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Abstract

This paper investigates the sequencing choice of a buyer who negotiates with the sellers of two complementary objects with uncertain payoffs. We show that the sequencing matters to the buyer only when equilibrium trade can be inefficient. In this case, the buyer begins with the *less* powerful seller if the sellers have sufficiently diverse bargaining powers. If, however, both sellers are strong bargainers, then the buyer begins with the *stronger* of the two. For either choice, the buyer's sequencing (weakly) increases the social surplus. Our analysis further reveals that it is sometimes optimal for the buyer to raise her *own* cost of acquisition to better manage the supplier competition. As such, we find that the buyer may commit to paying the sellers a minimum price strictly above the marginal cost; and that the buyer may outsource an input even though it can be made in-house. Finally, we identify the first- and second-mover advantages in negotiations for the sellers.

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1 Introduction

In a variety of bargaining settings, a buyer sequentially negotiates with the sellers of complementary objects. Examples include a shopping mall developer negotiating with several landowners to assemble parcels of land; academic departments trying to recruit multiple faculty members with complementary skills; a vaccine manufacturer bargaining with patent holders of various antigens; and a home-owner dealing with multiple contractors for complementary parts of a large project.[1]

With sequential negotiations, a key strategic choice for the buyer is the sequence itself because the sellers are likely to price objects differently depending on the order. In this paper, we investigate this sequencing choice by the buyer and its social efficiency consequences. While doing so, we also discover that the buyer may sometimes be better off weakening her bargaining power against the sellers. In particular, we identify an incentive for the buyer to raise her *own* cost of acquiring goods to better manage the supplier competition.

Our model consists of two sellers who own complementary objects and a buyer with unit demands. While the buyer's joint valuation is commonly known, her stand-alone valuations are each independently drawn from a binary distribution.[2] In each buyer-seller negotiation, one player makes a price offer with a pre-specified probability that reflects his/her relative bargaining power. After receiving both price offers and ascertaining all her valuations in the process, the buyer decides ex post which objects to purchase.[3]

For a fixed sequence, there is a unique (perfect Bayesian) equilibrium in our negotiation game. In the special case of no payoff uncertainty, we show that the buyer is completely

[1]Although, for concreteness, our examples will mostly relate to procurements, similar sequencing issues also arise in other contexts such as international negotiations where one central country aims to sign bilateral trade agreements with others, or build a coalition for an international mission (Sebenius 1996), and political vote-buying where an interest group tries to secure endorsements of several legislators (Groseclose and Snyder 1996).

[2]In particular, we assume that the buyer's stand-alone payoffs are (at least initially) more uncertain than her joint payoff. For example, a developer may be more uncertain about the profitability of a smaller shopping mall built on a subset of targeted parcels; an academic department may be more uncertain about the stand-alone contributions of faculty candidates than their joint contributions to the department; a vaccine manufacturer may be more uncertain about the effectiveness of the vaccine that uses only a subset of the antigens; and a home-owner may be more uncertain about the use of a backyard porch without landscaping than with it. It is, however, conceivable that the buyer will resolve her payoff uncertainty as she meets with the sellers and learn about the objects.

[3]An ex post purchasing decision guarantees that the buyer does not incur a loss, and this assumption makes most sense if the buyer is credit-constrained by the value of the project. For instance, in land acquisitions, it is a common practice to secure an option on the property at a nominal fee, that specifies a price and expiration date (Poorvu 1999, pp. 151-3).

indifferent to the sequence because the sellers perfectly coordinate their prices in equilibrium, resulting in an efficient trade.[4] With a sufficient payoff uncertainty, however, equilibrium trade can be inefficient. In such cases, we show that the buyer optimally begins with the *weak* seller if one seller is weak and the other is a strong bargainer. If, on the other hand, both sellers are strong bargainers, then the buyer begins with the *stronger* of the two. To understand these observations, note that the buyer –not surprisingly– proposes to pay only the marginal cost in each negotiation. Thus, the leading seller prices aggressively, if he is followed by a weak seller who is unlikely to propose against the buyer and capture any surplus. To curb this behavior, the buyer begins with the weak seller. When both sellers are strong bargainers, the buyer's concern for aggressive pricing shifts to the last seller. By leaving the weaker seller of the two to be the last, the buyer minimizes the likelihood of a high price response in the second negotiation in the event that the first one ends in her favor. In either case, we show that the buyer's sequencing (weakly) improves the social surplus.

