Leader-Based Collective Bargaining: Cooperation Mechanism and Incentive Analysis

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Abstract

We study a leader-based collective bargaining (LCB), under which a leading buyer (leader) and a following buyer (follower) form an alliance to jointly purchase a common component from a supplier. Although the leader and the follower cooperate in their component purchase, they compete in selling their end products. We first analyze the most common and simple form of LCB, the equal price LCB, under which the follower pays to the leader the same wholesale price that the leader obtains from his negotiation with the supplier. We compare each buyer's profit under the equal price LCB with the benchmark where each buyer purchases separately from the supplier. We find that although the alliance might obtain a lower wholesale price and although the leader is always better off under the equal price LCB, the follower can be worse off if the competition intensity of the leader's and follower's products is within an intermediate region. We identify a competition effect resulting from the equal price LCB that can place the follower at a disadvantage in the competition. This finding implies that the equal price LCB might not be sustainable in practice. In view of this limitation, we investigate an alternative form of LCB, the fixed price LCB, under which the follower pays a fixed price to the leader regardless of the wholesale price the leader obtains from the supplier. We show that the fixed price LCB benefits not only the leader but also the follower, compared with separate purchases, which implies that the fixed price LCB always achieves a win-win outcome for the buyers. Our analysis further shows that even the supplier might benefit from this form of LCB.

Keywords: leader-based collective bargaining; cooperative game; generalized Nash solution

1 Introduction

Collective bargaining, by which two or more competing buyers form an alliance to jointly purchase goods or services from their suppliers, has become a frequently used cooperation strategy (King 2013). The Australian Competition and Consumer Commission (ACCC) acknowledges that public interest can be served and small businesses can be protected by collective bargaining (Nagarajan 2013). The use of collective bargaining by non-profit organizations for their purchases has been well documented (European Commission 2008), and collective bargaining is now increasingly being used by firms in private sectors, such as construction, healthcare, automobile, logistics, retailing, and telecommunications, to jointly purchase raw materials, components, professional services, and equipment (Komatsu Corporate Communications 2002, Kaufmann 2008, Telekom 2011, ACCC 2011, Hu et al. 2012, Nagarajan 2013).

Among various forms of collective bargaining, two are the most popular in practice (ACCC 2011): the *representative-based collective bargaining (RCB)* alliance, which relies on a separate entity (e.g, an industry association) to manage and coordinate the joint purchases, and the *leader-based collective bargaining (LCB)* alliance, in which one of the alliance members (the leader) is given the authority to carry out the purchase activities on behalf of the other members (the followers). RCB has often been used by large buyers to form long-term cooperations (e.g., the joint procurement of automobile components between major car manufacturers). Meanwhile, LCB is less formal but more flexible, as it usually does not require establishing and operating a separate firm/association.[1] In recent years, LCB has received increasing attention from both public and private sectors because of its flexibility and low operating costs (Birch 2001, Schotanus and Telgen 2007, and European Commission 2008). For example, Mai Wiru Corporation in Australia has bargained with suppliers on behalf of six local competitors since 2010. Mai Wiru is responsible for drafting and implementing the internal purchasing agreement, Mai Wiru Policy, which is signed by the other buyers.[2] Another example is R J Nuss Removals Pty Ltd. Australia, authorized by five competing companies as the leader to negotiate with the monopolistic rail linehaul freight services provider—Pacific National. The companies need these professional services to finish their own removal services. Since 2008, Nuss has successfully coordinated the alliance and obtained the formal approval of the ACCC.[3]

[1] Although our study focuses on LCB, we also provide in Online Appendix a quantitative comparison between RCB and LCB in our context.

[2] ACCC public registers: Mai Wiru Regional Stores Council Aboriginal Corporation-Collective Bargaining Notifications-CB00150-CB00155.

[3] ACCC public registers: R J Nuss Removals Pty Ltd & Ors–Collective Bargaining Notification–CB00007-CB00283.

Despite many documented practices of LCB, prior literature has rarely investigated this specific form of buyer cooperation. A critical question for the sustainability of LCB is how the collective bargaining profits should be shared among the buyers in the alliance (Schotanus et al. 2010). In practice, this distribution is often determined through an internal purchasing agreement between the leader and the followers, which is referred to as the collective arrangement (Schotanus et al. 2008, ACCC 2011, Nagarajan 2013). According to Schotanus (2007), many documented alliances use the equal price purchasing agreement, under which all the participants receive the same negotiated wholesale price charged by the suppliers. Although this mechanism is very convenient to use, its performance is not fully understood. Whether more effective mechanisms exist is also unclear.

In this paper, we aim to provide a thorough investigation of LCB. To that end, we consider two downstream buyers who purchase a common component from a single supplier to make their end products that compete in the downstream market. We first investigate the setting where the two buyers form an LCB under the equal price mechanism and thus pay the same wholesale price that the leader obtains from his negotiation with the supplier. Interestingly, we find that although the leader is always better off, the follower can be worse off under this cooperation mechanism if the competition intensity between the leader's and follower's products is in an intermediate region. As a result, the equal price LCB can be unsustainable. To explain this result, we identify two driving forces: the bargaining power effect and the competition effect. Intuitively, if the leader is a stronger bargainer than the follower (which is often the case in the LCB alliances in practice), then the wholesale price that the leader can obtain from the negotiation would be lower than what the follower can obtain when negotiating separately with the supplier. We call this positive effect the bargaining power effect. However, more subtly, the equal price LCB can change the balance of the competition between the two buyers. Specifically, the equal price LCB can put the follower in a disadvantageous position in the competition because his influence on the wholesale price can be weakened. As such, the leader will be able to sell more of his products while the follower will sell less under the equal price LCB, compared to the case under separate procurement. Such a competition effect, which hurts the follower, is the strongest when the competition intensity of their products is in an intermediate region.

In view of this potential limitation of the equal price mechanism, we explore an alternative fixed price mechanism for LCB formation. In particular, under this scheme, the follower pays a fixed transfer price to the leader, regardless of the wholesale price that is determined in the negotiation with the supplier. We find that LCB is always sustainable under this mechanism. The fixed price LCB can benefit not only the leader but also the follower compared to separate procurement—a win-win outcome for the buyers. Therefore, this fixed price mechanism can likely facilitate LCB formation in practice.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the model and analyzes the benchmark case in which each buyer purchases separately from the supplier. We analyze the equal price LCB in Section 4 and the fixed price LCB in Section 5. Section 6 discusses three extensions, and we conclude in Section 7.

2 Literature Review

Our work is related to the stream of literature that studies group buying. Anand and Aron (2003) provide an excellent survey of the online group buying research. This literature generally focuses on how a seller can design an appropriate pricing mechanism with volume discounts in anticipation of the potential responses from the buyers. More recently, Chen et al. (2007) study group buying auction and compare it with the fixed price mechanism in terms of the seller's profitability. Chen et al. (2010) investigate two common group buying mechanisms under quantity discounts: the uniform price mechanism, under which all buyers pay the same discounted price, and the proportional mechanism, under which the buyers that order large quantities enjoy lower prices. Interestingly, they find that group buying at times might not be sustainable under either mechanism. They then propose an IF-VCG mechanism based on second-price auctions to facilitate group buying. Chen and Roma (2011) study a decentralized supply chain in which a supplier sells to two competing retailers. They consider both linear and nonlinear demand curves to investigate the benefits of group buying when the retailers are either symmetric or asymmetric with respect to their market base and/or efficiency. Although these studies also focus on joint purchases, LCB has a fundamental difference from group buying. For LCB, the buyers first form an alliance and then the leader negotiates with the supplier for the purchase price. In contrast, for group buying, the seller first designs a price scheme and then the buyers decide on their participation in the group purchase. As such, our study can enrich the joint purchase literature by analyzing this special cooperative procurement mechanism applied in practice.

Another related stream of research investigates the value of joint procurement, inventory pooling, and exclusive purchase commitments. For instance, Chen (2009) studies a scenario where a group of retailers considers jointly procuring a product from a common supplier and pools their inventories to benefit both from the quantity discounts and from the hedging of demand uncertainty. He shows that an equilibrium profit allocation mechanism exists among the retailers to achieve joint procurement. In contrast, Hu et al. (2013) investigate a setting with asymmetric information between a powerful supplier and a group of buyers. They show that if the supplier can offer a take-it-or-leave-it menu of contracts, then a joint purchase from the supplier might hurt the buyers because it can help the supplier to extract information rents. Chen and Li (2013) investigate the effect of exclusive purchase commitments from buyers on sellers' quality improvement efforts. They find that an exclusive purchase commitment can benefit the buyers only if the intrinsic qualities of the products offered by the sellers are similar. Our study is different, considering how joint procurement through LCB might affect the buyers' bargaining power and their competitive advantages.

Our work also follows the recent research that uses the cooperative bargaining framework to study supply chain problems in the environment where the traditional take-it-or-leave-it contract approach is less appropriate (Lovejoy 2010). For instance, Nagarajan and Bassok (2008) study an assembling system in which a single manufacturer buys components from multiple suppliers. They identify the conditions under which the supply chain parties might form stable coalitions so as to enhance their bargaining powers. Leng and Parlar (2009) focus on a three-level supply chain in which a cooperative game is studied to find a fair allocation method for sharing the cost savings among the supply chain parties. Feng and Lu (2012, 2013a,b) use the generalized Nash bargaining (GNB) framework to investigate the outsourcing decisions and the effects of contract formats in competitive supply chains. We refer the readers to Bernstein and Nagarajan (2012) for an extensive review of the papers in this stream.

3 The Model and Benchmark

We first describe the model in Section 3.1 and then analyze a benchmark in Section 3.2.

3.1 Model Description

We consider a supply chain setting where two downstream buyers (indexed by $i = 1, 2$) source a critical component from a common upstream supplier (labeled by s) to make their products. The buyers' end products are potentially substitutable. We assume the inverse demand function for buyer i's product as follows: $p_i = a - q_i - bq_j$, $i, j = 1, 2, i \neq j$, where p_i is the market price for product i, and q_i and q_j are the selling quantities of the two products. a represents the market size and $b \in [0, 1]$ measures the degree of competition intensity. When $b = 0$, the two products are independent, and when $b = 1$, the two products are perfect substitutes. Similar settings have been used in the supply chain literature (e.g., Cachon and Harker 2002, Feng and Lu 2012). To focus on the strategic driving forces, we assume away the factors that tend to benefit joint procurement, such as the economies of scale effect in contracting, production, and logistics. We assume that the supplier incurs a constant production cost c per unit for the component, while the buyers' production and selling costs are normalized to zero. This market setting and the supply chain parties' characteristics are common knowledge.

The buyers can choose to procure the component separately from the supplier, or they can form a leader-based alliance to collectively bargain with the supplier (LCB). In either case, we use the generalized Nash bargaining framework (GNB) to model the contracting process among the supply chain parties. This bargaining framework has been increasingly used in the supply chain literature for a cooperative and more balanced allocation of the surplus (Bernstein and Nagarajan 2012). Let buyer i's bargaining power relative to the supplier be $\alpha_{is} \in (0, 1)$, and accordingly, the supplier's bargaining power is $1 - \alpha_{is}$. We further use $\alpha_{ij} \in (0, 1)$ to denote the bargaining power of buyer i relative to buyer j. Finally, for simplicity, we normalize the profits that the supply chain parties can obtain from their outside options to zero. This assumption is relaxed in an extension study provided in Online Appendix.

3.2 The Benchmark: Separate Procurement

In this subsection, we study a benchmark case in which the buyers separately decide their procurement quantity q_i and separately negotiate the wholesale price w_i with the supplier.[4] Clearly, if both negotiations succeed, buyer i's profit follows:

$$\pi_i(q_i, q_j, w_i) = (a - q_i - bq_j - w_i)q_i,$$

and the supplier's profit follows:

$$\pi_s(q_i, q_j, w_i, w_j) = (w_i - c)q_i + (w_j - c)q_j.$$

To solve this benchmark case, we adopt the so-called Nash-Nash solution concept commonly used in prior literature (see, e.g., Davidson 1988, Dukes et al. 2006, Horn and Wolinsky 1988, Feng and Lu 2012, 2013a,b), which assumes that the two bilateral negotiations are independent and take

[4]The procurement quantity can be decided either before or during the price negotiation, which leads to the same outcome because of the cooperative feature of the Nash bargaining framework. Detailed discussions on this point can be found in the bargaining literature (see, e.g., Nash 1951, Roth 1979, and Nagarajan and Sosic 2008).

place simultaneously[5], renegotiation is not permitted, and in each negotiation, the disagreement for the buyer is his reservation profit from the outside option, while the disagreement point for the supplier is his profit from the other negotiation, assuming it succeeds.[6] This framework requires that no information exchange between the two negotiation processes occurs even if they involve the same supplier. This situation is not uncommon in practice. Suppliers have confidentiality obligations to protect the transaction information of their clients. When the business involves competing clients, a supplier might even need to set up independent units to negotiate and execute the transactions. We make this assumption for our benchmark case. Specifically, in our context, the corresponding unit in one negotiation–whether that of the buyer or the supplier–needs to conjecture the order quantity and the wholesale price of the other negotiation. The goal of the supplier's two independent units is to maximize the supplier's total profit. Note that in a Nash-Nash equilibrium, the conjectures held by the supply chain parties are consistent with their actual decisions. We use "$\sim$" to indicate the conjectured variables. Based on the GNB framework, the bargaining problem for the wholesale price can be formulated as follows:

$$\max_{w_i} \pi_i(q_i, \widetilde{q}_j, w_i)^{\alpha_{is}}[\pi_s(q_i, \widetilde{q}_j, w_i, \widetilde{w}_j) - (\widetilde{w}_j - c)\widetilde{q}_j]^{1-\alpha_{is}}.$$

Lemma 1. *The wholesale prices under the Nash-Nash bargaining solution follow:* $w_i(q_i, \widetilde{q}_j) = \alpha_{is}c + (1 - \alpha_{is})(a - q_i - b\widetilde{q}_j)$*, under which the profits of the buyers are* $\pi_i(q_i, \widetilde{q}_j, w_i(q_i, \widetilde{q}_j)) = \alpha_{is}(a - q_i - b\widetilde{q}_j - c)q_i$*, for* $i, j = 1, 2, i \neq j$*.*

All proofs are provided in Online Appendix. For each buyer, the wholesale price follows a weighted average of the supplier's production cost and the product's market price based on their bargaining power. Clearly, a lower market price directly implies a lower wholesale price. Therefore, when a buyer increases his quantity, not only the market price but also the wholesale price decreases. Because of competition, a product's market price and thus the wholesale price decrease in the other product's (conjectured) quantity, depending on the competition intensity b. Hence, in equilibrium, one buyer's quantity decision influences not only his own product's prices but also those for the other buyer. Given the characterized wholesale price, we can see that buyer i's profit is a proportion, based on his bargaining power, of the total surplus that can be obtained from the sales of his product. Specifically, if buyer i's bargaining power goes to one, he can push the wholesale price

[5]An extension where the two buyers negotiate with the supplier sequentially is discussed in Online Appendix.

