^*}{2t}$. On the one hand, because $p_B^* > p_A^*$, the consumers located at $[\frac{1}{2}, \hat{x}]$ consume product A instead of product B, although they derive higher utilities from product B. On the other hand, given dual sourcing, when a supply shortage occurs, all consumer demands are satisfied, among which Q is served by the common supplier and $1 - Q$ by the alternative supplier. As we can show, as long as consumers' reservation value v is higher than a threshold (see the Supporting Information appendix for the detailed condition and proof), both the expected overall consumer utility (i.e., the total value realized) and the social welfare (i.e., the total value minus the total procurement cost) increase in the dual-sourcing environment.

4.2. The Wholesale Price Is Higher than the Alternative Supply Price ($w > s$)

In this section, we consider the case where the wholesale price is higher than the alternative sourcing price; that is, $w > s$. Because ordering from the common supplier is more expensive, firm B might choose to place all its orders with the alternative supplier. For strategic reasons, however, firm B also might still order part of its expected market demand from the common supplier, to compete with firm A for the scarce supply on which firm A completely depends. The following lemma characterizes firm B's incentive to order from the common supplier.

LEMMA 2. *When* $w > s$, *if* $q_A \leq \frac{Q}{2}$, *firm B has no incentive to order from the common supplier; if* $q_A > \frac{Q}{2}$, *firm B orders at most* $\frac{Q}{2}$ *from the common supplier.*

The intuition for Lemma 2 is as follows. When q_A is small (i.e., $q_A \leq \frac{Q}{2}$), by the uniform allocation rule, firm A always receives what it orders—no matter whether a supply shortage occurs or how much firm B orders from the common supplier. In other words, in this case, firm B's sourcing decision has no effect on the allocation to firm A. As a result, firm B strictly prefers to order from the alternative supplier because its price is lower than the wholesale price offered by the common supplier. When q_A is large (i.e., $q_A > \frac{Q}{2}$), any order greater than $\frac{Q}{2}$ from firm B will result in the same allocation to firm A (i.e., $g_A = \frac{Q}{2}$). Again, because the alternative supply price is lower, firm B has no incentive to order more than $\frac{Q}{2}$ from the common supplier.

Lemma 2 implies that firm B always orders no more than $\frac{Q}{2}$ when $w > s$. Immediately, we have $q_B \in \left[0, \min\{\frac{Q}{2}, D_B\}\right]$. As a result, firm B's order to the common supplier q_B is always fulfilled—even in the event of a supply shortage—according to Equation (2). Therefore, $g_B = q_B$. By the uniform rationing rule in Equation (2), we can specify g_A in this case as

$$g_A = \begin{cases} q_A & \text{if } q_A < Q - q_B \\ Q - q_B & \text{if } q_A \geq Q - q_B. \end{cases} \quad (10)$$

Subject to the condition $q_B \in \left[0, \min\{\frac{Q}{2}, D_B\}\right]$ and the above allocation rule, we solve the constrained optimization problems in Equations (3) and (4) simultaneously to derive the equilibrium prices and order quantity as follows.

Proposition 4. *When*

$$(w - s) \in \left[0, \min\left\{\frac{[(2+\alpha)(1-Q)-3\alpha Q]t}{\alpha}, \frac{(1-\alpha)[4(4-\alpha)-7(1-\alpha)Q]t}{4\alpha(2+\alpha)}\right\}\right]$$

firm B orders $q_B^* = \frac{Q}{2}$ from the common supplier, and the equilibrium prices are

$$\begin{cases} p_A^* = \dfrac{s+2w}{3} + \dfrac{t[2+\alpha+(1-\alpha)Q]}{3\alpha} \\ p_B^* = \dfrac{2s+w}{3} + \dfrac{t[4-\alpha-(1-\alpha)Q]}{3\alpha}. \end{cases} \quad (11)$$

The equilibrium profits are

$$\begin{cases} E\pi_A^* = \dfrac{[t(2+\alpha+(1-\alpha)Q)-\alpha(w-s)]^2}{18\alpha t} \\ E\pi_B^* = \dfrac{[t(4-\alpha-(1-\alpha)Q)+\alpha(w-s)]^2 - 9\alpha t Q(w-s)}{18\alpha t}. \end{cases} \quad (12)$$