An interesting implication of our bargaining analysis is that the buyer is sometimes strictly better off dealing with the sellers who have higher bargaining powers. The reason is that such sellers anticipate the other to be more demanding against the buyer and become more concerned about price coordination, leading them to lower prices. Put differently, the buyer can sometimes enhance her bargaining position by becoming *weaker* vis-à-vis the sellers. This finding has two important implications for procurement policies. First, the buyer may optimally adopt a *minimum* purchase price by which she commits to paying the sellers a price strictly above their marginal costs even when she makes the offers; and second, the buyer who can internally provide an input at the same cost as the outside seller may, nonetheless, choose to outsource it. Under each policy, the buyer weakens her bargaining power by raising her own cost of acquiring the goods in order to better manage the supplier competition.[5]

We also examine the sellers' preference for the negotiation sequence, as this may inform us of their incentives to actively solicit the buyer's business and even bid for the right to negotiate at the desired order. Although the standard IO theory establishes a first-mover advantage for price-setting duopolists selling complementary goods (e.g., Gal-Or 1985, and Dowrick 1986), a second-mover advantage also emerges in our model with a powerful buyer. The reason is that a powerful buyer is highly likely to secure a low price from the first negotiation, which leaves

[4]Given complementarity, it is socially efficient for the buyer to purchase both units in our model.

[5]This is a reminiscent of, but quite distinct from, the "handicapping" principle in procurement auctions where the buyer commits to purchasing a single good from the high-cost supplier at times to induce a more intense supplier competition (e.g., McAfee and McMillan 1989, and Lewis and Yildirim 2002).

a large surplus to the second negotiation.

Related Literature. Our paper belongs to a growing literature on one-to-many bargaining, and complements several papers that address the issue of optimal bargaining sequence *without* payoff uncertainty. Among them, Marx and Shaffer (2007) show that with contingent contracts, the buyer strictly prefers to negotiate first with the weaker seller in order to extract rents from the stronger one. Absent contingent contracts (as with our model), however, the buyer would be indifferent to the sequence in their setting. Xiao (2010) studies a complementary good setting with noncontingent contracts but with a pay-as-you-go scheme. Like Marx and Shaffer, he too finds that the buyer is better off starting with the weaker seller, though only to alleviate a "holdup" problem due to sunk payments for prior purchases. Such a problem does not arise in our setting because the buyer decides on purchases after receiving all the price offers. Li (2010) studies an infinite-horizon random-proposer model of complementary goods. Given no payoff uncertainty, he shows that any sequencing is sustainable in equilibrium.[6] In contrast, our model yields a unique equilibrium, and a strict sequencing preference. In two related papers, Krasteva and Yildirim (2010), and Noe and Wang (2004) compare public and private negotiations, and note that the buyer is indifferent to the sequence under both types of negotiations, though she may strictly randomize. We abstract from privacy concerns here, and show that with demand uncertainty, the buyer has a strict preference over the sequence.[7] In a labor union-multiple firm framework, Marshall and Merlo (2004) examine the sequencing issue using "pattern bargaining" where the buyer uses the contract agreed upon in the first negotiation as a starting point of the second negotiation.[8] In their case with non-pattern sequential negotiations, the buyer does not, however, care about the sequence. A similar indifference result is obtained by Moresi et al. (2010) in a fairly general model of bilateral negotiations. Without payoff uncertainty, our model would also result in the buyer's indifference to the sequence, which we further discuss below.