[6]Under the Nash bargaining framework, the two negotiations always succeed in equilibrium. Therefore, the purpose of the latter two assumptions is simply to justify the setting for the disagreement point.

down to the supplier's production cost and obtain the whole surplus. At the other extreme, if his bargaining power goes to zero, the wholesale price goes to the market price and buyer i obtains zero profit.

In the first stage, the two buyers decide their order quantities based on their conjectures of the other buyer's order quantity and the subsequent bargaining outcome. That is, they simultaneously solve: $q_i^S = \arg\max_{q_i} \pi_i(q_i, \widetilde{q}_j, w_i(q_i, \widetilde{q}_j)),\ i,j = 1,2,\ i \neq j$. A Nash equilibrium holds if the conjectures coincide with the actual optimal decisions; i.e., $q_i^S = \widetilde{q}_i$, $i = 1,2$. This case leads to the following equilibrium outcomes.

Proposition 1. *Under separate procurement, the equilibrium quantities, the wholesale prices and the profits of the supply chain parties follow:* $q_i^S = \frac{a-c}{2+b}$, $w_i^S = c + (1-\alpha_{is})\frac{a-c}{2+b}$, $\pi_i^S = \alpha_{is}\left(\frac{a-c}{2+b}\right)^2$, $i = 1,2$, *and* $\pi_s^S = (2-\alpha_{1s}-\alpha_{2s})\left(\frac{a-c}{2+b}\right)^2$, *respectively.*

Given the buyers' profit functions characterized in Lemma 1, their quantity decisions follow the classical Cournot game. Hence, we can notice from Proposition 1 that the total supply chain surplus does not achieve the first-best maximum under this separate procurement equilibrium. In particular, for an integrated supply chain, the optimal production quantities of the two products would be $q_i^I = \frac{a-c}{2(1+b)}$, based on which the total supply chain surplus would be $\pi_{sc}^I = \frac{(a-c)^2}{2(1+b)}$. Clearly, the buyers under separate procurement do not consider the effect of their quantity on the other buyer's market price and thus produce more than they would in the integrated solution. This intuition is helpful for the comparison between the outcomes of the benchmark case and the LCBs.

4 The Equal Price LCB

Under the equal price LCB, the buyers pay the same wholesale price to the supplier. For its simplicity and fairness,[7] most of the LCB practices adopt this agreement. This section aims to gain a better understanding of its performance. In our context, the two buyers first independently decide their procurement quantities q_i and q_j. Then, suppose buyer i is the designated leader who negotiates the wholesale price w with the supplier. If they reach an agreement, buyer i pays $w(q_i + q_j)$ to the supplier and gives q_j units to buyer j for a transfer payment wq_j. In contrast, if the negotiation breaks down, then no procurement would occur and all the supply chain parties would earn zero profit. An important element of the LCB alliances in practice is the members' commitment, which is often referred to as a collective boycott (Nagarajan 2013) or a group buying

[7] Schotanus(2007) shows that the equal price LCB satisfies most properties of fairness defined by prior literature.

commitment (Chae and Heidhues 2004, Chen and Li 2013). As such, *"collective bargaining increases the bargaining power of small businesses because it makes possible a credible threat of a collective boycott"* (Nagarajan 2013). A large-scale industry survey conducted by Schotanus et al. (2010) identifies the "enforcement of cooperation" as a critical factor that influences the effectiveness of a collective bargaining alliance. One way to enforce commitment is through an internal agreement to assign all negotiating and purchasing power to the leader. Hence, in our context, we assume that after a LCB is formed, the leader is fully in charge of the negotiation, and the buyers agree not to buy the component from the supplier separately if the negotiation between the leader and the supplier fails. The case of weaker LCB alliances that always have the separate procurement option available is discussed in Section 6.1.

4.1 The Equal Price LCB Equilibrium

In the following, we derive the equilibrium for the equal price LCB. Given q_i and q_j, the leader i's profit can be written as follows:

$$\pi_i(q_i, q_j, w) = (a - q_i - bq_j - w)q_i,$$

and the supplier's profit follows:

$$\pi_s(q_i, q_j, w) = (w - c)(q_i + q_j).$$

By backward induction, the leader negotiates the wholesale price w with the supplier in the second stage. Their problem can be formulated as:

$$\max_w [(a - q_i - bq_j - w)q_i]^{\alpha_{is}} [(w - c)(q_i + q_j)]^{1-\alpha_{is}}.$$

Because the Nash product is log-concave, the following results can be obtained.

Lemma 2. *Given q_i and q_j, the bargaining outcome of the wholesale price between the leader and the supplier follows:*

$$w(q_i, q_j) = \alpha_{is}c + (1 - \alpha_{is})(a - q_i - bq_j),$$

under which the leader's profit is $\pi_i(q_i, q_j, w(q_i, q_j)) = \alpha_{is}(a - q_i - bq_j - c)q_i$ and the follower's profit is $\pi_j(q_i, q_j, w(q_i, q_j)) = [a - q_j - bq_i - \alpha_{is}c - (1 - \alpha_{is})(a - q_i - bq_j)]q_j$.

From the above lemma, we can notice that both the wholesale price and the leader's profit function have the same form as those under separate procurement (see Lemma 1). In other words, under the equal price LCB, whether the follower's order quantity is included does not affect the negotiation outcome between the leader and the supplier. This is mainly because the leader does not gain any extra profit from jointly procuring the follower's quantity, when the follower simply pays the leader for what the supplier charges. Hence, their negotiation focuses only on the allocation of the surplus from the leader's sales.

For the follower, however, given that he is now charged for the same wholesale price that the leader gets from the supplier, his profit function clearly differs from what it would be under separate procurement, and his bargaining power becomes irrelevant. Furthermore, even though the follower's order quantity can still influence the wholesale price, its influence is weaker than that of the leader's quantity. Notice that the leader's quantity has a direct effect on the market price of his product, while the follower's quantity influences it only through the indirect substitution effect, with a factor b. This observation is useful in understanding the equilibrium outcome.

In the first stage, the two buyers independently decide their order quantities in anticipation of the outcome of the subsequent negotiation between the leader and the supplier. That is, they solve: $\max_{q_i} \pi_i(q_i, q_j, w(q_i, q_j))$, $i = 1, 2, i \neq j$, simultaneously.

Proposition 2. *(a) Under the equal price LCB, the equilibrium order quantities of the leader and the follower are:* $q_i^L = \frac{(2(1-b)+b\alpha_{is})(a-c)}{(4+b)(1-b)+3b\alpha_{is}}$ *and* $q_j^L = \frac{(1-b+\alpha_{is})(a-c)}{(4+b)(1-b)+3b\alpha_{is}}$*, respectively, and the wholesale price is:* $w^L = c+(1-\alpha_{is})\frac{(2(1-b)+b\alpha_{is})(a-c)}{(4+b)(1-b)+3b\alpha_{is}}$*, under which the profits of the three supply chain parties are:* $\pi_i^L = \alpha_{is}\left(\frac{(2(1-b)+b\alpha_{is})(a-c)}{(4+b)(1-b)+3b\alpha_{is}}\right)^2$, $\pi_j^L = \frac{(1-b+\alpha_{is})[(1-b)^2+\alpha_{is}(1-b^2+b\alpha_{is})](a-c)^2}{[(4+b)(1-b)+3b\alpha_{is}]^2}$*, and*
$\pi_s^L = \frac{(1-\alpha_{is})(2(1-b)+b\alpha_{is})[(1-b+\alpha_{is})+2(1-b)+b\alpha_{is}](a-c)^2}{[(4+b)(1-b)+3b\alpha_{is}]^2}$*, respectively.*
(b) $q_i^L \geq q_i^S$, $q_j^L \leq q_j^S$, *and* $q_i^L + q_j^L \leq q_j^S + q_j^S$.

Proposition 2 characterizes the equal price LCB equilibrium. Interestingly, we can see that, compared to separate procurement, the leader now sells more units, while the follower sells less. The intuition of this outcome is tied to the effect of the equal price LCB on the competition. Lemma 2 has shown that under the equal price LCB, the two buyers receive the same wholesale price $w(q_i, q_j) = \alpha_{is}c + (1 - \alpha_{is})(a - q_i - bq_j)$. We can readily observe that an increase of the leader's quantity q_i reduces the wholesale price more than an increase of the follower's quantity q_j does. This change can shift the balance of the competition. In fact, the leader now has more incentives to increase the output, while the follower is compelled to reduce his output. Another consequence of this change is that the buyers' total output becomes lower than their total output under separate procurement. We call this effect the competition effect of the equal price LCB.

4.2 Performance Comparison

The results of Proposition 2 enable us to assess the performance of the equal price LCB compared to the performance of the separate procurement scenario. In the following, we present the comparisons from the perspectives of the leader, the follower, and the overall supply chain, respectively.

The Leader's Perspective: Comparing the leader's profit under the equal price LCB with his profit under separate procurement, we obtain the following proposition.

Proposition 3. *The leader is always better off under the equal price LCB; i.e.,* $\pi_i^L \geq \pi_i^S$.

Although the result that the leader can benefit from LCB is likely to be anticipated, it does not directly stem from the larger order quantity that he negotiates with the supplier, a seemingly intuitive reason. In fact, as Lemma 2 has shown, simply adding the follower's order quantity to the negotiation does not change the negotiated wholesale price for the leader. To understand this result, recall our discussion about the competition effect following Proposition 2. Namely, when the two buyers receive the same wholesale price that the leader negotiates with the supplier, the leader has an advantage in the quantity competition against the follower because a change in his order quantity can shift the wholesale price more than does a change in the follower's quantity. As a consequence, the follower's weakened position in the competition results in a larger quantity being sold by the leader, which increases the latter's profit compared to the case of separate procurement.

The Follower's Perspective: For the follower, the situation is much subtler. On the one hand, the previous discussion on the competition effect clearly indicates that the equal price LCB puts the follower in a disadvantageous position in the competition against the leader. On the other hand, the leader can be a stronger bargainer relative to the supplier, which often is the reason a buyer joins LCB as a follower in practice. That is, joining LCB potentially renders the follower a lower wholesale price than he could negotiate with the supplier separately. We call this effect the bargaining power effect. How these two effects influence the follower's profit is not immediately clear. In the following, we present two results, focusing on the scenario in which $\alpha_{js} \leq \alpha_{is}$.

Proposition 4. *(a) Given the other parameters, there exists a threshold* $\underline{\alpha}_{js}$ *such that the follower is better off under the equal price LCB, i.e.,* $\pi_j^L \geq \pi_j^S$, *iff* $\alpha_{js} \leq \underline{\alpha}_{js}$.

(b) For any given α_{is}, α_{js}, *the follower is either always better off* ($\pi_j^L \geq \pi_j^S$) *under the equal price LCB for any* b, *or worse off* ($\pi_j^L < \pi_j^S$) *iff* $b \in (\underline{b}, \bar{b})$ *whenever such an interval exists.*

Proposition 4(a) implies that the follower is better off under the equal price LCB if and only if his bargaining power relative to the supplier is weak. In such a situation, the wholesale price that the leader can obtain from his negotiation with the supplier will be much more favorable than the price the follower could negotiate by himself. Hence, the benefit from the bargaining power effect dominates the loss from the competition effect.

Proposition 4(b) focuses on the competition intensity factor. It indicates that the equal price LCB is more likely to benefit the follower when the competition intensity between them is either low or high. In particular, when b is small, one buyer's quantity has little affect on the other buyer's market price either under separate procurement or under the equal price LCB. Hence, joining the equal price LCB does not place the follower in a severely disadvantaged position, while he can gain from teaming up with a stronger bargainer to access a lower wholesale price. That is, a small b implies the dominance of the bargaining power effect over the competition effect for the follower. The result is more intriguing when b is large, which seems to imply strong competition. However, from the wholesale price $w(q_i, q_j) = \alpha_{is}c + (1 - \alpha_{is})(a - q_i - bq_j)$ characterized in Lemma 2 under the equal price LCB, we can see that when b is large, the influence of the two buyers' quantities on the wholesale price is similar. That is, the buyers can obtain similar gains by increasing their quantities, and thus, the leader does not gain a significant advantage in the competition against the follower compared to the case of separate procurement. In other words, the competition effect resulting from the equal price purchasing agreement under LCB is in fact weak when b is large, which allows the follower to benefit from the equal price LCB. When b is in an intermediate region, the competition effect is the strongest, and thus joining the equal price LCB can make the follower worse off, even though the leader has greater bargaining power.

The Supply Chain's Perspective: Besides the results for the leader and the follower, it is also interesting to investigate the effect of the equal price LCB on the overall supply chain performance.

Proposition 5. *There exists $\hat{b}$ such that the whole supply chain is better off under the equal price LCB, i.e., $(\pi_i^L + \pi_j^L + \pi_s^L) \geq (\pi_i^S + \pi_j^S + \pi_s^S)$, iff $b \geq \hat{b}$.*

Proposition 5 shows that the equal price LCB benefits the supply chain if and only if the competition intensity factor is above a certain threshold. To understand this result, it is useful to recall our discussion following Proposition 1. When the buyers make their quantity decisions under the separate procurement scenario, they do not take into account the external effect of their quantity on the other buyer's profit. As a result, they overproduce compared to the amount produced for the integrated supply chain, and this distortion increases in competition factor b. (When $b = 0$, there is no competition, and the total output under separate procurement coincides with the integrated solution.) Meanwhile, Proposition 2 reveals that the competition effect resulting from the equal price purchasing agreement leads to a smaller total supply chain output under LCB than under the separate procurement scenario. This downward "correction" might make the supply chain either more or less efficient. In particular, when b is large, this downward "correction" results in a total supply chain output closer to the integrated solution and the supply chain thus becomes more efficient under the equal price LCB. However, when b is small, it can instead lead to a downward distortion of the total supply chain output and thus make the supply chain less efficient.