This proposition shows the effect of strategic sourcing. That is, if the wholesale price w is within the identified interval, firm B has incentive to order from the common supplier, even if the alternative supplier offers a lower wholesale price. By ordering from the common supplier, firm B shares the scarce supply provided by the common supplier with firm A and thus limits its rival's supply to the market in the event of a supply shortage. This strategic sourcing comes with a higher procurement cost, but the benefit resulting from the end consumer market competition can outweigh the extra cost paid to the common supplier. In other words, firm B pays a premium (relative to the alternative supply price) to the common supplier to raise its rival's opportunity cost. Meanwhile, note that the wholesale price w is bounded. If the wholesale price is higher than the upper bound, firm B has no incentive to pursue strategic sourcing because ordering from the low-cost supplier is more cost effective.

Proposition 5. *Compared with the single-sourcing benchmark, when* $(w - s) \in \left[0, \min\left\{\frac{2t(1-\alpha)(1-Q)}{\alpha}, \frac{[(2+\alpha)(1-Q)-3\alpha Q]t}{\alpha}, \frac{(1-\alpha)[4(4-\alpha)-7(1-\alpha)Q]t}{4\alpha(2+\alpha)}\right\}\right]$, *and in the presence of firm B's alternative sourcing, (a) both firms increase their prices in equilibrium, with firm B increasing its price more than firm A does; that is, $p_B^* > p_A^* > p_A^{s*} = p_B^{s*}$; and (b) both firms' expected profits increase; that is, $E\pi_A^* > E\pi_A^{s*}$ and $E\pi_B^* > E\pi_B^{s*}$.*

We see that, even when the common supplier's wholesale price is higher than the alternative supplier's price, both firms charge higher prices and earn higher expected profits in the dual-sourcing environment than in the single-sourcing benchmark, and firm B still charges a higher price than firm A does. The insights follow similar lines of reasoning as in Proposition 3.

5. Extensions and Discussions

In this section, we relax some of our assumptions to discuss several model variations. Our objective is to demonstrate that the major insights are robust when the common supplier's wholesale price is endogenous, when the common supplier can price discriminate between the two firms, and when one firm obtains priority allocation on scarce resources.

5.1. Endogenous Wholesale Price

To show that firm A can still benefit from firm B's dual-sourcing strategy and that firm B still has incentive to pursue strategic sourcing when we endogenize w, we need to demonstrate that the cases discussed in sections 4.1 and 4.2 can arise in equilibrium for an endogenously determined wholesale price w.

Denote the common supplier's marginal production cost as c. Recall that, if $w \leq s$, then by Proposition 2, the total order from the two firms is 1 (i.e., $q_A^* + q_B^* = 1$). If $w > s$, then by Proposition 4,

$$q_A^* = \frac{1}{2} + \frac{s-w}{6t} + \frac{(1-\alpha)(1-Q)}{3\alpha}$$

and $q_B^* = \frac{Q}{2}$. The total order $q_A^* + q_B^* < 1$. The common supplier compares its expected profit under each case and chooses an optimal wholesale price w to maximize its expected profit $(w - c)[\alpha(q_A^* + q_B^*) + (1 - \alpha)Q]$.

If $w \leq s$, the common supplier has a fixed expected demand of $\alpha + (1 - \alpha)Q$. Because its profit function linearly increases in the wholesale price, the common supplier would like to charge a price as high as possible. However, an extremely high wholesale price pushes up the firms' retail prices and leaves some consumers unserved in the market. Hence, as in the baseline model, we impose a full market coverage condition that ensures all consumer demands get satisfied. By Proposition 3, we have $p_B^* > p_A^*$. Thus, full market coverage requires that the consumer located at point zero on the Hotelling line derives non-negative utility from buying product B. Solving $v - t - p_B^* = 0$, we can derive the upper-bound wholesale price as

$$w_1 = v - \frac{t[4 + 2\alpha - (1 - \alpha)Q]}{3\alpha}.$$

Therefore, within the range of $w \leq s$, the common supplier might optimally set wholesale price w_1 if $w_1 \leq s$, or, equivalently, if

$$v \leq v_1 \equiv s + \frac{t[4 + 2\alpha - (1 - \alpha)Q]}{3\alpha};$$

otherwise, the supplier optimally sets wholesale price s.