Our paper is also related to models of endogenous sequencing through sellers' bidding for positions, e.g., Arbatskaya (2007), and Marx and Shaffer (2010). While these papers uncover either a first- or second-mover advantage for the sellers, our setting features the presence of both advantages depending on the degree of payoff uncertainty and the buyer's bargaining

[6]Both Li (2010) and Xiao (2010) build on Cai (2000) who assume homogenous sellers. See also Horn and Wolinsky (1988), and Stole and Zwiebel (1996) who assume a fixed order of negotiations.

[7]Note that this is not a simple "purification" argument for mixed strategies, because, under the present setup, Krasteva and Yildirim (2010) would imply that without any uncertainty, the ordering issue is inconsequential under both public and private negotiations.

[8]See also Banerji (2002).

power, even though goods are complements at all realizations.

The remainder of the paper is organized as follows. We set up the model in the next section, and then fully characterize the equilibrium prices in Section 3. In Section 4, we address the buyer's optimal sequencing choice. In Section 5, we show that the buyer's expected payoff may decrease with her own bargaining power and examine the two procurement policies alluded to above. In Section 6, we investigate the first- and second-mover advantages for the sellers, followed by concluding remarks in Section 7. The proofs of all formal results are relegated to an appendix.

2 The Model

There are three risk-neutral parties: one buyer (b) and two sellers (s_i, $i = 1, 2$). Each seller costlessly provides a complementary good for which the buyer has a unit demand. It is commonly known at the outset that the buyer possesses a joint value normalized to 1, while her stand-alone value for good i, v^i, is an independent draw from a Bernoulli distribution where $\Pr\{v^i = 0\} = q_i \in [0, 1]$ and $\Pr\{v^i = \frac{1}{2}\} = 1 - q_i$.[9] In particular, with probability $q_1 q_2$, she views goods to be perfect complements, whereas, with probability $(1 - q_1)(1 - q_2)$, she views them to be unrelated. We assume that the buyer privately learns v^i as she meets with seller i to negotiate.[10]

The buyer negotiates with the sellers sequentially and only once. The price for good i is determined between the buyer and seller i through a one-shot random-proposer bargaining. Let $\sigma_i \in \{b, s_i\}$ denote the player who makes the offer such that $\sigma_i = s_i$ with probability $\alpha_i \in (0, 1)$, and $\sigma_i = b$ with probability $1 - \alpha_i$, where α_i measures seller i's bargaining power relative to the buyer's.[11] We assume that σ_1 and σ_2 are independently distributed, and the realization of σ_i is observed only by the buyer and seller i during their negotiation.

The timing and information structure of our negotiation game unfolds as described by Figure 1. First, the buyer publicly chooses the sequence, $s_1 \to s_2$ or $s_2 \to s_1$. Next, the

[9]Our qualitative results remain unchanged by a more general support $v_L = 0$ and $v_H = v \leq \frac{1}{2}$, leading us to set $v = \frac{1}{2}$ in the text to ease exposition. See Appendix B for details.

[10]In this regard, we have in mind environments in which information is too costly for the buyer to acquire independently. For instance, an employer often has to interview a job candidate to determine the match value; a home-owner frequently needs to consult with a contractor for a customized project; and a real-estate developer may require access to the construction history of a land parcel from the landowner.

[11]For instance, α_i may proxy a seller's likelihood of having other customers at the time or his urgent need for cash; and a landowner's likelihood of having an alternative use for his land. It is also conceivable that α_i may simply reflect the intrinsic bargaining ability of the seller vis-à-vis the buyer.