This analysis has an intriguing implication: Despite the popularity of the equal price LCB in practice, it might not be as beneficial as anticipated for the supply chain parties.[8] In fact, the imbalanced competition positions between the buyers surprisingly might lead to a smaller profit for the follower and can also undermine the overall supply chain performance. Clearly, if the follower is rational, he would deduce the harmful outcome of joining the LCB in such scenarios, and the LCB would not be formed in the first place. The observation of this competition effect suggests the question of whether a more efficient transfer price agreement exists that can always make LCB a "win-win" strategy and thus facilitate its implementation. This question is explored in the following section.

5 The Fixed Price LCB

From the previous analysis, we notice that the potential amplification of market competition is caused by the dependence of the transfer price on the subsequent negotiation between the leader and the supplier, which can lead to imbalanced incentives between the buyers. Furthermore, a "win-win" transfer price agreement, if it exists, needs to guarantee that both buyers obtain no less than what they would get under separate procurement. This goal motivates us to search for alternative transfer price agreements that can incorporate the buyers' reservation profits and can also disentangle the follower's procurement cost from the subsequent negotiation between the leader and the supplier. To answer the question of whether such purchasing agreements exist, we focus on fixed transfer prices and adopt the Nash bargaining framework to model the two buyers' transaction process in the first stage of LCB formation. Specifically, the two buyers first decide their procurement quantities q_i and q_j and then negotiate a fixed transfer price t per unit that

[8] We have assumed away other factors in our analysis that tend to benefit joint procurement (e.g., the economies of scale effect). To incorporate such factors likely would make the equal price LCB more beneficial.

the follower pays to the leader when the component is delivered. If the negotiation between the buyers fails to reach an agreement, they separately procure the component from the supplier. In contrast, if their negotiation reaches an agreement, then the designated leader is authorized with all negotiating and purchasing power, and the buyers are committed not to separately procure the component from the supplier, regardless of the subsequent negotiation outcome. That is, the leader, buyer i, negotiates the wholesale price w with the supplier to jointly procure $q_i + q_j$ units of the component. If this second stage negotiation breaks down, all the supply chain parties earn zero profit. (The case for the weaker LCB which always includes the option of separate purchases is discussed in Section 6.1.) Otherwise, the leader pays $w(q_i + q_j)$ to the supplier, the component is delivered, and the follower pays the leader tq_j for his portion, independent of w. To model the contracting processes in the two stages, we assume that buyer i's bargaining power relative to buyer j is $\alpha_{ij} \in (0, 1)$ and that his bargaining power relative to the supplier remains at α_{is}.

5.1 The Fixed Price LCB Equilibrium

In the following, we derive the fixed price LCB equilibrium. Under this fixed transfer price agreement, we can formulate the profit functions of the leader (buyer i) and the follower (buyer j) as:

$$\pi_i(q_i, q_j, w, t) = (a - q_i - bq_j - w)q_i + (t - w)q_j \quad \text{and} \quad \pi_j(q_i, q_j, t) = (a - q_j - bq_i - t)q_j,$$

and the supplier's profit function as:

$$\pi_s(q_i, q_j, w) = (w - c)(q_i + q_j).$$

By backward induction, we first analyze the negotiation between the leader and the supplier:

$$\max_{w} \quad [\pi_i(q_i, q_j, w, t)]^{\alpha_{is}} [\pi_s(q_i, q_j, w)]^{1-\alpha_{is}}.$$

Maximizing the above Nash product results in the following lemma.

Lemma 3. *Given q_i and q_j, under the fixed price LCB, the bargaining outcome of the wholesale price between the leader and the supplier follows:*

$$w(q_i, q_j, t) = \alpha_{is}c + (1 - \alpha_{is})\frac{(a - q_i - bq_j)q_i + tq_j}{q_i + q_j},$$

under which the leader's profit is $\pi_i(q_i, q_j, w(q_i, q_j, t), t) = \alpha_{is}[(a - q_i - bq_j - c)q_i + (t - c)q_j]$.

Notice that under this fixed transfer price agreement, once t is decided, the follower's profit is not affected by the subsequent negotiation between the leader and the supplier. Therefore, the negotiated wholesale price does not have any indirect competition effect. On the other hand, under this fixed transfer price agreement, the leader can make extra profit from the follower's transfer payment, which the supplier takes a share through the wholesale price according to their bargaining power. As a result, we can observe from Lemma 3 that the leader's profit function contains an additional term, $\alpha_{is}(t - c)q_j$, compared to the previous cases. Clearly, with t appearing in both the leader's and the follower's profit functions, their quantity decisions can be influenced by this transfer price. In the following, we set up a generalized Nash product over the buyers' surplus, relative to separate procurement, to search for a "win-win" outcome.

$$\max_t [\pi_i(q_i, q_j, w(q_i, q_j, t), t) - \pi_i^S]^{\alpha_{ij}} [\pi_j(q_i, q_j, t) - \pi_j^S]^{1-\alpha_{ij}}.$$

Lemma 4. *Given* q_i *and* q_j*, the optimal transfer price follows:*

$$t(q_i, q_j) = \alpha_{ij}((a - q_j - bq_i)q_j - \pi_j^S)/q_j + (1 - \alpha_{ij})(\pi_i^S/\alpha_{is} - ((a - q_i - bq_j)q_i - c(q_i + q_j)))/q_j,$$

under which the leader's and follower's profits, denoted by $\pi_i(q_i, q_j)$ *and* $\pi_j(q_i, q_j)$*, respectively, are*

$$\begin{aligned}
\pi_i(q_i, q_j) &= \alpha_{is}\alpha_{ij}((a - q_i - bq_j - c)q_i + (a - q_j - bq_i - c)q_j - \pi_j^S) + (1 - \alpha_{ij})\pi_i^S, \text{and} \\
\pi_j(q_i, q_j) &= (1 - \alpha_{ij})((a - q_i - bq_j - c)q_i + (a - q_j - bq_i - c)q_j) + \alpha_{ij}\pi_j^S - (1 - \alpha_{ij})\pi_i^S/\alpha_{is}.
\end{aligned}$$

Lemma 4 solves for a unique transfer price that maximizes the Nash product of the two buyers' joint surplus. It follows a weighted average of the follower's marginal surplus and the leader's marginal deficit relative to their reservation profits. To build intuition about this closed-form expression, consider the extreme cases. In particular, when $\alpha_{ij} = 1$, this closed-form expression for $t(q_i, q_j)$ implies that the leader can demand a transfer price that captures all of the follower's surplus. In contrast, when $\alpha_{ij} = 0$, then the follower has full bargaining power relative to the leader, and this closed-form expression implies that the latter can only ask for a transfer price that warrants him the reservation profit.

In the first stage, the buyers decide their procurement quantities in anticipation of the outcomes of the subsequent negotiations. That is, they solve: $\max_{q_i} \pi_i(q_i, q_j)$ and $\max_{q_j} \pi_j(q_i, q_j)$, simultaneously. This results in a Nash equilibrium as presented below.

Proposition 6. *Under the fixed price LCB, the equilibrium quantities are:* $q_i^L = q_j^L = \frac{a-c}{2(1+b)}$*, and the wholesale price is:* $w^L = \alpha_{is}c + (1-\alpha_{is})(a - q_i^L - bq_j^L + t(q_i^L, q_j^L))/2$*, under which the profits of the supply chain parties follow:* $\pi_i^L = (1-\alpha_{ij})\pi_i^S + \alpha_{ij}\alpha_{is}(\frac{(a-c)^2}{2(1+b)} - \pi_j^S)$*,* $\pi_j^L = \alpha_{ij}\pi_j^S + (1-\alpha_{ij})(\frac{(a-c)^2}{2(1+b)} - \frac{\pi_i^S}{\alpha_{is}})$*, and* $\pi_s^L = \frac{(a-c)^2}{2(1+b)} - \pi_i^L - \pi_j^L$*, respectively.*

5.2 Performance Comparison

Based on the above results, we can readily assess the performance of this fixed price LCB.

Proposition 7. $\pi_i^L \geq \pi_i^S$*,* $\pi_j^L \geq \pi_j^S$*, and* $(\pi_i^L + \pi_j^L + \pi_s^L) \geq (\pi_i^S + \pi_j^S + \pi_s^S)$*; that is, the fixed price LCB benefits the leader, the follower, and the overall supply chain.*

Proposition 7 shows that both the leader and the follower can obtain higher profits under the fixed price LCB, compared to the case of separate procurement. Therefore, the buyers' participation is assured. Clearly, LCB becomes more appealing to both buyers if the leader's bargaining power α_{is} increases relative to the supplier's. More interestingly, we can notice from Proposition 6 that under this fixed price LCB, the two buyers' procurement quantities coincide with the optimal solution for the integrated supply chain (i.e., q_i^I characterized in Section 3.2). That is, this transfer price incorporates the external effect that one buyer's quantity has over the other's profit and hence can lead them to refrain from overproduction. What becomes immediately clear is that, under this fixed transfer price, LCB can improve the overall supply chain performance. For the supplier, however, the situation is more complex. On the one hand, such an LCB can lead to more efficient order quantities, which might benefit the supplier; on the other hand, the leader is a stronger bargainer than the follower, which might reduce the share of the surplus that the supplier can obtain from the negotiation. The following proposition addresses this question.

Proposition 8. *There exists* $\tilde{b}$ *such that the supplier is better off under the fixed price LCB, i.e.,* $\pi_s^L \geq \pi_s^S$*, iff* $b \geq \tilde{b}$ *and* $\alpha_{ij}(1-\alpha_{is}) \geq 4(1-\alpha_{js})(1-\alpha_{ij}(1-\alpha_{is}))$*.*

Proposition 8 reveals the conditions under which the supplier can also benefit from the fixed price LCB. To achieve such an outcome, b needs to exceed a threshold and thus the market competition would be overly intense under separate procurement. Furthermore, α_{ij} and α_{js} need to be large, while α_{is} needs to be moderate. A large α_{js} implies that the supplier would obtain a small share of the profit from buyer j under separate procurement. In contrast, a large α_{ij} implies that the leader can demand a large transfer price from the follower under LCB, of which the supplier obtains a share, and a relatively small α_{is} implies that the supplier can have a large share of the profit from the negotiation with the leader for the joint procurement. We find from our numerical analysis that these conditions can be satisfied under various parameters. Therefore, the fixed price LCB can lead to an "all-win" outcome for the supply chain parties.

In the above, we compared the fixed price LCB with the separate procurement case. One might also compare the fixed price LCB with the equal price LCB. However, such an analysis is cumbersome. From our numerical study, where we vary $\alpha_{ij}, \alpha_{is}, \alpha_{js} \in \{0, 0.1, 0.2, ..., 1\}$ with $\alpha_{is} > \alpha_{js}$ and $b \in \{0, 0.02, 0.04, ..., 1\}$, we observe that the leader is always better off under the fixed price LCB, while the follower is better off when the competition intensity b exceeds a certain threshold. This numerical result is consistent with our theoretical result that the fixed price LCB completely eliminates the quantity distortions (from the first-best solution), whereas the equal price LCB can only mitigate the distortions to a certain extent because the quantity distortions are more costly to the alliance as the competition intensity b increases. Another observation is that under the fixed price LCB, the two buyers can be charged different wholesale prices, which can make the agreement appear less "fair" compared to the equal price LCB. However, these issues might be mitigated–particularly in the scenarios where the equal price LCB is not sustainable and by the fact that all the supply chain parties can benefit from the fixed price LCB.

6 Discussions

6.1 LCB Without Commitment

We have assumed in our main model that the buyers agree not to negotiate separately with the suppler if the LCB negotiation fails, which is common in practice. As pointed out in the *Guide to Collective Bargaining Notifications* by the ACCC, a commitment not to negotiate separately can put the supplier under increased pressure because of the buyers' threat of withdrawing orders. In essence, such a commitment can increase the LCB alliance's bargaining power. This subsection aims to provide a comparison with the case where the buyers are allowed to purchase separately from the supplier if the LCB negotiation fails. We again first consider the equal price LCB, and then discuss the fixed transfer price LCB.

The Equal Price LCB. Without such a commitment, in the last stage of the game, the Nash product of the negotiation between the leader and the supplier changes to:

$$\max_{w}[(a - q_i - bq_j - w)q_i - \pi_i^S]^{\alpha_{is}}[(w - c)(q_i + q_j) - \pi_s^S]^{1-\alpha_{is}}.$$

Solving this problem leads to the following lemma:

Lemma 5. *Given q_i and q_j, the bargaining outcome of the wholesale price between the leader and the supplier follows:*

$$w(q_i, q_j) = c + (1 - \alpha_{is})(a - q_i - bq_j - c) + \frac{\alpha_{is}\pi_s^S}{q_i + q_j} - \frac{(1 - \alpha_{is})\pi_i^S}{q_i},$$

under which the leader's profit is $\pi_i(q_i, q_j, w(q_i, q_j)) = \alpha_{is}(a - q_i - bq_j - c)q_i - \frac{\alpha_{is}q_i\pi_s^S}{q_i+q_j} + (1 - \alpha_{is})\pi_i^S$ *and the follower's profit is* $\pi_j(q_i, q_j, w(q_i, q_j)) = (a - q_j - bq_i - c - (1 - \alpha_{is})(a - q_i - bq_j - c) - \frac{\alpha_{is}\pi_s^S}{q_i+q_j} + \frac{(1-\alpha_{is})\pi_i^S}{q_i})q_j$.

Compared to the case with commitment, deriving the equilibrium q_i and q_j without commitment becomes more challenging because the profit functions involve the buyers' reservation profits from separate purchases. Hence, to gain more insight, we conduct an extensive numerical study with the parameters chosen from Table 1. A total of 4440 feasible instances is possible by keeping $\alpha_{is} \geq \alpha_{js}$ and $w(q_i, q_j) > c$. In each instance, we search for the equilibrium order quantities and then derive the corresponding profits.

Table 1: Summary of Parameters

Market Potential:	$a = 50, 100, 150, 200$
Buyers' Bargaining Powers:	$\alpha_{is} \in [0, 1]$, step length=0.1 $\alpha_{js} \in [0, 1]$, step length=0.1
Competition Intensity:	$b \in [0, 1]$, step length=0.01
Cost:	$c = 1, 10, 20$

Without the commitment, both buyers' profits under the equal price LCB clearly must be greater than their profits under separate purchases because they can always choose the latter option. However, we find that the lack of a commitment always hurts the leader, even though it might benefit the follower when the competition intensity b is in the middle region (the competition effect is weakened with the separate purchase option). On average, the leader's profit increases about 5 percent with the commitment, while the follower's profit increases about 3 percent. Another interesting observation from our numerical study is that, without commitment, the equal price LCB might still benefit the supplier, compared to the separate procurement case. Figure 1 provides an example with a middle range of b, where the supplier's profit under the equal price LCB can be significantly higher than his profit under the separate procurement case. This result is mainly because the equal price LCB can increase the total supply chain surplus by softening downstream competition. This effect is the most significant when the competition intensity resides in the middle region.