Similarly, if $w > s$, the full market coverage condition requires that the wholesale price not be too high. By Proposition 5 we have $p_B^* > p_A^*$. Based on p_B^* in Proposition 4, we can derive the upper-bound wholesale price as

$$w_2 = 3\left(v - \frac{t[4 + 2\alpha - (1 - \alpha)Q]}{3\alpha}\right) - 2s.$$

The condition $w_2 > s$ is equivalent to $v > v_1$. Furthermore, by substituting q_A^* and q_B^* from Proposition 4 into the common supplier's expected profit function, we can solve the unconstrained optimization problem and derive its optimal wholesale price

$$w_e = \frac{c + s}{2} + \frac{t[2 + 4Q + \alpha(1 - Q)]}{2\alpha}.$$

Note that $w_e \leq w_2$ requires that

$$v \geq \frac{5s + c}{6} + \frac{(2 + \alpha)(5 + Q)t}{6\alpha} \equiv v_2.$$

By simple algebra, we can verify that when $s - c < \frac{t[2 + 4Q + \alpha(1 - Q)]}{\alpha}$, $w_e > s$ and $v_1 < v_2$. So in this case, by the concavity of its objective function, the common supplier can optimally set wholesale price w_e if $v > v_2$ and wholesale price w_2 if $v \in (v_1, v_2]$.

Combining the above two cases, the optimal wholesale price is w_1 if $v \leq v_1$. If $v \in (v_1, v_2]$, the supplier faces a trade-off between charging a higher w_2 but with a lower expected total order quantity and charging a lower wholesale price s but with a higher expected total order quantity. Therefore, the optimal wholesale price is w_2 if

$$(w_2 - c)\left[\alpha\left(\frac{1}{2} + \frac{s - w_2}{6t} + \frac{(1 - \alpha)(1 - Q)}{3\alpha} + \frac{Q}{2}\right) + (1 - \alpha)Q\right] \geq (s - c)[\alpha + (1 - \alpha)Q], \tag{13}$$

where the left-hand side is the expected profit under wholesale price w_2 and the right-hand side is the expected profit under wholesale price s. (If $v > v_2$, the optimal wholesale price can also be similarly characterized.)

We can verify that the wholesale price assumed in Proposition 2 and the wholesale price assumed in Proposition 4 can arise in equilibrium as the common supplier's optimal wholesale price. For example, when v is less than but close to v_1, the common supplier optimally chooses w_1 (where $w_1 < s$) as the wholesale price, and $(s - w_1)$ can be in the interval specified in Proposition 2. When $v \in (v_1, v_2]$ and $(s - c)$ is small enough, the inequality condition in Equation (13) holds, and the common supplier optimally sets $w_2 > s$. In addition, when v is close to v_1, $(w_2 - s)$ can be in the interval specified in Proposition 4. Therefore, the scenarios in both sections 4.1 and 4.2 can arise in equilibrium, and our major insights are not affected when the wholesale price is endogenously determined.

5.2. Wholesale Price Discrimination

In our base model we assume that the common supplier offers the same wholesale price w to the two firms. Such an assumption makes sense for two reasons. First, the prevailing Anti-Price Discrimination Act (i.e., The Robinson–Patman Act) prohibits anti-competitive wholesale price discrimination for identical products by producers. Second, price discrimination can induce arbitrage/resale behaviors that hurt fair competition. For instance, the firm that gets a favorable price may procure more and resell the input to the other firm in the secondary market. In this extension, we look at the case where the common supplier can price discriminate between the two retail firms. We show that our main insights continue to hold, even in the presence of wholesale price discrimination.