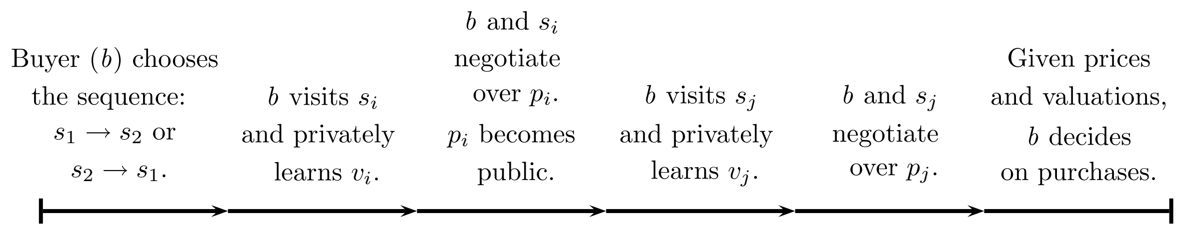

Figure 1: Timing and Information Structure

buyer approaches the first seller in the sequence, say s_i, and privately observes her valuation v^i. Then, the buyer and s_i bargain over the price of product i, denoted by p_i. The buyer, then, proceeds to s_j. She privately learns v^j while s_j learns p_i. Subsequently, the buyer bargains with s_j over p_j. Having obtained the two prices p_i and p_j, and ascertained her valuations v^i and v^j, the buyer decides which goods to purchase (if any). Our solution concept is perfect Bayesian equilibrium throughout.

Note that given the complementarity, trade is (socially) efficient if and only if the buyer acquires both goods with probability 1. Thus, we call any equilibrium *inefficient* if it involves less than joint purchase with a positive probability. In case of indifference, we assume that all players break ties in favor of efficiency, i.e., purchasing and selling more units. Before proceeding to the analysis, we briefly discuss some of the modeling assumptions.

2.1 Discussion of the Assumptions

We keep each buyer-seller bargaining simple to better focus on sequencing; nevertheless, our one-shot bargaining can be a good approximation of applications in which the buyer has a short time to acquire the goods, or else the trade opportunity is lost.[12] Such take-it-or-leave-it offer bargaining has also been used extensively in other bilateral contracting models, e.g., Marx and Shaffer (2007), Noe and Wang (2004), and Segal (1999). Next, our assumption that the second seller, s_j, observes p_i can be justified in two ways. First, if procurement is performed on behalf of the government, the buyer in many countries will be subject to "sunshine" laws that typically enable the public to have access to transaction records and even to actual negotiation meetings (e.g., Berg et al. , pp. 42-44). Second, if it were up to the buyer to disclose such price information, it is readily verified that she would have an incentive to disclose a high p_i so as to induce price accommodation by s_j. But, such a "monotonic" incentive would then lead to the

[12]For instance, for many customized goods and services such as home re-modeling and landscaping, contractors give a free (binding) price estimate to which the customer needs to respond in a short-time period.

full disclosure of p_i, much like in the literature on signaling a verifiable quality, e.g., Grossman (1981). Thus, the important assumption in this regard is that p_i information is hard, i.e., the buyer cannot forge it; but this seems reasonable in many procurement settings – if not most – as price quotes are often provided in the form of a written contract. Perhaps, what is more important is that sellers know the sequence. In this respect, we envision environments where any meeting between the buyer and sellers is highly visible or publicized, or it can be easily inferred by the sellers from the calendar time.

We also assume that the buyer makes purchases at the very end, with the full knowledge of the prices and her valuations. Alternatively, she could make purchases soon after negotiating with each seller. This latter type of negotiations would clearly result in a holdup problem, as the second seller in the sequence would ignore any previous payment by the buyer. Hence, under such pay-as-you-go procurement, it is readily verified that the sum of the sellers' equilibrium prices would always exceed the buyer's value from the entire project.[13] This means that a buyer who is averse to any loss or who is credit-constrained by the project value will prefer to make purchases at the very end as in our present setting since it never yields an ex post negative payoff. Moreover, certain government policies such as the Federal Trade Commission's "cooling-off" rule allow consumers to cancel a contract or return a purchase within a fixed time period, effectively extending their decision deadline.[14]

3 Equilibrium Characterization

In this section, we characterize the equilibrium prices for a fixed negotiation sequence. The following proposition states that the equilibrium always involves pooling by the two types of the buyer, *i.e.*, $v^i = \frac{1}{2}$ and $v^i = 0$, as well as an aggressive pricing by the first seller in the sequence.