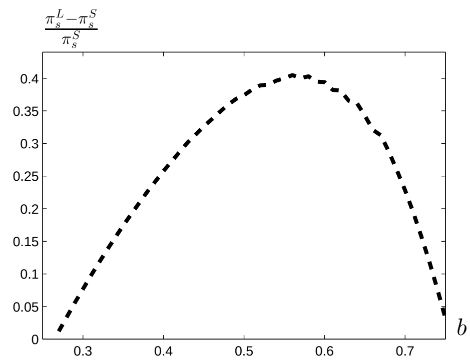

Figure 1: Comparison between the supplier's profit under the equal price LCB without commitment and that under separate procurement. The parameters are $a = 200$, $c = 1$, $\alpha_{is} = 0.4$, $\alpha_{js} = 0.3$.

The Fixed Price LCB. We also investigate the fixed price LCB by allowing the buyers to purchase separately from the supplier if the LCB negotiation fails. In the last stage, the Nash product of the negotiation between the leader and the supplier becomes:

$$\max_{w} \quad [(a - q_i - bq_j - w)q_i + (t - w)q_j - \pi_i^S]^{\alpha_{is}}[(w - c)(q_i + q_j) - \pi_s^S]^{1-\alpha_{is}}.$$

Maximizing this Nash product leads to the following lemma:

Lemma 6. *Given q_i and q_j, under the fixed price LCB, the bargaining outcome of the wholesale price between the leader and the supplier follows:*

$$w(q_i, q_j, t) = \alpha_{is}c + \frac{(1 - \alpha_{is})[(a - q_i - bq_j)q_i + tq_j - \pi_i^S] + \alpha_{is}\pi_s^S}{q_i + q_j},$$

under which the leader's profit is $\pi_i(q_i, q_j, w(q_i, q_j, t), t) = \alpha_{is}[(a - q_i - bq_j - c)q_i + (t - c)q_j - \pi_s^S] + (1 - \alpha_{is})\pi_i^S$.

With this outcome, the negotiation between the leader and the follower for the fixed transfer price t can be formulated as:

$$\max_{t} \quad [\pi_i(q_i, q_j, w(q_i, q_j, t), t) - \pi_i^S]^{\alpha_{ij}}[\pi_j(q_i, q_j, t) - \pi_j^S]^{1-\alpha_{ij}}.$$

Clearly, the Nash product is log-concave, and we can obtain a closed-form solution for the transfer price and for the buyers' profits.

Lemma 7. *Given q_i and q_j, the optimal transfer price follows:*

$$t(q_i, q_j) = (1 - \alpha_{ij})c + \alpha_{ij}(a - q_j - bq_i) - \frac{\alpha_{ij}\pi_j^S + (1 - \alpha_{ij})[(a - q_i - bq_j - c)q_i - \pi_s^S - \pi_i^S]}{q_j},$$

under which the leader's and follower's profits are:

$$\begin{aligned}
\pi_i(q_i, q_j) &= \alpha_{is}\alpha_{ij}[(a - q_i - bq_j - c)q_i + (a - q_j - bq_i - c)q_j - \pi_i^S - \pi_j^S - \pi_s^S] + \pi_i^S, \text{ and} \\
\pi_j(q_i, q_j) &= (1 - \alpha_{ij})[(a - q_i - bq_j - c)q_i + (a - q_j - bq_i - c)q_j - \pi_i^S - \pi_j^S - \pi_s^S] + \pi_j^S.
\end{aligned}$$

In the first stage, the buyers decide their procurement quantities simultaneously, which results in the following equilibrium.

Proposition 9. *Under the fixed price LCB without commitment, the equilibrium quantities are $q_i^L = q_j^L = \frac{a-c}{2(1+b)}$, under which the profits of the supply chain parties follow: $\pi_i^L = \pi_i^S + \alpha_{ij}\alpha_{is}\left(\frac{(a-c)^2}{2(1+b)} - \frac{2(a-c)^2}{(2+b)^2}\right)$, $\pi_j^L = \pi_j^S + (1 - \alpha_{ij})\left(\frac{(a-c)^2}{2(1+b)} - \frac{2(a-c)^2}{(2+b)^2}\right)$, and $\pi_s^L = \pi_s^S + \alpha_{ij}(1 - \alpha_{is})\left(\frac{(a-c)^2}{2(1+b)} - \frac{2(a-c)^2}{(2+b)^2}\right)$, respectively.*

Comparing Propositions 6 and 9, we can readily observe that under the fixed price LCB, both buyers' profits decrease while the supplier's profit increases if the commitment is absent. Hence, the buyer commitment is beneficial for the buyers but harmful for the supplier.

6.2 LCB with Enhanced Bargaining Power

In our main model, we have assumed that the parameter α_{is}—which represents the leader's bargaining power relative to the supplier—does not change from the case of separate procurement to the case of LCB. In this subsection, we relax this assumption to incorporate the possibility that having a larger procurement quantity might increase the buyer's bargaining power. In particular, we assume that the leader's bargaining power is increased to $\alpha_{is} + \xi$ in the LCB negotiation, where $\xi \in [0, 1 - \alpha_{is}]$; meanwhile, the supplier's bargaining power is reduced to $1 - \alpha_{is} - \xi$. Let $\alpha'_{is} = \alpha_{is} + \xi$. Clearly, all our previous analysis remains intact. In the following, we discuss the effect of this modification on the negotiation outcomes.

The Equal Price LCB. Similar to Proposition 2, we can derive the equilibrium order quantities under the equal price LCB: $q_i^L = \frac{(2(1-b)+b\alpha'_{is})(a-c)}{(4+b)(1-b)+3b\alpha'_{is}}$ and $q_j^L = \frac{(1-b+\alpha'_{is})(a-c)}{(4+b)(1-b)+3b\alpha'_{is}}$, with the enhanced bargaining power α'_{is}. Taking the first derivatives with respect to ξ, we obtain:

$$\frac{\partial q_i^L}{\partial \xi} = \frac{\partial q_i^L}{\partial \alpha'_{is}} \frac{\partial \alpha'_{is}}{\partial \xi} \leq 0; \quad \frac{\partial q_j^L}{\partial \xi} = \frac{\partial q_j^L}{\partial \alpha'_{is}} \frac{\partial \alpha'_{is}}{\partial \xi} \geq 0; \quad \text{and } \frac{\partial (q_i^L + q_j^L)}{\partial \xi} \geq 0.$$

Interestingly, the increase of the leader's bargaining power under the equal price LCB can increase the follower's procurement quantity but decrease the leader's own quantity. We also find an increase of the total procurement quantity. This finding indicates that the competition effect is weakened, which can benefit the follower and possibly also the overall supply chain. Finally, greater bargaining power clearly can increase the buyer alliance's total profit.

The Fixed Price LCB. From Proposition 6, we can notice that the equilibrium procurement quantities under the fixed price LCB do not depend on α_{is}, and thus the change of the leader's bargaining power does not change the procurement quantities. Furthermore, from Proposition 6, we can readily observe that an increase of the leader's bargaining power reduces the supplier's profit but increases the buyer alliance's total profit, as the leader becomes a stronger bargainer.

6.3 LCB Leader Choice

Thus far, we have assumed that the LCB leader is exogenously determined. In the following, we discuss the possible outcomes for an endogenous choice. We focus on the perspective of maximizing the two buyers' total profit, recognizing that they can always use a lump-sum transfer payment to share the gain.

The Equal Price LCB. Recall from Proposition 2 that if buyer i is the leader, then the alliance obtains a total profit:

$$\pi_i^L + \pi_j^L = \frac{(1-b+\alpha_{is})[(1-b)^2 + (1-b^2+b\alpha_{is})\alpha_{is}] + \alpha_{is}[2(1-b)+b\alpha_{is}]^2}{[(4+b)(1-b)+3b\alpha_{is}]^2}(a-c)^2.$$

In contrast, if buyer i is the follower, then the alliance's total profit follows:

$$\pi_i^{L'} + \pi_j^{L'} = \frac{(1-b+\alpha_{js})[(1-b)^2 + (1-b^2+b\alpha_{js})\alpha_{js}] + \alpha_{js}[2(1-b)+b\alpha_{js}]^2}{[(4+b)(1-b)+3b\alpha_{js}]^2}(a-c)^2.$$

Comparing these two profit functions, we can readily see that, from the buyer alliance's perspective, the buyer who has greater bargaining power relative to the supplier should be the leader. This outcome is intuitive because greater bargaining power relative to the supplier results in a larger share of the total supply chain surplus. This result also is in line with the anecdotal observations that the equal price LCB leaders are often the more powerful buyers in practice.

The Fixed Price LCB. First, notice that under the fixed price LCB, the first-best solution is always achieved regardless of which buyer is the leader. This outcome can be immediately seen from Proposition 6 because the result there does not depend on the leader choice. Second, in contrast to the equal price LCB, now the two buyers' total profit depends on their relative bargaining power. This relationship can be seen from the comparison of the two buyers' total profits under different leader choices ($\pi_i^{L'} + \pi_j^{L'}$ denote the two buyers' total profit if buyer j is the leader):

$$\begin{aligned}\pi_i^{L'} + \pi_j^{L'} - (\pi_i^L + \pi_j^L) &= [\alpha_{ij}(1-\alpha_{is}) - (1-\alpha_{ij})(1-\alpha_{js})]\left(\frac{(a-c)^2}{2(1+b)} - (1+\alpha_{is})\frac{(a-c)^2}{(2+b)^2}\right) \\ &\quad +(\alpha_{is}-\alpha_{js})(1+\alpha_{ij}(1-\alpha_{is}))\frac{(a-c)^2}{(2+b)^2}.\end{aligned}$$

The sign of this equation depends on the three bargaining power coefficients. In fact, we find that even if buyer i has greater bargaining power relative to the supplier than buyer j, buyer i does not necessarily have to be the leader; the choice also depends on the relative bargaining power between the two buyers. This is because, under the fixed price scheme, the profit that the supplier obtains from the negotiation with the leader depends on the profit that the leader obtains from the subsequent negotiation with the follower. As a result, if the leader is a stronger bargainer relative to the follower, he would obtain a large profit from the negotiation with the follower but would then share more profit with the supplier, which can reduce the two buyers' total profit. Clearly, the actual outcome depends on the specification of the three bargaining power coefficients. A more sophisticated investigation into this aspect is beyond the scope of this research.

7 Conclusion

This paper analyzes a few important issues related to the incentives and the cooperation schemes for the LCB formation. First, we investigate the equal price purchasing agreement, which has been commonly adopted for LCB alliances in practice. Interestingly, we find that such a joint procurement alliance always benefits the leader but might hurt the follower. Although teaming up with a stronger leader can provide the follower a lower wholesale price, the equal price LCB can also change the balance of the competition, turn it in the leader's favor, and undermine the follower's profit. We identify conditions under which the equal price LCB can lead to "win-win" and "win-lose" outcomes. Second, in view of the limitations of the equal price LCB, we explore whether more efficient transfer price agreements exist that can facilitate LCB formation in practice. Specifically, we find that a fixed transfer price agreement, when properly designed, can resolve the competition effect and always result in a "win-win" outcome for the buyers. This scheme can improve the overall supply chain performance and also can benefit the supplier in various scenarios. These findings are potentially useful for LCB implementations in practice.

Acknowledgments

The authors are grateful to the Editor-in-Chief, the Associate Editor, and the anonymous referees for their constructive comments which led to the present improved version of this paper. The corresponding author, Baozhuang Niu, is supported by the National Natural Science Foundation of China under Grant 71571194.

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Online Appendix I: Proofs for Main Results

Proof of Lemma 1. The results can be directly derived from the Nash bargaining solution.

Proof of Proposition 1. The two buyers solve $q_i^S = \arg\max_{q_i} \alpha_{is}(a - q_i - b\widetilde{q}_j - c)q_i$, for $i, j = 1, 2, j \neq i$, simultaneously. Moreover, in equilibrium, we must have $q_i^S = \widetilde{q}_i$, $i = 1, 2$. Given the specific concavity of the objective functions, we can find a fixed point. In particular, $q_i^S = \frac{a-c}{2+b}$, and accordingly, $w_i^S = c + (1 - \alpha_{is})\frac{a-c}{2+b}$, $\pi_i^S = \alpha_{is}\left(\frac{a-c}{2+b}\right)^2$, $i = 1, 2$, and $\pi_s^S = (2 - \alpha_{1s} - \alpha_{2s})\left(\frac{a-c}{2+b}\right)^2$.

Proof of Lemma 2. This lemma follows directly from the arguments preceding the lemma.

Proof of Proposition 2. Taking the first order conditions of $\pi_i(q_i, q_j)$ and $\pi_j(q_i, q_j)$ with respect to their procurement quantities, we obtain $q_i = \frac{a-bq_j-c}{2}$ and $q_j = \frac{\alpha_{is}(a-c)+(1-b-\alpha_{is})q_i}{2(1-(1-\alpha_{is})b)}$. Solving them simultaneously we obtain the equilibrium quantities

$$q_i^L = \frac{(2(1-b) + b\alpha_{is})(a-c)}{(4+b)(1-b) + 3b\alpha_{is}}; \quad q_j^L = \frac{(1-b+\alpha_{is})(a-c)}{(4+b)(1-b) + 3b\alpha_{is}}.$$

The outcomes in (a) can be derived accordingly.