Denote w_A and w_B as the wholesale prices offered by the common supplier to the two firms. For ease of exposition, we assume the difference between the two wholesale prices is not too large. Following an approach similar to that in Proposition 1, we can derive the equilibrium retail prices and the expected profits for the single-sourcing benchmark as

$$\begin{cases} p_A^{s*} = \dfrac{2w_A + w_B}{3} + t + \dfrac{(1-\alpha)}{\alpha} tQ \\ p_B^{s*} = \dfrac{w_A + 2w_B}{3} + t + \dfrac{(1-\alpha)}{\alpha} tQ \end{cases} \quad (14)$$

and

$$\begin{cases} E\pi_A^{s*} = \dfrac{[3t(\alpha + Q - \alpha Q) - \alpha(w_A - w_B)]^2}{18\alpha t} \\ E\pi_B^{s*} = \dfrac{[3t(\alpha + Q - \alpha Q) + \alpha(w_A - w_B)]^2}{18\alpha t}. \end{cases} \quad (15)$$

Note that now the equilibrium retail prices are the functions of the wholesale prices charged to both firms and that the equilibrium profits depend on the wholesale price difference.

In the dual-sourcing environment, we first consider the case in which the wholesale price offered to firm B is less than the alternative supply price (i.e., $w_B \leq s$). As in Proposition 2, the equilibrium retail prices and the expected profits for the two firms are

$$\begin{cases} p_A^* = \dfrac{2w_A + w_B}{3} + \dfrac{t}{3\alpha}[2 + \alpha + (1-\alpha)Q] \\ p_B^* = \dfrac{w_A + 2w_B}{3} + \dfrac{t}{3\alpha}[4 - \alpha - (1-\alpha)Q] \end{cases} \quad (16)$$

and

$$\begin{cases} E\pi_A^* = \dfrac{[[2 + \alpha + (1-\alpha)Q]t - \alpha(w_A - w_B)]^2}{18\alpha t} \\ E\pi_B^* = \dfrac{[[4 - \alpha - (1-\alpha)Q]t + \alpha(w_A - w_B)]^2}{18\alpha t} \\ \qquad - \dfrac{18\alpha t(1-\alpha)(s - w_B)(1-Q)}{18\alpha t}. \end{cases} \quad (17)$$

Similar to the proof of Proposition 3, we can verify that, compared with the single-sourcing benchmark, both firms increase their prices and both firms' expected profits increase. Therefore, the presence of firm B's dual sourcing also benefits firm A. The main insight from the baseline model continues to hold in the case of wholesale price discrimination. The major effect of wholesale price discrimination is that the equilibrium price difference,

$$p_B^* - p_A^* = \frac{w_B - w_A}{3} + \frac{2t(1-Q)(1-\alpha)}{3\alpha},$$

now depends on the difference between the wholesale prices. In the baseline model, firm B always charges a higher retail price than firm A. In contrast, given wholesale price discrimination, firm B might charge a lower retail price than firm A when it gets a more favorable wholesale price from the common supplier (i.e., $w_B < w_A - \frac{2t(1-Q)(1-\alpha)}{\alpha}$).

For the case in which the wholesale price offered to firm B is higher than the alternative supply price (i.e., $w_B > s$), we can similarly derive the equilibrium retail prices and equilibrium profits for the two firms, as in Proposition 4. The same driving force continues to exist, and the main insight about strategic sourcing derived in the baseline model continues to hold. In general, firm B has an incentive to order from the common supplier because doing so would put its rival at a disadvantage in the event of a supply shortage. With the common supplier's ability to price discriminate between the two firms, a more favorable price to firm A would discourage firm B from pursuing strategic sourcing because of the decrease in firm B's benefit, while a more favorable price to firm B would strengthen its incentive. Therefore, the common supplier can leverage price discrimination to influence firm B's incentive to pursue strategic sourcing.

5.3. Priority Allocation

Now we consider the scenario in which the two firms bid for the common supplier's priority allocation. By accepting an up-front fee (i.e., the priority fee) from one of the two firms, the common supplier agrees to fulfill that firm's order first in the event of a supply shortage. A natural method to use by the common supplier is standard sealed-bid second-price auctions, where the firm with the highest bid wins the auction and pays the second highest bid. For illustration purposes, we consider a simple case where $Q < \min\{q_A, q_B\}$; that is, the supply shortage is significant enough to warrant the bidding for priority allocation. We focus on strategic sourcing by looking at the $w > s$ case. Other cases can be similarly analyzed.