Proposition 1. *Given any negotiation sequence $s_i \to s_j$, there is a unique (perfect Bayesian) equilibrium. In equilibrium, the buyer always makes a marginal-cost offer, 0, to the sellers, whereas seller i never makes an offer below $\frac{1}{2}$.*

It is intuitive that in the last negotiation, the buyer will make a marginal cost offer, 0, to seller j. She will also make a 0 price offer to seller i whenever her valuation for i is high in order to maximize her outside option against seller j. Given this incentive, a buyer with low

[13] See Appendix B for a proof.

[14] See http://www.ftc.gov/bcp/edu/pubs/consumer/products/pro03.shtm.

valuation for i pools with a buyer with high valuation, rendering her price for good i to be uninformative of her valuation v^i.

Unlike the buyer, each seller is likely to weigh two options when setting his price: (1) he can try to coordinate his price with the rival's to induce a joint purchase, or (2) he can ignore coordination and set a monopoly price for his product. Proposition 1 states that seller i never sets a price below $\frac{1}{2}$ because any such price will guarantee a joint purchase irrespective of the second negotiation. Given the buyer's offer, this implies that seller j can perfectly infer the identity of the proposer in the first negotiation, namely $\sigma_i^* \in \{b, s_i\}$, from the observed price. Thus, it is without loss of generality to condition seller j's equilibrium price on σ_i^*.[15] Our next result fully characterizes sellers' equilibrium prices.

Proposition 2. *Suppose that the negotiation sequence is $s_i \rightarrow s_j$. In equilibrium,*

(a) *if the buyer makes the offer for product i, then seller j responds by:*

$$p_j^*(s_j|b) = \begin{cases} 1 & if \quad q_i > \frac{1}{2} \\ \frac{1}{2} & if \quad q_i \leq \frac{1}{2}; \end{cases} \tag{1}$$

(b) *if, on the other hand, seller i makes the offer, then*

$$\left(p_i^*(s_i), p_j^*(s_j|s_i)\right) = \begin{cases} \left(1, \frac{1}{2}\right) & if \quad \alpha_j < \widehat{\alpha}(q_j) \\ \left(\frac{1+q_j}{2}, \frac{1-q_j}{2}\right) & if \quad \alpha_j \geq \widehat{\alpha}(q_j) \ \ and \ \ q_j > \frac{\sqrt{5}-1}{2} \\ \left(\frac{1}{2}, \frac{1}{2}\right) & if \quad \alpha_j \geq \widehat{\alpha}(q_j) \ \ and \ \ q_j \leq \frac{\sqrt{5}-1}{2}, \end{cases} \tag{2}$$

where

$$\widehat{\alpha}(q_j) \equiv \begin{cases} 0 & if \quad q_j \leq \frac{1}{2} \\ 1 - \frac{1}{2q_j} & if \quad \frac{1}{2} < q_j \leq \frac{\sqrt{5}-1}{2} \\ \frac{1-q_j}{2} & if \quad q_j > \frac{\sqrt{5}-1}{2}. \end{cases} \tag{3}$$

Part (a) simply records seller j's (monopoly) price response to the buyer's offer of 0 in the first negotiation: he sets the maximum price of 1 if good i is unlikely to have value by itself (i.e., $v^i = 0$) and he sets a low price of $\frac{1}{2}$ otherwise. Part (b) records sellers' equilibrium prices when seller i proposes over product i. Refer to Figure 2. Note that $p_i^*(s_i) \geq \frac{1}{2}$ as stated in Proposition 1. Thus, the only way seller i will realize a sale is if the buyer acquires both units.[16]

[15] In terms of notation, we find conditioning p_j^* on σ_i^* more informative than conditioning on p_i^* – at least in the text.