For part (b): first, we have

$$\frac{q_i^L}{q_i^S} = \frac{(2+b)[2(1-b) + b\alpha_{is}]}{[(4+b)(1-b) + 3b\alpha_{is}]}.$$

Note that $(2+b)[2(1-b) + b\alpha_{is}] - [(4+b)(1-b) + 3b\alpha_{is}] = b(1-b)(1-\alpha_{is}) \geq 0$. Thus, $q_i^L \geq q_i^S$. Second, we have

$$\frac{q_j^L}{q_j^S} = \frac{(2+b)[1-b+\alpha_{is}]}{[(4+b)(1-b) + 3b\alpha_{is}]}.$$

Note that $(2+b)[1-b+\alpha_{is}] - [(4+b)(1-b) + 3b\alpha_{is}] = -2(1-b)(1-\alpha_{is}) \leq 0$. Thus, $q_j^L \leq q_j^S$. Moreover,

$$\begin{aligned}
q_i^L - q_i^S + q_j^L - q_j^S &= \frac{(2+b)[3(1-b) + (1+b)\alpha_{is}] - 2[(4+b)(1-b) + 3b\alpha_{is}]}{[(4+b)(1-b) + 3b\alpha_{is}]}(a-c) \\
&= \frac{-(1-b)(2-b)(1-\alpha_{is})}{[(4+b)(1-b) + 3b\alpha_{is}]}(a-c) \\
&\leq 0,
\end{aligned}$$

which shows $q_i^L + q_j^L \leq q_i^S + q_j^S$.

Proof of Proposition 3. The result holds because $\pi_i^L/\pi_i^S = (q_i^L/q_i^S)^2$ and $q_i^L \geq q_i^S$ which has been shown in the above.

Proof of Proposition 4. We first prove (a). Define $\underline{\alpha}_{js} = \frac{(2+b)^2(1-b+\alpha_{is})[(1-b)^2+\alpha_{is}(1-b^2+b\alpha_{is})]}{[(4+b)(1-b)+3b\alpha_{is}]^2}$, then $\pi_j^L \geq \pi_j^S$ iff $\alpha_{js} \leq \underline{\alpha}_{js}$. We can verify that

$$\begin{aligned} 1-\underline{\alpha}_{js} &= \frac{(1-\alpha_{is})[12-16b+b^3+2b^4+b^5+(4+12b-8b^2-6b^3-2b^4)\alpha_{is}+(4b+4b^2+b^3)(\alpha_{is})^2]}{[(4+b)(1-b)+3b\alpha_{is}]^2} \\ &\geq 0, \end{aligned}$$

thus $\underline{\alpha}_{js} \in [0,1]$. This completes the proof for Proposition 4(a).

We next prove (b). Note that $\frac{\pi_j^L}{\pi_j^S} = \frac{(2+b)^2(1-b+\alpha_{is})[(1-b)^2+\alpha_{is}(1-b^2+b\alpha_{is})]}{\alpha_{js}[(4+b)(1-b)+3b\alpha_{is}]^2}$. Define

$$\begin{aligned} A &= (2+b)^2(1-b+\alpha_{is})[(1-b)^2+\alpha_{is}(1-b^2+b\alpha_{is})]-\alpha_{js}[(4+b)(1-b)+3b\alpha_{is}]^2 \\ &= b(2+b)^2\alpha_{is}^3+(4+8b-3b^2-7b^3-2b^4-9b^2\alpha_{js})\alpha_{is}^2 \\ &\quad +(8-4b-10b^2+b^3+4b^4+b^5-b(24-18b-6b^2)\alpha_{js})\alpha_{is} \\ &\quad +4-8b+b^2+5b^3-b^4-b^5-(16-24b+b^2+6b^3+b^4)\alpha_{js}. \end{aligned}$$

Then $\pi_j^L \geq \pi_j^S$ iff $A \geq 0$.

Rewriting A in terms of b we have

$$\begin{aligned} A &= -(1-\alpha_{is})b^5-(1-4\alpha_{is}+2\alpha_{is}^2+\alpha_{js})b^4+(5+\alpha_{is}-7\alpha_{is}^2+\alpha_{is}^3-6\alpha_{js}+6\alpha_{is}\alpha_{js})b^3 \\ &\quad +(1-10\alpha_{is}-3\alpha_{is}^2+4\alpha_{is}^3-\alpha_{js}+18\alpha_{is}\alpha_{js}-9\alpha_{is}^2\alpha_{js})b^2 \\ &\quad -(8+4\alpha_{is}-8\alpha_{is}^2-4\alpha_{is}^3-24\alpha_{js}+24\alpha_{is}\alpha_{js})b+4+8\alpha_{is}+4\alpha_{is}^2-16\alpha_{js}. \end{aligned} \tag{1}$$

A is a five-degree function of b, so there may exist at most 5 real roots for $A(b)=0$. It can be shown that $A(0)=4(1+\alpha_{is})^2-16\alpha_{js} > 4(1+\alpha_{js})^2-16\alpha_{js} = 4(1-\alpha_{js})^2 > 0$. It can also be shown that $A(1)=9(\alpha_{is}-\alpha_{js})\alpha_{is}^2 > 0$. Therefore, only three cases may exist when $b \in [0,1]$: There are zero real roots, 2 real roots, or 4 real roots. The first two cases are similar since the first is a special case of the second. Next we show that it is impossible for the third case to arise.

First, note that $A(1) > 0$ and $A(+\infty) < 0$, so there at least exists one real root when $b \in (1,+\infty)$. Suppose there exist 4 real roots when $b \in [0,1]$, then there must exist one real root, labeled as b_1, in the interval $b \in (1,+\infty)$. Label the 4 real roots in $b \in [0,1]$ as b_2, b_3, b_4 and b_5, respectively. Thus $b_i, i=\{1,2,3,4,5\}$ is positive. Second, rewriting $A(b)$ in terms of the real roots yields $A(b) = -(1-\alpha_{is})(b-b_1)(b-b_2)(b-b_3)(b-b_4)(b-b_5)$, which can be rewritten as

$$\begin{aligned}
A(b) \;=\; & -(1-\alpha_{is})[b^5 - (b_1+b_2+b_3+b_4+b_5)b^4] \\
& -(1-\alpha_{is})(b_1b_2+b_1b_3+b_2b_3+b_4(b_1+b_2+b_3)+b_5(b_1+b_2+b_3+b_4))b^3 \\
& +(1-\alpha_{is})(b_1b_2b_3+b_1b_2b_4+b_1b_3b_4+b_2b_3b_4+b_5(b_1b_2+b_1b_3+b_2b_3+b_4(b_1+b_2+b_3)))b^2 \\
& -(1-\alpha_{is})(b_1b_2b_3b_4+b_5(b_1b_2b_3+b_1b_2b_4+b_1b_3b_4+b_2b_3b_4))b \\
& +(1-\alpha_{is})b_1b_2b_3b_4b_5.
\end{aligned}$$

Corresponding to function (1), we find that b^3's coefficient $(b_1b_2+b_1b_3+b_2b_3+b_4(b_1+b_2+b_3)+b_5(b_1+b_2+b_3+b_4))$ should be positive, equal to $-\frac{5+\alpha_{is}-7\alpha_{is}^2+\alpha_{is}^3-6\alpha_{js}+6\alpha_{is}\alpha_{js}}{1-\alpha_{is}}$. However, it can be shown that $-\frac{5+\alpha_{is}-7\alpha_{is}^2+\alpha_{is}^3-6\alpha_{js}+6\alpha_{is}\alpha_{js}}{1-\alpha_{is}} = -[5-\alpha_{is}^2+6(\alpha_{is}-\alpha_{js})] < 0$, which leads to contradiction, and hence it is impossible for 4 real roots to exist in the interval $b \in [0,1]$. Thus, we can conclude that in the interval $b \in [0,1]$, there may exist two threshold values $\underline{b}$ and $\bar{b}$, where $\underline{b} < \bar{b}$. LCB hurts the follower j when $b \in [\underline{b}, \bar{b}]$ and benefits him otherwise. This completes the proof for Proposition 4(b).

Proof of Proposition 5. Under LCB, the supply chain's profit is

$$\Pi^L = \pi_i^L + \pi_j^L + \pi_s^L = \frac{[7-15b+9b^2-b^3+(2+4b-7b^2+b^3)\alpha_{is}-(1-3b)\alpha_{is}^2](a-c)^2}{[(4+b)(1-b)+3b\alpha_{is}]^2}.$$

Under separate procurement, its profit is $\Pi^S = \pi_i^S + \pi_j^S + \pi_s^S = \frac{2(a-c)^2}{(2+b)^2}$. We find that

$$\frac{\Pi^L}{\Pi^S} = \frac{(2+b)^2[7-15b+9b^2-b^3+(2+4b-7b^2+b^3)\alpha_{is}-(1-3b)\alpha_{is}^2]}{2[(4+b)(1-b)+3b\alpha_{is}]^2}.$$

Define

$$C = (2+b)^2[7-15b+9b^2-b^3+(2+4b-7b^2+b^3)\alpha_{is}-(1-3b)\alpha_{is}^2] - 2[(4+b)(1-b)+3b\alpha_{is}]^2,$$

thus $\Pi^L \geq \Pi^S$ if $C \geq 0$. It can be shown that $C = (1-b)(1-\alpha_{is})C_1(b)$, where $C_1(b) = b^4 - 2b^3 - (7-3\alpha_{is})b^2 + (12-4\alpha_{is})b - 4 + 4\alpha_{is}$. Because $C_1''(b) = 12b^2 - 12b - 2(7-3\alpha_{is}) < 0$ for $b \in [0,1]$, $C_1(b)$ changes sign at most once over $b \in [0,1]$. This, together with the facts that $C_1(0) = -4(1-\alpha_{is}) \leq 0$ and $C_1(1) = 3\alpha_{is} \geq 0$, proves the proposition.

Proof of Lemma 3. This lemma follows from the arguments preceding the lemma.

Proof of Lemma 4. It is straightforward to verify that the Nash product is log-concave. Thus, by the first-order condition, we have that the transfer price satisfies

$$\alpha_{is} t q_j = \alpha_{is}\alpha_{ij}((a - q_j - bq_i)q_j - \pi_j^S) - \alpha_{is}(1-\alpha_{ij})((a - q_i - bq_j)q_i - c(q_i + q_j)) + (1-\alpha_{ij})\pi_i^S.$$

Then, buyer i's profit function can be written as

$$\pi_i(q_i, q_j) = \alpha_{is}\alpha_{ij}((a - q_i - bq_j - c)q_i + (a - q_j - bq_i - c)q_j - \pi_j^S) + (1-\alpha_{ij})\pi_i^S,$$

and buyer j's profit function can be written as

$$\pi_j(q_i, q_j) = \frac{\alpha_{is}(1-\alpha_{ij})((a - q_i - bq_j - c)q_i + (a - q_j - bq_i - c)q_j) + \alpha_{is}\alpha_{ij}\pi_j^S - (1-\alpha_{ij})\pi_i^S}{\alpha_{is}}.$$

Solving these two functions simultaneously we have the optimal production quantities which achieve the first-best solution:

$$q_i^L = q_j^L = \frac{a-c}{2(1+b)}.$$

Proof of Proposition 6. The proposition follows directly from the closed-form expressions of the profits of the leader and the follower in Lemma 4.

Proof of Proposition 7.

$$\begin{aligned}
\pi_i^L - \pi_i^S &= (1-\alpha_{ij})\pi_i^S + \alpha_{ij}\alpha_{is}\left(\frac{(a-c)^2}{2(1+b)} - \pi_j^S\right) - \pi_i^S \\
&= \alpha_{ij}\alpha_{is}\left(\frac{1}{4(1+b)} - \frac{1}{(2+b)^2} + \frac{1}{4(1+b)} - \frac{\alpha_{js}}{(2+b)^2}\right)(a-c)^2 \\
&\geq 0.
\end{aligned}$$

$$\begin{aligned}
\pi_j^L - \pi_j^S &= \alpha_{ij}\pi_j^S + (1-\alpha_{ij})\left(\frac{(a-c)^2}{2(1+b)} - \frac{\pi_i^S}{\alpha_{is}}\right) - \pi_j^S \\
&= (1-\alpha_{ij})\left(\frac{(a-c)^2}{2(1+b)} - \frac{\pi_i^S}{\alpha_{is}} - \pi_j^S\right) \\
&= (1-\alpha_{ij})\left(\frac{1}{4(1+b)} - \frac{1}{(2+b)^2} + \frac{1}{4(1+b)} - \frac{\alpha_{js}}{(2+b)^2}\right)(a-c)^2 \\
&\geq 0.
\end{aligned}$$

$$(\pi_i^L + \pi_j^L + \pi_s^L) - (\pi_i^S + \pi_j^S + \pi_s^S) = \frac{(a-c)^2}{2(1+b)} - \frac{2(a-c)^2}{(2+b)^2} = \frac{b^2(a-c)^2}{2(1+b)(2+b)^2} \geq 0.$$

Proof of Proposition 8. The supplier's profit gain under the fixed price LCB is

$$\pi_s^L - \pi_s^S = B(b) = \frac{\alpha_{ij}(1-\alpha_{is})}{\alpha_{is}}\left(\alpha_{is}\frac{(a-c)^2}{2(1+b)} - \alpha_{is}\pi_j^S - \pi_i^S\right) - \frac{1-\alpha_{js}}{\alpha_{js}}\pi_j^S.$$

Thus, the supplier will benefit from the fixed price LCB iff $B(b) \geq 0$. $B(b)$ can be simplified as

$$B(b) = \frac{\alpha_{ij}(1-\alpha_{is})(a-c)^2}{2(1+b)(2+b)^2}\left(b^2 - \frac{2(1-\alpha_{js})(1-\alpha_{ij}(1-\alpha_{is}))}{\alpha_{ij}(1-\alpha_{is})}b - \frac{2(1-\alpha_{js})(1-\alpha_{ij}(1-\alpha_{is}))}{\alpha_{ij}(1-\alpha_{is})}\right),$$

Define $B_1(b) = b^2 - \frac{2(1-\alpha_{js})(1-\alpha_{ij}(1-\alpha_{is}))}{\alpha_{ij}(1-\alpha_{is})}b - \frac{2(1-\alpha_{js})(1-\alpha_{ij}(1-\alpha_{is}))}{\alpha_{ij}(1-\alpha_{is})}$. Then $B_1(b)$ is a convex function of b. If $b=0$, then $B_1(0) = -\frac{2(1-\alpha_{js})(1-\alpha_{ij}(1-\alpha_{is}))}{\alpha_{ij}(1-\alpha_{is})} \leq 0$. If $b=1$, then $B_1(1) = \frac{\alpha_{ij}(1-\alpha_{is})-4(1-\alpha_{js})(1-\alpha_{ij}(1-\alpha_{is}))}{\alpha_{ij}(1-\alpha_{is})}$. $B_1(1)$ will be positive when $\alpha_{ij}(1-\alpha_{is}) \geq 4(1-\alpha_{js})(1-\alpha_{ij}(1-\alpha_{is}))$. If so, then there exists a unique threshold value $\tilde{b}$, larger than which $B(b) \geq 0$. This completes the proof.