First, we consider the case when the single-sourcing firm has the priority allocation. In this case, the single-sourcing firm receives Q in the event of a supply shortage, by the assumption $Q < q_A$. Because $w > s$, the dual-sourcing firm has no incentive to order from the common supplier. Therefore, the two firms' optimization problems can be formulated as

$$\begin{cases} \max_{p_A} E\pi_{1A} = (p_A - w)\left[\alpha\left(\frac{1}{2} + \frac{p_B - p_A}{2t}\right) + (1-\alpha)Q\right] \\ \max_{p_B} E\pi_{2B} = (p_B - s)\left[\alpha\left(\frac{1}{2} + \frac{p_A - p_B}{2t}\right) + (1-\alpha)(1-Q)\right]. \end{cases}$$

Following an approach similar to that in the baseline model, we can derive the firms' optimal retail prices and expected profits:

$$\begin{cases} p_{1A}^* = \dfrac{s+2w}{3} + \dfrac{t[2+\alpha+2(1-\alpha)Q]}{3\alpha} \\ p_{2B}^* = \dfrac{2s+w}{3} + \dfrac{t[4-\alpha-2(1-\alpha)Q]}{3\alpha} \end{cases}$$

and

$$\begin{cases} E\pi_{1A}^* = \dfrac{[t(2+\alpha+2(1-\alpha)Q)-\alpha(w-s)]^2}{18\alpha t} \\ E\pi_{2B}^* = \dfrac{[t(4-\alpha-2(1-\alpha)Q)+\alpha(w-s)]^2}{18\alpha t}. \end{cases}$$

We next consider the case when the dual-sourcing firm has the priority. Note that, by ordering Q from the common supplier, the dual-sourcing firm in the event of a supply shortage can deplete the supply from the common supplier so that the single-sourcing firm has no supply to the market. Meanwhile, because $w > s$, the dual-sourcing firm accrues no additional benefit by ordering more than Q from the common supplier. Therefore, the dual-sourcing firm orders Q from the common supplier and the rest from the alternative supplier, based on our assumption that $Q \le q_B$. We formulate the two firms' optimization problems as

$$\begin{cases} \max_{p_A} E\pi_{2A} = \alpha(p_A - w)\left(\frac{p_B-p_A}{2t}+\frac{1}{2}\right) \\ \max_{p_B} E\pi_{1B} = (p_B - w)Q + (p_B - s) \\ \qquad\qquad \times\left[\alpha\left(\frac{1}{2}+\frac{p_A-p_B}{2t}-Q\right)+(1-\alpha)(1-Q)\right]. \end{cases}$$

Similarly, we can derive the firms' optimal retail prices and expected profits:

$$\begin{cases} p_{2A}^* = \dfrac{s+2w}{3} + \dfrac{t(2+\alpha)}{3\alpha} \\ p_{1B}^* = \dfrac{2s+w}{3} + \dfrac{t(4-\alpha)}{3\alpha} \end{cases}$$

and

$$\begin{cases} E\pi_{2A}^* = \dfrac{[t(2+\alpha)-\alpha(w-s)]^2}{18\alpha t} \\ E\pi_{1B}^* = \dfrac{[t(4-\alpha)+\alpha(w-s)]^2 - 18\alpha t Q(w-s)}{18\alpha t}. \end{cases}$$

It is well known that bidding its true value is each bidder's weakly dominant strategy in second-price auctions. In our case, the value of the priority allocation for each firm is the difference between the expected profit from receiving the priority allocation and the expected profit when not receiving it. Each firm's equilibrium bid can be derived as

$$\begin{cases} b_A = E\pi_{1A}^* - E\pi_{2A}^* \\ \quad = \dfrac{2(1-\alpha)Q[t(2+\alpha+(1-\alpha)Q)-\alpha(w-s)]}{9\alpha} \\ b_B = E\pi_{1B}^* - E\pi_{2B}^* \\ \quad = \dfrac{Q[2(1-\alpha)t(4-\alpha-(1-\alpha)Q)-\alpha(2\alpha+7)(w-s)]}{9\alpha}. \end{cases}$$