[16] To be more precise, in any equilibrium with $p_i^*(s_i) = \frac{1}{2}$, the buyer is indifferent between purchasing both goods and purchasing only good i, as each decision leaves her with no surplus. Recall, however, that we break ties in favor of social efficiency. Moreover, if the goods were strict complements, i.e., $v^i < \frac{1}{2}$, then we would have $p_i^*(s_i) > \frac{1}{2}$ (see Proposition B1 in Appendix B).

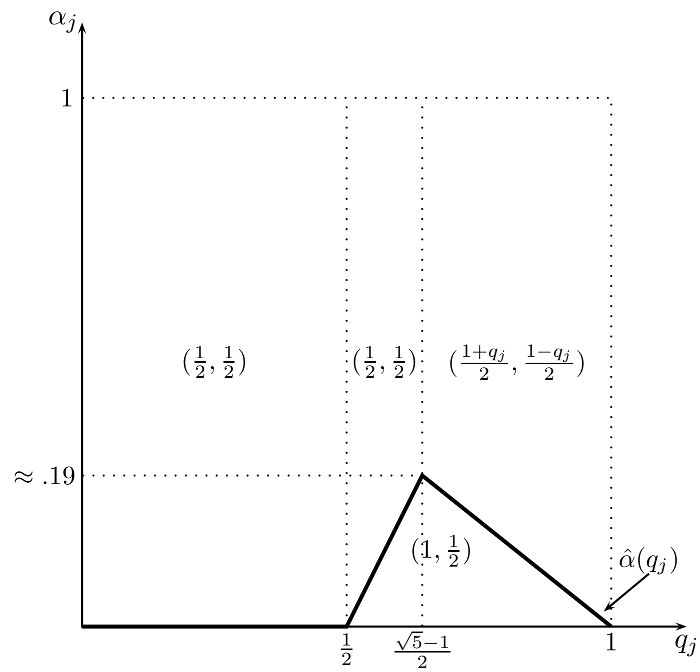

Figure 2: Sellers' equilibrium prices $(p_i^*(s_i), p_j^*(s_j|s_i))$

This requires a price coordination with seller j. Clearly, if seller j is sufficiently powerful, seller i lowers his price to induce coordination; otherwise, seller i ignores the coordination problem and charges the full price of 1 (inside the triangle region in Figure 2). Note also that as the likelihood of having a low-value product j, q_j, increases, seller j's price decreases; but seller i's price is increasing in q_j only when α_j is large due to the coordination incentive. Otherwise, when α_j is small, seller i 's price is non-monotone in q_j, reaching its maximum for some intermediate level of q_j that eliminates the coordination incentive.

Armed with the equilibrium characterization, we now investigate the buyer's sequencing choice.

4 Strategic Sequencing

A key observation from Proposition 2 is that for a fixed sequence of negotiations, the sellers' bargaining powers and the buyer's payoff uncertainty each influence equilibrium prices. The buyer can also influence these prices by strategically sequencing the sellers. To establish a benchmark, we first note that the sequencing is inconsequential to the buyer if an efficient trade is obtained.

Proposition 3. (Efficiency) *Equilibrium trade is efficient irrespective of the sequence if and only if* $q_i \notin (\frac{1}{2}, 1)$, *or equivalently* $\widehat{\alpha}(q_i) = 0$, *for* $i = 1, 2$. *In addition, if* $q_i \notin (\frac{1}{2}, 1)$ *for* $i = 1, 2$, *then the buyer is indifferent to the sequencing.*

Recall that given the complementarity, efficient trade occurs whenever both goods are acquired with probability 1. In the absence of payoff uncertainty, i.e., $q_i \in \{0, 1\}$, it is intuitive that the sellers will perfectly coordinate their prices in equilibrium and induce a joint purchase irrespective of who makes the offer in each negotiation. This is also true when goods are sufficiently weak complements, namely $q_i \leq \frac{1}{2}$, because equilibrium prices still stay at their low level, $\frac{1}{2}$. Since, under an efficient trade, the extra surplus due to complementarity is captured by the sellers unless the buyer proposes in both negotiations, the buyer is indifferent to the sequence.[17]

Proposition 3 implies that the sequencing matters to the buyer only if the equilibrium trade is inefficient for at least one sequencing choice.[18] It also implies that the payoff uncertainty is the main source of inefficiency in our model. Our next finding uncovers how the buyer's sequencing choice depends on the sellers' bargaining powers.