Proof of Lemma 5. Given q_i and q_j, the Nash product is log-concave in w, which yields

$$w(q_i, q_j) = c + (1-\alpha_{is})(a - q_i - bq_j - c) + \frac{\alpha_{is}\pi_s^S}{q_i + q_j} - \frac{(1-\alpha_{is})\pi_i^S}{q_i},$$

Substituting $w(q_i, q_j)$ into the profit functions of i and j yields Lemma 5.

Proof of Lemma 6. Given q_i, q_j and t, the Nash product between buyer i and the supplier is log-concave. Substituting $w(q_i, q_j)$ into the profit functions of buyers i and j yields Lemma 6.

Proof of Lemma 7. The results are immediate given that the objective function is log-concave.

Proof of Proposition 9. Maximizing the buyers' profit functions shown in Lemma 7 we have two best-response functions: (1) $q_i(q_j) = (a - c - 2bq_j)/2$; (2) $q_j(q_i) = (a - c - 2bq_i)/2$. Solving them simultaneously yields the equilibrium quantities $q_i^L = q_j^L = \frac{a-c}{2(1+b)}$, based on which the results of Proposition 9 can be obtained.

Online Appendix II: Extra Extensions

In this section, we present four extra extensions of our main model and the associated proofs.

A. Alternative Benchmark: Sequential Price Negotiation

In this subsection, we analyze an alternative benchmark where the two buyers negotiate with the supplier sequentially under separate procurement. Without loss of generality, we assume that buyer i negotiates with the supplier first. If the negotiation fails, then buyer i will earn zero profit, while buyer j will become the monopoly buyer and his quantity will be $q_j = q_j^m = (a-c)/2$. Thus, the supplier's reservation profit for the first negotiation is $\pi_s^m = (1-\alpha_{js})(a-c)^2/4$. Solving this problem, we can obtain the following proposition.

Proposition 10. *Suppose buyer i negotiates with the supplier before buyer j. In equilibrium, the procurement quantities, the wholesale prices and the profits of the supply chain parties follow:*
$q_i^S = \frac{(2-2b+\alpha_{js}b)(a-c)}{4-3b^2+\alpha_{js}b^2}$, $q_j^S = \frac{(4-2b-b^2)(a-c)}{2(4-3b^2+\alpha_{js}b^2)}$,
$w_i^S = c+\frac{[2(4-4b^2+b^3-2\alpha_{js}b(1-b))-\alpha_{is}(8-4(2-\alpha_{js})b-2(3-\alpha_{js})b^2+(2-\alpha_{js})(3-\alpha_{js})b^3)](a-c)}{4(4-3b^2+\alpha_{js}b^2)}$, $w_j^S = c+\frac{(1-\alpha_{js})(4-2b-b^2)(a-c)}{2(4-3b^2+\alpha_{js}b^2)}$,
$\pi_i^S = \alpha_{is}\frac{(2-2b+a_{js}b)^2(a-c)^2}{4(4-3b^2+a_{js}b^2)}$, $\pi_j^S = \alpha_{js}\left(\frac{(4-2b-b^2)(a-c)}{2(4-3b^2+\alpha_{js}b^2)}\right)^2$, *and*
$\pi_s^S = \frac{[8-8b+b^2-4\alpha_{js}(1-b)-\alpha_{is}(2-2b+\alpha_{js}b)^2](a-c)^2}{4(4-3b^2+\alpha_{js}b^2)}$.

From the above results, we can find that if the supplier can decide whom to negotiate with first, he will always choose to first negotiate with the buyer with greater bargaining power. This is because to negotiate with a weaker buyer later will give the supplier a larger reservation profit in the first negotiation, which benefits the supplier.

Performance Comparison with Equal Price LCB. It is analytically challenging to compare the buyers' profits under this new benchmark with those under the equal price LCB. Thus, we rely on a numerical analysis. The parameters are listed in Table 2, which gives us total 1923 feasible combinations. Figure 2 provides an illustration. In general, we find that the equal price LCB benefits the leader, while it may hurt the follower when the competition intensity b is in a middle range. This is similar to our findings in the main model.

Table 2: Summary of Parameters

Buyers' Bargaining Powers:	$\alpha_{is} \in [0.1, 0.9]$, step length=0.05 $\alpha_{js} = 0.5\alpha_{is}$
Competition Intensity:	$b \in [0, 1]$, step length=0.01

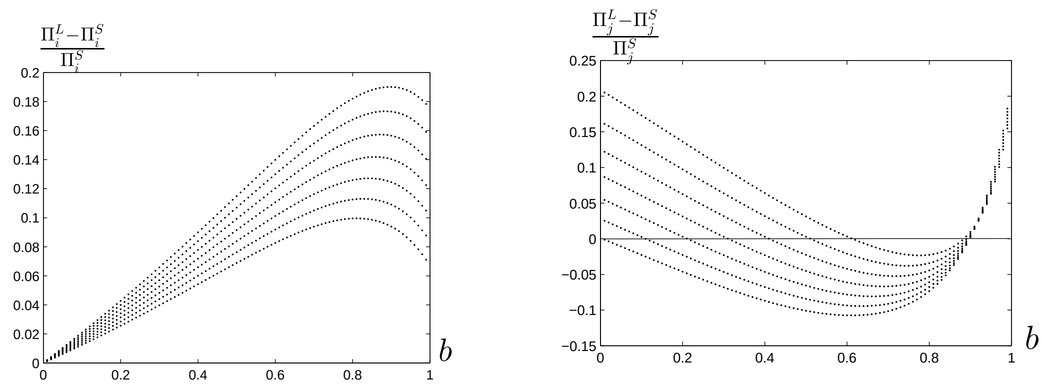

Figure 2: Leader and Follower's Preferences for Equal Price LCB and Separate Procurement

Performance Comparison with Fixed Price LCB. It is straightforward to show that all our analytical results in our main model remain to hold, given that the buyers' profits under separate procurement serve as their reservation profits when they form the fixed price LCB. It is still possible for the supplier to be better off due to the enlargement of the total supply chain surplus under the fixed price LCB.

B. The Existence of Spot Market

In this section, we assume that there is a spot market from which the buyers can procure the component if they fail to negotiate with the supplier. Suppose the spot price c_p satisfies $c < w_i < c_p$.

Separate Procurement. We again assume the buyers negotiate with the supplier in parallel simultaneously and use the Nash-Nash solution concept to solve the problem. Suppose buyer i's negotiation with the supplier fails while buyer j's negotiation with the supplier succeeds. Then, buyer i would purchase from the spot market at c_p for a quantity $q_i^p = (a - bq_j - c_p)/2$ and his profit would be $(a - bq_j - c_p)^2/4$. This serves as buyer i's reservation profit. As before, the supplier's reservation profit for the negotiation with buyer i is: $(w_j - c)q_j$. We can then solve the two parallel negotiations by backward induction. The results are presented in the following proposition.

Proposition 11. *If the buyers can purchase from the spot market, then under separate procurement, their reservation profits are* $\pi^p = \frac{(2a+bc-2c_p-bc_p)^2}{4(2+b)^2}$, *and their equilibrium procurement quantities, the wholesale prices and the profits of the supply chain parties follow:* $q_i^S = \frac{a-c}{2+b}$, $w_i^S = c + (1 - \alpha_{is})\frac{(c_p-c)[4a-(2-b)c-(2+b)c_p]}{4(a-c)}$, $\pi_i^S = \pi^p + \alpha_{is}\left[\left(\frac{a-c}{2+b}\right)^2 - \pi^p\right]$, $i = 1, 2$, *and* $\pi_s^S = (2 - \alpha_{1s} - \alpha_{2s})\left[\left(\frac{a-c}{2+b}\right)^2 - \pi^p\right]$, *respectively.*

The existence of the spot market increases the buyers' reservation profits and hence their equilibrium profits. The wholesale prices are lower than before, and the supplier obtains less profit.

The Equal Price LCB. In the presence of the spot market, both buyers would source from there if the leader's negotiation with the supplier fails. We can thus obtain the buyers' reservation profits: $\pi_p = \left(\frac{a-c_p}{2+b}\right)^2$. Then, the GNB between the leader i and the supplier can be formulated as:

$$\max_{w} \quad [(a - q_i - bq_j - w)q_i - \pi_p]^{\alpha_{is}}[(w - c)(q_i + q_j)]^{1-\alpha_{is}}. \tag{2}$$

Solving the game backward, we can obtain the following results.

Lemma 8. *Given q_i and q_j, the bargaining outcome of the wholesale price between the leader and the supplier follows:*

$$w(q_i, q_j) = \alpha_{is}c + (1 - \alpha_{is})(a - q_i - bq_j) - (1 - \alpha_{is})\pi_p/q_i,$$

under which the leader's profit is $\pi_i(q_i, q_j) = \alpha_{is}(a - q_i - bq_j - c)q_i + (1 - \alpha_{is})\pi_p$ and the follower's profit is $\pi_j(q_i, q_j) = [\alpha_{is}(a - c) - (1 - b + \alpha_{is}b)q_j + (1 - b - \alpha_{is})q_i + (1 - \alpha_{is})\pi_p/q_i]q_j$.

With the above lemma, we can derive the equilibrium results.

Proposition 12. *If the buyers can purchase from the spot market, then under the equal price LCB, the equilibrium quantities of the leader and the follower are:*

$$q_i^L = \frac{(2(1-b) + b\alpha_{is})(a-c) + \sqrt{(2(1-b) + b\alpha_{is})^2(a-c)^2 + 4b((4+b)(1-b) + 3b\alpha_{is})(1-\alpha_{is})\pi_p}}{2((4+b)(1-b) + 3b\alpha_{is})}$$

and $q_j^L = \frac{\alpha_{is}(a-c)+(1-b-\alpha_{is})q_i^L+\frac{(1-\alpha_{is})\pi_p}{q_i^L}}{2(1-b+\alpha_{is}b)}$, respectively, and the wholesale price is: $w^L = c + (1-\alpha_{is})q_i^L - (1-\alpha_{is})\pi_p/q_i^L$, under which the supply chain parties' profits are: $\pi_i^L = \pi_p + \alpha_{is}((q_i^L)^2 - \pi_p)$, $\pi_j^L = (1 - b + \alpha_{is}b)(q_j^L)^2$, and $\pi_s^L = (1 - \alpha_{is})((q_i^L)^2 - \pi_p) + (1 - \alpha_{is}) \left((q_j^L)^2 - \left(\frac{q_j^L}{q_i^L}\right)^2 \pi_p \right) \frac{q_i^L}{q_j^L}$.

From the above proposition, we can find that it is similar to the case in the main model without spot market that the follower's procurement quantity is smaller than that of the leader because of the competition effect, and we can also establish the following result.

Proposition 13. *The leader is always better off under the equal price LCB; i.e., $\pi_i^L \geq \pi_i^S$.*

For the follower, it is challenging to analytically compare his profit under the equal price LCB with that under separate procurement. Our numerical analysis (the parameters are presented in

Table 3: Summary of Parameters

Market Potential:	$a = 1$
Buyers' Bargaining Powers:	$\alpha_{is} \in [0, 1]$, step length=0.01 $\alpha_{js} \in [0, 1]$, step length=0.01
Competition Intensity:	$b \in [0, 1]$, step length=0.01
Cost:	$c = 0$
Spot Price:	$c_p \in [0.3, 1]$, step length=0.1

Table 3 and the results are illustrated in Figure 3) again shows that there might exist two threshold values of b between which the follower's profit is reduced by the equal price LCB, which is consistent with our previous finding without spot market. We also observe that the benefit of the equal price LCB relative to separate procurement for the follower is greater when the spot price is higher. This is mostly because when the spot price is small, the buyers can already obtain large profits from separate procurement with their large reservation profits.

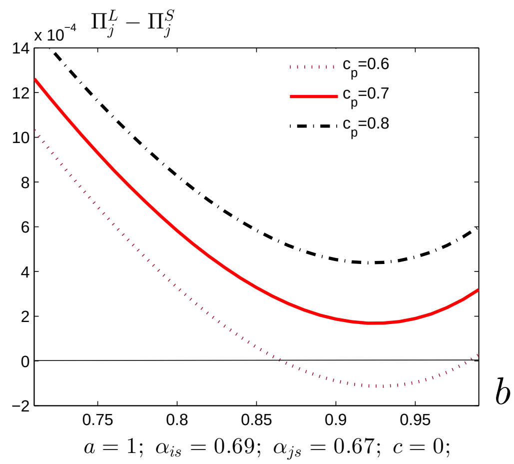

Figure 3: Benefit of equal price LCB for the follower.

The Fixed Price LCB. Similarly to the equal price LCB case, the leader i's reservation profit is π_p, and the GNB can be formulated as:

$$\max_{w} \qquad [(a - q_i - bq_j - w)q_i + (t - w)q_j - \pi_p]^{\alpha_{is}}[(w - c)(q_i + q_j)]^{1-\alpha_{is}}.$$

Lemma 9. *Given q_i and q_j, the bargaining outcome of the wholesale price between the leader and* *the supplier follows:*

$$w(q_i, q_j) = \alpha_{is}c + (1-\alpha_{is})\frac{(a - q_i - bq_j)q_i + tq_j - \pi_p}{q_i + q_j},$$

under which the leader's profit is $\pi_i(q_i, q_j) = \alpha_{is}[(a - q_i - bq_j - c)q_i + (t - c)q_j] + (1 - \alpha_{is})\pi_p$.

In the first stage, the buyers negotiate the transfer price t with their reservation profits π_i^S and π_j^S equal to the profits under separate procurement.

$$\max_t \qquad [\pi_i(q_i, q_j) - \pi_i^S]^{\alpha_{ij}}[\pi_j(q_i, q_j) - \pi_j^S]^{1-\alpha_{ij}}. \tag{3}$$

It can be shown that t is unique and follows:

$$t(q_i, q_j) = \frac{\alpha_{ij}((a - q_j - bq_i)q_j - \pi_j^S) + (1 - \alpha_{ij})(\frac{\pi_i^S - (1-\alpha_{is})\pi_p}{\alpha_{is}} - ((a - q_i - bq_j)q_i - c(q_i + q_j)))}{q_j}. \tag{4}$$

We can find that this transfer price is lowered with the spot market than without. Substituting $t(q_i, q_j)$ into the buyers' profit functions we can derive the equilibrium.