Note that as long as $(w - s)$ is not too large, both firms have incentives to submit positive bids. By simple algebra, we have

$$b_A - b_B = \frac{Q[\alpha(4\alpha+5)(w-s) - 4(1-\alpha)^2(1-Q)t]}{9\alpha}.$$

Therefore, if $(w-s) > (4(1-\alpha)^2(1-Q)t)/(\alpha(4\alpha+5))$, the single-sourcing firm wins the auction and has the priority in the common supplier's allocation; otherwise, the dual-sourcing firm wins the auction and has the priority. The intuition is as follows. When the price difference is small, the single-sourcing firm in general is in a disadvantageous position because its competitor has an alternative supplier, which limits the value of priority allocation to the single-sourcing firm. As a result, the dual-sourcing firm wins the auction. However, when the wholesale price from the common supplier is sufficiently higher than its alternative supplier, the benefit to the dual-sourcing firm from ordering from the cheap alternative is large enough to compensate for the loss from not securing the priority allocation (i.e., from preventing the single-sourcing firm from serving the market in the event of a supply shortage). Therefore, the single-sourcing firm wins the auction.

In sum, when both firms can bid for the common supplier's priority allocation, the dual-sourcing firm's incentive for strategic sourcing continues to exist (i.e., it has incentive to place a positive bid for the priority allocation). Moreover, when the price difference is not too large, the dual-sourcing firm even outbids the single-sourcing firm and actually pays a premium for the more expensive source of supply to deplete the single-sourcing firm's supply to the market in the event of a supply shortage.

6. Conclusion

In this study, we develop an analytical model to study the joint effects of both uncertain supply and retail competition on firms' sourcing strategies, price equilibrium, and expected profits. We find a number of insights concerning both the tactical benefits and strategic value of dual sourcing. Compared with the single-sourcing benchmark, we find that one firm's dual-sourcing strategy can create a win–win situation that leads to increased retail prices and expected profits for both firms. We also show that, under certain conditions, the dual-sourcing firm might strategically source from the more expensive common supplier even if an alternative, cheaper source of supply exists.

In fact, the dual-sourcing procurement strategy bears certain similarities to the concept of "taper integration" discussed in the strategic outsourcing literature. Following the original notion of Harrigan (1984) and a recent work by Rothaermel et al. (2006), taper integration is defined as the situation in which "a firm sources inputs externally from independent suppliers, as well as internally within the boundaries of the firm." The simultaneous pursuit of in-sourcing (i.e., vertical integration) and outsourcing of the taper integration strategy fits well with our dual-sourcing framework. For example, we can interpret firm A as a firm that does not have in-house production capability and therefore outsources its input production to the common supplier. Firm B, in contrast, has an in-house production capability with per unit production cost s, but it might prefer to outsource part or all of its production to the common supplier. In this context, we say firm A pursues outsourcing and firm B the taper integration strategy. Rothaermel et al. (2006) empirically demonstrate that the taper integration strategy can enhance a firm's product portfolio, new product success, and firm performance. Under the risk management framework, our model sheds new light on the competitive advantage and potential synergy created by this unique organizational form.

We can identify a number of opportunities for building on our work. Clearly, firms' reactions to supply uncertainty critically depend on the allocation rule that the common supplier uses to ration orders. In our current framework, we consider the uniform rationing rule. Other allocation rules, such as proportional allocation and linear allocation, although prone to order manipulation, are also used in practice. A comprehensive comparison of different allocation rules is an area for future research. In addition, in this study, we consider price competition for horizontally differentiated products. In particular, we consider a model with price commitment by the retail firms. Another interesting direction to explore is to consider quantity competition, which can be modeled, for example, as a Cournot game. The extent to which our main insights can be carried over to the Cournot game setting is unclear. The comparison between price competition and quantity competition deserves future study.

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Supporting Information

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

Appendix S1. Proofs.