Proposition 4. (Bargaining Powers) *Let* $q_i = q \in (\frac{1}{2}, 1)$, *and* $\alpha_1 < \alpha_2$. *Then,*

(a) *the buyer*

$$\begin{cases} \text{is indifferent to the sequence} & if \quad \alpha_1 < \alpha_2 < \widehat{\alpha}(q) \\ \text{strictly prefers the sequence } s_1 \to s_2 & if \quad \alpha_1 < \widehat{\alpha}(q) \leq \alpha_2 \\ \text{strictly prefers the sequence } s_2 \to s_1 & if \quad \widehat{\alpha}(q) \leq \alpha_1 < \alpha_2; \end{cases}$$

(b) *the buyer's sequencing choice (weakly) improves ex ante social surplus.*

According to part (a), when goods are strong but imperfect complements, the buyer is indifferent to the sequence if both sellers are weak bargainers, i.e., $\alpha_1 < \alpha_2 < \widehat{\alpha}(q)$. This indifference, however, is not due to efficient trade; rather switching the order would not alter the sellers' pricing behavior. In particular, the leading seller would set a noncoordinating price of 1 given that the follower is unlikely to make an offer against the buyer. This implies that if the buyer could increase the leading seller's concern for price coordination by switching

[17] It is readily verified that, regardless of the sequence, the buyer's expected payoff in this case is $\pi(b) = (1 - \alpha_1)(1 - \alpha_2) + \alpha_1(1 - \alpha_2)v^2 + \alpha_2(1 - \alpha_1)v^1$.

[18] We believe that this efficiency reasoning can explain why sequencing may or may not be nontrivial in other papers discussed in the Introduction.

the order, she would choose to do so. This is possible if the sellers' bargaining powers are sufficiently diverse in the sense that $\alpha_1 < \widehat{\alpha}(q) \leq \alpha_2$. In this case, the buyer strictly prefers to start negotiations with seller 1 because, being followed by a strong rival, seller 1 has an equilibrium incentive to coordinate prices by lowering his own. If, on the other hand, both sellers are sufficiently powerful such that $\widehat{\alpha}(q) \leq \alpha_1 < \alpha_2$, it is optimal for the buyer to start with seller 2 instead. Notice that with two sufficiently strong sellers, price coordination occurs in equilibrium irrespective of the sequence. Hence, the buyer's objective in this case is to prevent an aggressive price response in the second negotiation in the event that she receives a favorable offer in the first.[19] According to part (b), even though the buyer is not maximizing the social surplus per se, her sequencing choice (weakly) increases it. This observation is also consistent with Proposition 3 above: since the maximum social surplus is obtained irrespective of the sequence, the buyer is indifferent to the sequence.

In light of Proposition 4, it is worth noting that unlike the papers discussed in the Introduction, our model with a simple payoff uncertainty breaks the buyer's indifference to the sequence, and more importantly, shows that the optimal sequencing varies with the sellers' bargaining powers. Our model can further inform us about the sequencing decision when the buyer faces different levels of uncertainty about the objects' valuations.