Proposition 14. *Under the fixed price LCB with the existence of spot market, the buyers' equilibrium procurement quantities are:* $q_i^L = q_j^L = \frac{a-c}{2(1+b)}$, *and the profits of the supply chain parties follow:* $\pi_i^L = (1 - \alpha_{ij})\pi_i^S + \alpha_{ij}(1 - \alpha_{is})\pi_p + \alpha_{ij}\alpha_{is}(\frac{(a-c)^2}{2(1+b)} - \pi_j^S)$, $\pi_j^L = \alpha_{ij}\pi_j^S + \frac{(1-\alpha_{ij})(1-\alpha_{is})\pi_p}{\alpha_{is}} + (1 - \alpha_{ij})(\frac{(a-c)^2}{2(1+b)} - \frac{\pi_i^S}{\alpha_{is}})$, *and* $\pi_s^L = \frac{(a-c)^2}{2(1+b)} - \pi_i^L - \pi_j^L$.

We can see that the procurement quantities remain the same with or without the spot market, and also the buyers' profit functions follow the same form except for the addition of their reservation profits with the spot market compared to those without the spot market. Similar results about the benefits of the fixed price LCB can be obtained. Hence, the existence of the spot market does not change any of our insights qualitatively.

Proposition 15. $\pi_i^L \geq \pi_i^S$, $\pi_j^L \geq \pi_j^S$, $(\pi_i^L + \pi_j^L) \geq (\pi_i^S + \pi_j^S)$, *and* $(\pi_i^L + \pi_j^L + \pi_s^L) \geq (\pi_i^S + \pi_j^S + \pi_s^S)$; *i.e., the fixed price LCB benefits the buyer alliance, as well as the whole supply chain.*

C. Representative-based Collective Bargaining

As we discussed in the introduction, buyers may also form a representative-based alliance to delegate the negotiation with the supplier to an independent agent firm; i.e., the so-called representative-based collective bargaining (RCB). Notice that for RCB, the representative firm often charges a commission for the trade (see Ahn et al. 2011 for a recent A.T. Kearney report on procurement outsourcing). In Li & Fung's case (Li & Fung is a Hong-Kong-based buying agency to negotiate with material/component supplier for its customers), the buying commission is 5% of the F.O.B. Country of Origin Price.[9]

We use r to label the sourcing agent and γ to denote the commission rate. The buyers first decide their procurement quantities independently. Then, the agent will negotiate with the supplier for the wholesale price w. Thus, we can formulate buyer i's profit as $\pi_i = [a - q_i - bq_j - (1+\gamma)w]q_i$, the supplier's profit as $\pi_s = (w - c)(q_i + q_j)$, and the agent's profit as $\pi_r = \gamma w(q_i + q_j)$. Let the agent's bargaining power over the supplier be α, and he will negotiate with the supplier on behalf of the buyers to maximize the total RCB profits $(a - q_i - bq_j - w)q_i + (a - q_j - bq_i - w)q_j$. Hence, we can formulate the GNB problem as:

$$\max_{w} \qquad [(a - q_i - bq_j - w)q_i + (a - q_j - bq_i - w)q_j]^{\alpha}[(w - c)(q_i + q_j)]^{1-\alpha}.$$

We can derive the wholesale price $w(q_i, q_j) = \alpha c + (1-\alpha)[(a - q_i - bq_j)q_i + (a - q_j - bq_i)q_j]/(q_i + q_j)$. Then, buyer i's profit function can be rewritten as:

$$\pi_i(q_i, q_j) = \frac{q_i}{q_i + q_j}[\alpha(a - q_i - bq_j)q_i + (a - q_i - bq_j - (1-\alpha)(a - q_j - bq_i))q_j - (1+\gamma)\alpha c(q_i + q_j)].$$

However, it is challenging to solve the equilibrium procurement quantities analytically from the above equations. Thus, we resort to a numerical analysis. We set $a = 200, c = 1, \gamma = 0.05, \alpha/\alpha_{is} = 1, 1.1, 1.2$, and let b vary in $[0, 1]$ with 0.01 per step. We compare the buyers' profits under RCB with those under the equal price LCB. Figure 4 provides an illustration.

Clearly, if the agent's bargaining power is no greater than the buyers', RCB makes the buyers worse off compared to the equal price LCB because the agent charges a commission. Hence, RCB will be used only if the agent has a sufficiently larger bargaining power. Moreover, we observe that the comparison also depends on the market competition intensity b. In particular, RCB tends to benefit the buyers when the downstream competition is intense (i.e., b is large). This finding is in line with the anecdotal evidence that strong competitors tend to cooperate less in LCB.

[9] see the buying agency agreement by Designs Apparel, Inc. and Li & Fung via http://www.sec.gov/Archives/edgar/data/813298/000119312506070549/dex1047.htm

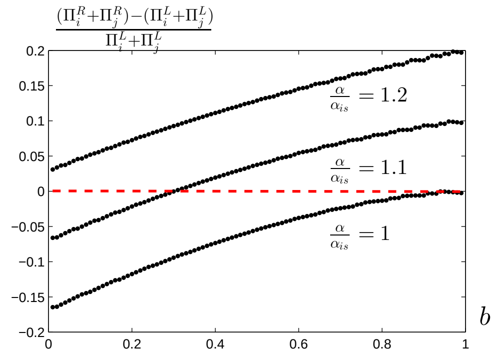

Figure 4: Comparison of the buyers' profits between RCB and equal price LCB.

D. Quantity Decision after Price Negotiation

In our study, we have assumed that the buyers make their quantity decisions before negotiating the prices with the supplier. This is in line with the business examples and anecdotal evidence we find (such as the Mai Wiru and Nuss LCB cases discussed in the introduction section). However, some prior studies have also assumed that buyers make their quantity decisions after the price negotiations (e.g., Feng and Lu 2013a,b). In the following, we provide an analysis for this alternative sequence of events in our context. We shall note that this sequence can induce double marginalization which may make the supply chain less efficient.

Separate Procurement. We use backward induction to first determine the procurement quantities: $q_i(w_i, w_j) = \frac{(2-b)a-2w_i+bw_j}{4-b^2}$ and $q_j(w_i, w_j) = \frac{(2-b)a-2w_j+bw_i}{4-b^2}$, if both negotiations succeed. To solve the wholesale prices in equilibrium, we need to specify the disagreement points in each negotiation. Clearly, without an outside option, the buyer's reservation profit is still zero. For the supplier's reservation profit, following Feng and Lu (2013a,b), it will be the profit he can obtain from the other negotiation, assuming it succeeds and the buyer becomes the monopoly buyer; that is, $(w_j - c)q_j^m$ where $q_j^m(w_j) = \frac{a-w_j}{2}$. Then, we can formulate the GNB problem over the wholesale prices as follows:

$$\max_{w_i} \quad \left[\left(\frac{(2-b)a-2w_i+bw_j}{4-b^2}\right)^2\right]^{\alpha_{is}} \left(\frac{((2-b)a-2w_i+bw_j)(2w_i-bw_j-(2-b)c)}{2(4-b^2)}\right)^{1-\alpha_{is}}.$$

Proposition 16. *Under separate procurement, if the quantity decisions are made after the price negotiations, then the equilibrium follows:* $q_i^S = \frac{(1+\alpha_{is})(a-c)}{2(2+b)}$, $w_i^S = c + \frac{[2(1-\alpha_{is})+b(1-\alpha_{js})](a-c)}{2(2+b)}$, $\pi_i^S = \left(\frac{(1+\alpha_{is})(a-c)}{2(2+b)}\right)^2$, $i = 1, 2$, *and* $\pi_s^S = \frac{[2-\alpha_{is}^2-\alpha_{js}^2+b(1-\alpha_{is}\alpha_{js})](a-c)^2}{2(2+b)^2}$, *respectively.*

The Equal Price LCB. We again solve the problem by backward induction. Since the wholesale price is the same for the two buyers, it's easy to show that $q_i(w) = q_j(w) = \frac{a-w}{2+b}$. Thus, we can obtain $\pi_i(w) = \left(\frac{a-w}{2+b}\right)^2$ and $\pi_s(w) = \frac{2(w-c)(a-w)}{2+b}$ for the leader and the supplier if the negotiation succeeds; if the negotiation fails, they obtain zero profit. Hence, we can formulate the GNB problem as:

$$\max_w \quad \left[\left(\frac{a-w}{2+b}\right)^2\right]^{\alpha_{is}} \left(\frac{2(w-c)(a-w)}{2+b}\right)^{1-\alpha_{is}}.$$

Proposition 17. *Under the equal price LCB, if the quantity decisions are made after the price negotiation, then the equilibrium follows:* $q_i^L = q_j^L = \frac{(1+\alpha_{is})(a-c)}{2(2+b)}$, $w^L = c + \frac{(1-\alpha_{is})(a-c)}{2}$, $\pi_i^L = \pi_j^L = \left(\frac{(1+\alpha_{is})(a-c)}{2(2+b)}\right)^2$, *and* $\pi_s^L = \frac{(1-\alpha_{is}^2)(a-c)^2}{2(2+b)}$.

Performance Comparison with Separate Procurement. We compare the supply chain parties' profits under these two cases.

Proposition 18. *Suppose $\alpha_{is} > \alpha_{js}$. The leader (i.e., buyer i) is indifferent between separate procurement and the equal price LCB, the follower is always better off, while the supplier is always worse off by the equal price LCB.*

Under the equal price LCB, the follower receives the same wholesale price as does the leader. Hence, compared to separate procurement, the follower's wholesale price gets lower and his procurement quantity increases, which increases his profit. For the leader, on the one hand, the equal price LCB leads to a larger procurement quantity of the follower which hurts the leader; on the other hand, the equal price LCB helps lower the wholesale price. Interestingly, the leader's equilibrium profit remains the same in these two cases and thus he is indifferent. These results imply that under this alternative sequence of events, the equal price LCB will always be feasible since neither buyer is worse off. In contrast, the supplier will always be worse off by the equal price LCB, because he negotiates a single wholesale price with a stronger buyer, which determines the buyers' subsequent procurement quantities.

The Fixed Price LCB. For the fixed price LCB, we adopt the following sequence of events. First, the two buyers negotiate a transfer price t and form the alliance. Second, assume buyer i is the leader who negotiates with the supplier for the wholesale price w. Third, given t and w, the two buyers decide their procurement quantities simultaneously. With this sequence, we can derive the two buyers' profit functions as:

$$\pi_i(q_i, q_j) = (a - q_i - bq_j - w)q_i + (t - w)q_j \quad \text{and} \quad \pi_j(q_i, q_j) = (a - q_j - bq_i - t)q_j,$$

and the supplier's profit function as:

$$\pi_s(q_i, q_j) = (w - c)(q_i + q_j).$$

We solve the problem by backward induction. First, we determine the buyers' procurement quantities: $q_i(t, w) = \frac{(2-b)a-2w+bt}{4-b^2}$ and $q_j(t, w) = \frac{(2-b)a-2t+bw}{4-b^2}$. Then, the leader i's profit function can be rewritten as $\pi_i(t, w) = \left(\frac{(2-b)a-2w+bt}{4-b^2}\right)^2 + \frac{(t-w)((2-b)a-2t+bw)}{4-b^2}$, and the supplier's profit function follows $\pi_s(t, w) = \frac{(w-c)(a-w-t)}{2+b}$, if their negotiation succeeds; otherwise, they obtain zero reservation profit. Hence, we can formulate the GNB problem as:

$$\max_{w} \qquad [\pi_i(t, w)]^{\alpha_{is}}[\pi_s(t, w)]^{1-\alpha_{is}}.$$

From the above negotiation, w can be determined as a function of t. Then, in the first stage, the two buyers negotiate to determine the transfer price t by solving the GNB problem:

$$\max_{t} \qquad [\pi_i(t) - \pi_i^S]^{\alpha_{ij}}[\pi_j(t) - \pi_j^S]^{1-\alpha_{ij}},$$

where the reservation profits π_i^S and π_j^S are the profits they can obtain from separate procurement. Clearly, given this feature, the two buyers will always be better off under the fixed price LCB. To assess the supplier's profit, we would need to solve the whole problem, which is technically challenging. From our numerical analysis (with the parameters presented in Table 1), we observe that the supplier now is always worse off under the fixed price LCB (recall from Proposition 8 that in our main model, the supplier might also benefit from the fixed price LCB).

E. Proofs for Extension Results

Proof of Proposition 10. We solve the game backwards. Step 1, the supplier negotiates with buyer j and obtains $w_j(q_i, q_j, w_i) = \alpha_{js}c + (1 - \alpha_{is})(a - q_j - bq_i)$. Step 2, buyer j determines his production quantity $q_j(q_i, w_i) = \frac{a-bq_i-c}{2}$. Step 3, the supplier negotiates with buyer i to determine w_i. It can be shown that $\pi_i - Di = \left(\frac{(2-b)a-(2-b^2)q_i+bc-2w_i}{2}\right)q_i$, and $\pi_s - d_i = \frac{4(w_i-c)q_i+(1-\alpha_{js})(a-bq_i-c)^2-4\pi_s^m}{4}$. Solving the negotiation problem between the supplier and buyer i, we have
$w_i(q_i) = \frac{4\alpha_{is}cq_i+2(1-\alpha_{is})[(2-b)aq_i-(2-b^2)q_i^2+bcq_i]-\alpha_{is}(1-\alpha_{js})(a-bq_i-c)^2+4\alpha_{is}\pi_s^m}{4q_i}$. Therefore, buyer i's profit can be written as $\pi_i(q_i) = \frac{2\alpha_{is}[(2-b)aq_i-(2-b^2)q_i^2+bcq_i]-4\alpha_{is}cq_i+\alpha_{is}(1-\alpha_{js})(a-bq_i-c)^2-4\alpha_{is}\pi_s^m}{4}$, which results in $q_i^S = \frac{(2-2b+\alpha_{js}b)(a-c)}{4-3b^2+\alpha_{js}b^2}$ and then the results of Proposition 10.

We now show that the supplier will prefer to negotiate with the buyer with greater bargaining power first. If the supplier negotiates with buyer i first, his equilibrium profit is

$$\pi_s^S = \frac{[8-8b+b^2-4\alpha_{js}(1-b)-\alpha_{is}(2-2b+\alpha_{js}b)^2](a-c)^2}{4(4-3b^2+\alpha_{js}b^2)}.$$

If the supplier negotiates with buyer j first, his equilibrium profit is

$$\pi_s^{S'} = \frac{[8-8b+b^2-4\alpha_{is}(1-b)-\alpha_{js}(2-2b+\alpha_{is}b)^2](a-c)^2}{4(4-3b^2+\alpha_{is}b^2)}.$$

Comparing the supplier's profits in these two cases, we find that the difference

$$\pi_s^S - \pi_s^{S'} = \frac{(a-c)^2(\alpha_{is}-\alpha_{js})bD(b)}{4(4-3b^2+\alpha_{is}b^2)(4-3b^2+\alpha_{js}b^2)},$$

where $D(b) = 16-8b-4\alpha_{is}b-4\alpha_{js}b+4\alpha_{is}\alpha_{js}b-20b^2+8\alpha_{is}b^2+8\alpha_{js}b^2-4\alpha_{is}\alpha_{js}b^2+13b^3-4\alpha_{is}b^3-4\alpha_{js}b^3+\alpha_{is}\alpha_{js}b^3$.

We further find that

$$\begin{aligned}
D(b)' &= -8-4\alpha_{is}-4\alpha_{js}+4\alpha_{is}\alpha_{js}-40b+16\alpha_{is}b+16\alpha_{js}b-8\alpha_{is}\alpha_{js}b+39b^2-12\alpha_{is}b^2-12\alpha_{js}b^2+3\alpha_{is}\alpha_{js}b^2;\\
D(b)'' &= -40+16\alpha_{is}+16\alpha_{js}-8\alpha_{is}\alpha_{js}+78b-24\alpha_{is}b-24\alpha_{js}b+6\alpha_{is}\alpha_{js}b;\\
D(b)''' &= 78-24\alpha_{is}-24\alpha_{js}+6\alpha_{is}\alpha_{js}\\
&> 0.
\end{aligned}$$

Therefore, $D(b)''$ is increasing in b with the minimizer $D''(b=0) = -40+16\alpha_{is}+16\alpha_{js}-8\alpha_{is}\alpha_{js} < 0$ and the maximizer $D''(b=1) = 38-8\alpha_{is}b-8\alpha_{js}b-2\alpha_{is}\alpha_{js} > 0$. This indicates that $D(b)'$ is convex in b its the domain. Then the maximizer of $D(b)'$ is either $D'(b=0)$ or $D'(b=1)$. Note that $D'(b=0) = -8-4\alpha_{is}-4\alpha_{js}+4\alpha_{is}\alpha_{js} < 0$ and $D'(b=1) = -9-\alpha_{is}\alpha_{js} < 0$, we can show that $D(b)$ is decreasing in b. Therefore, we have $D(b) \geq D(b=1) = 1+\alpha_{is}\alpha_{js} > 0$. Given this finding, we show that $\pi_s^S \geq \pi_s^{S'}$ iff $\alpha_{is} \geq \alpha_{js}$.

Proof of Proposition 11. For separate procurement, when the negotiation with supplier fails, a buyer can purchase components from the spot market at unit price c_p. So the Nash-Nash framework for the buyers' reservation profit is: the failed buyer buys from the spot market, assuming the other negotiation succeeds and that buyer buys from the supplier for the predetermined quantity, then the two buyers compete in the downstream market.

If buyer i fails to negotiate with the supplier, then the buyers' profit functions are

$$\pi_i = (a - q_i - bq_j - c_p)q_i; \quad \pi_j = (a - q_j - bq_i - w_j)q_j.$$

Then, given q_j, we have $q_i^p = \frac{a-bq_j-c_p}{2}$, and $\pi_i^p = \left(\frac{a-bq_j-c_p}{2}\right)^2$. Similarly, we $q_j^p = \frac{a-bq_i-c_p}{2}$, and $\pi_j^p = \left(\frac{a-bq_i-c_p}{2}\right)^2$. For the negotiation between buyer j and the supplier, they need to solve the following problem

$$\max_{w_j} \qquad [\pi_j(q_i, q_j) - \pi_j^p]^{\alpha_{js}}[\pi_s(q_i, q_j) - (w_i - c)q_i]^{1-\alpha_{js}},$$

which yields $w_j = \frac{\alpha_{js}cq_j+(1-\alpha_{js})(a-q_j-bq_i)q_j-(1-\alpha_{js}\pi_j^p)}{q_j}$. Substituting w_j into buyer j's profit function we have $\pi_j = \alpha_{js}(a - q_j - bq_i - c)q_j + (1 - \alpha_{js})\pi_j^p$. Similarly, we can derive $\pi_i = \alpha_{is}(a - q_i - bq_j - c)q_i + (1 - \alpha_{is})\pi_i^p$. We finally solve the buyers' problems with respect to q_i and q_j and find that $q_i^S = q_j^S = \frac{a-c}{2+b}$. Then $\pi_i^p = \pi_j^p = \left(\frac{(2a+bc-2c_p-bc_p)}{2(2+b)}\right)^2 = \pi^p$. The results summarized in Proposition 11 become straightforward. Note that we need guarantee $q_i^p \geq 0$, which requires $q_i^p = \frac{a-bq_j-c_p}{2} = \frac{(2a+bc-2c_p-bc_p)}{2(2+b)} \geq 0$.

Proof of Lemma 8. The proof is similar to that for Lemma 2.

Proof of Proposition 12. In the buyers' quantity determination problems, the best response functions are: $q_i(q_j) = \frac{a-bq_j-c}{2}, q_j(q_i) = \frac{\alpha_{is}(a-c)+(1-b-\alpha_{is})q_i+\frac{(1-\alpha_{is})\pi_p}{q_i}}{2(1-b+\alpha_{is}b)}$. Solving them simultaneously we find that $q_i = \frac{(2(1-b)+b\alpha_{is})(a-c)\pm\sqrt{(2(1-b)+b\alpha_{is})^2(a-c)^2+4b((4+b)(1-b)+3b\alpha_{is})(1-\alpha_{is})\pi_p}}{2((4+b)(1-b)+3b\alpha_{is})}$. Note that $\pi_i = \alpha_{is}q_i^2 + (1 - \alpha_{is})\pi_p$, which is increasing in q_i, we have the optimal production quantity $q_i^L = \frac{(2(1-b)+b\alpha_{is})(a-c)+\sqrt{(2(1-b)+b\alpha_{is})^2(a-c)^2+4b((4+b)(1-b)+3b\alpha_{is})(1-\alpha_{is})\pi_p}}{2((4+b)(1-b)+3b\alpha_{is})}$. Then the follower's production quantity is $q_j^L = \frac{\alpha_{is}(a-c)+(1-b-\alpha_{is})q_i^L+\frac{(1-\alpha_{is})\pi_p}{q_i^L}}{2(1-b+\alpha_{is}b)}$, and the follower's profit can be written as $\pi_j^L = (1 - b + \alpha_{is}b)q_j^L$.

Clearly, $q_i^L > \frac{(2(1-b)+b\alpha_{is})(a-c)}{(4+b)(1-b)+3b\alpha_{is}}$, and we have shown that $\frac{(2(1-b)+b\alpha_{is})(a-c)}{(4+b)(1-b)+3b\alpha_{is}} > q_i^S$ in Proposition 2. This results in $q_i^L > q_i^S$.

Regarding q_j^L, we find that $q_j^L = \frac{\alpha_{is}(a-c)q_i^L+(1-b-\alpha_{is})(q_i^L)^2+(1-\alpha_{is})\pi_p}{2(1-b+\alpha_{is}b)q_i^L}$. Therefore,

$$\begin{aligned}
q_j^L - q_i^L \quad &= \frac{-(1-b+\alpha_{is}(1+2b))(q_i^L)^2 + \alpha_{is}(a-c)q_i^L + (1-\alpha_{is})\pi_p}{2(1-b+\alpha_{is}b)q_i^L} \\
&= \frac{(1-\alpha_{is})(1-b)[(-1+(1-\alpha_{is})b)(a-c)q_i^L + (2+\alpha_{is}b)\pi_p]}{(1-b+\alpha_{is}b)((4+b)(1-b)+3b\alpha_{is})q_i^L} \\
&= \frac{(1-\alpha_{is})(1-b)}{(4+b)(1-b)+3b\alpha_{is}}\left[-(a-c)+\frac{(2+\alpha_{is}b)\pi_p}{(1-b+\alpha_{is}b)q_i^L}\right] \\
&< \frac{(1-\alpha_{is})(1-b)}{(4+b)(1-b)+3b\alpha_{is}}\left[-(a-c)+\frac{(2+\alpha_{is}b)(a-c)^2}{(1-b+\alpha_{is}b)(2+b)^2 q_i^L}\right] \\
&< \frac{(1-\alpha_{is})(1-b)}{(4+b)(1-b)+3b\alpha_{is}}\left[-(a-c)+\frac{(2+\alpha_{is}b)((4+b)(1-b)+3b\alpha_{is})(a-c)}{(1-b+\alpha_{is}b)(2(1-b)+b\alpha_{is})(2+b)^2}\right] \\
&< 0.
\end{aligned}$$

The first inequality is due to $\pi_p < \frac{(a-c)^2}{(2+b)^2}$. The second inequality is due to $q_i^L > \frac{(2(1-b)+b\alpha_{is})(a-c)}{(4+b)(1-b)+3b\alpha_{is}}$. The last inequality is due to

$$\begin{aligned}
&(2+\alpha_{is}b)((4+b)(1-b)+3b\alpha_{is}) - (1-b+\alpha_{is}b)(2(1-b)+b\alpha_{is})(2+b)^2 \\
&= -(1-\alpha_{is})(2+4b+\alpha_{is}b-4b^2+4\alpha_{is}b^2-2b^3+\alpha_{is}b^3)b \\
&< 0.
\end{aligned}$$

Proof of Proposition 13. We first show that a buyer's reservation profit under separate procurement (i.e., π^p) is less than that under equal price LCB (i.e., π_p).

$$\begin{aligned}
\pi_p - \pi^p \quad &= \left(\frac{a-c_p}{2+b}\right)^2 - \left(\frac{(2a+bc-2c_p-bc_p)}{2(2+b)}\right)^2 \\
&= \frac{b(c_p-c)(4a+bc-4c_p-bc_p)}{4(2+b)^2} \\
&> 0.
\end{aligned}$$

Clearly, $c_p > c$. Thus, the last inequality holds due to $4a+bc-4c_p-bc_p > 2(2a+bc-2c_p-bc_p) = 4(2+b)q_i^p \geq 0$. Then, note that $q_i^L > q_i^S$, and hence the result, $\pi_i^L > \pi_i^S$, becomes immediate.

Proof of Lemma 9. The proof is similar to that for Lemma 2.

Proof of Proposition 14. Substituting (4) into buyer i's profit function yields $\pi_i(q_i, q_j) = \alpha_{is}\alpha_{ij}[(a-q_i-bq_j-c)q_i + (a-q_j-bq_i-c)q_j - \pi_j^S] + (1-\alpha_{ij})\pi_i^S + \alpha_{ij}(1-\alpha_{is})\pi_p$, and $\pi_j(q_i, q_j) = \alpha_{ij}\pi_j^S + \frac{(1-\alpha_{ij})(1-\alpha_{is})\pi_p}{\alpha_{is}} + (1-\alpha_{ij})[(a-q_i-bq_j-c)q_i + (a-q_j-bq_i-c)q_j - \frac{\pi_i^S}{\alpha_{is}}]$. We solve buyers' problems simultaneously and find that $q_i^L = q_j^L = \frac{a-c}{2(1+b)}$. Then Proposition 14 is immediate.

Proof of Proposition 15. The proof is similar to that for Proposition 7.

Proof of Proposition 16. We solve the game by backward induction. The first step is the determination of q_i and q_j: $q_i(w_i, w_j) = \frac{(2-b)a-2w_i+bw_j}{4-b^2}$, and $q_j(w_i, w_j) = \frac{(2-b)a-2w_j+bw_i}{4-b^2}$. The second step is the price negotiation. Take buyer i as the example. In the negotiation, buyer i's reservation profit is 0, while the supplier's reservation profit is his profit from the negotiation with buyer j as the monopoly buyer. That is, $d_i = (w_j - c)q_j^m$, where $q_j^m(w_j) = \frac{a-w_j}{2}$, because the buyers can determine the order quantities after they observe the negotiation outcomes. Thus, we have $\pi_i(w_i, w_j) = (a - q_i - bq_j - w_i)q_i = \left(\frac{(2-b)a-2w_i+bw_j}{4-b^2}\right)^2$, and $\pi_s(w_i, w_j) - d_i = (w_i - c)q_i(w_i, w_j) + (w_j - c)q_j(w_i, w_j) - (w_j - c)q_j^m(w_j) = \frac{((2-b)a-2w_i+bw_j)(2w_i-bw_j-(2-b)c)}{2(4-b^2)}$. They solve the following maximization problem.

$$
\begin{aligned}
&\max_{w_i} \quad \left(\frac{(2-b)a - 2w_i + bw_j}{4-b^2}\right)^{2\alpha_{is}} \left(\frac{((2-b)a - 2w_i + bw_j)(2w_i - bw_j - (2-b)c)}{2(4-b^2)}\right)^{1-\alpha_{is}} \\
= &\max_{w_i} \quad \left(\frac{(2-b)a - 2w_i + bw_j}{4-b^2}\right)^{1+\alpha_{is}} \left(\frac{2w_i - bw_j - (2-b)c}{2}\right)^{1-\alpha_{is}} .
\end{aligned}
$$

We have $w_i(w_j) = \frac{(2-b)((1-\alpha_{is})a+(1+\alpha_{is})c)+2bw_j}{4}$. Symmetrically, we have $w_j(w_i) = \frac{(2-b)((1-\alpha_{js})a+(1+\alpha_{js})c)+2bw_i}{4}$. These two best response functions yield: $w_i^S = \frac{[2(1-\alpha_{is})+b(1-\alpha_{js})]a+[2(1+\alpha_{is})+b(1+\alpha_{js})]c}{2(2+b)}$, $i, j \in \{1, 2\}, i \neq j$. The other results can be obtained from w_i^S.

Proof of Proposition 17. This proposition follows from the arguments preceding the proposition.

Proof of Proposition 18. It can be shown that $\pi_i^L = \pi_i^S$, and $\pi_j^L \geq \pi_j^S$ iff $\alpha_{is} \geq \alpha_{js}$. Regarding the supplier's performance, we have $\pi_s^S - \pi_s^L = \frac{(\alpha_{is}-\alpha_{js})(\alpha_{is}+\alpha_{js}+\alpha_{is}b)}{2(2+b)^2}$.