Proposition 5. (Payoff Uncertainty) *Suppose that $\alpha_i = \alpha$, and that $q_1 \notin (\frac{1}{2}, 1)$ and $q_2 \in (\frac{1}{2}, 1)$. Then, the buyer strictly prefers to approach seller 1 first if $\alpha \geq \widehat{\alpha}(q_2)$, but she is indifferent to the order if $\alpha < \widehat{\alpha}(q_2)$.*

Proposition 5 indicates that the buyer will begin negotiations with the (stochastically) higher value seller if the sellers are sufficiently powerful. To see why, note that the leading seller always charges a price greater than the buyer's stand-alone value, and that with sufficiently powerful sellers, the buyer is likely to purchase only one good, namely that of the last seller. To ensure the lowest price by the last seller, the buyer first visits the high value seller 1 whose high price induces low coordinating price by seller 2.[20]

[19] Note that concealing a low price of 0 obtained from the first negotiation in order to prevent an aggressive response by the second seller would not work for the buyer. As mentioned earlier, since the buyer has an incentive to disclose a high price, a nondisclosure will be inferred as being 0 by the second seller.

[20] For a slightly more formal argument, suppose that α and q_2 are both close to 1. If the buyer sequences seller 1 first, then they charge coordination prices, $\left(\frac{1+q_2}{2}, \frac{1-q_2}{2}\right)$. In this case, the buyer obtains some surplus if she values good 2, yielding an expected surplus: $(1-q_2)(\frac{1}{2} - \frac{1-q_2}{2}) > 0$. On the other hand, if the buyer sequences seller 2 first, then the sellers charge moderate prices, $\left(\frac{1}{2}, \frac{1}{2}\right)$, leaving (virtually) no surplus to the buyer.

5 Benefits of Being a Weak Buyer

Up to now, two robust insights have emerged from our analysis. First, the buyer cares about the negotiation sequence when equilibrium trade is inefficient *and* at least one seller is a powerful bargainer. Second, to the extent that he is followed by a powerful rival, the leading seller will care about price coordination and reduce his price. These insights raise the following question: would the buyer ever prefer sellers with *greater* bargaining powers, or equivalently would the buyer ever prefer to be in a *weaker* bargaining position against the sellers? The answer to this question can indeed be affirmative.

Proposition 6. (Being a Weak Buyer) *Suppose* $q_i = q$, *and that* $\alpha^L = (\alpha_1, \alpha_2^L)$ *and* $\alpha^H = (\alpha_1, \alpha_2^H)$ *are two bargaining power profiles where* $\alpha_2^L < \alpha_2^H$.

(a) *For* $q \in (\frac{1}{2}, 1)$, *let* $\alpha_1 \neq \widehat{\alpha}(q)$, $\alpha_2^L = \widehat{\alpha}(q) - \Delta$, *and* $\alpha_2^H = \widehat{\alpha}(q) + \Delta$. *Then, there is some* $\overline{\Delta} > 0$ *such that the buyer is strictly better off under* α^H *than under* α^L *for all* $\Delta \in (0, \overline{\Delta})$.

(b) *For* $q \notin (\frac{1}{2}, 1)$, *the buyer is strictly worse off under* α^H *than under* α^L.

Part (a) follows from Proposition 4. When goods are strong but imperfect complements, equilibrium trade is inefficient, which means that there is room for improving social surplus by strategically sequencing the sellers. The buyer can, however, increase the surplus *and* claim a portion of this increase only if the sellers soften their pricing behaviors. As argued above, this is possible when the leading seller is followed by a sufficiently powerful rival who will be demanding against the buyer. Thus, while, for fixed prices, powerful sellers will have a negative *direct effect* on the buyer's payoff, they may also have a positive *strategic effect* on her payoff through pricing. Part (a) demonstrates that when the sellers' bargaining powers are not too high, the strategic effect dominates. That is, the buyer may prefer to be in a weaker bargaining position against the sellers.

To illustrate this observation more formally, consider $\alpha_1 < \widehat{\alpha}(q)$ and $q \in (\frac{1}{2}, \frac{\sqrt{5}-1}{2})$. When faced with the sellers whose bargaining powers are α_1 and $\alpha_2^L = \widehat{\alpha}(q) - \Delta$, Proposition 4 implies that the buyer is indifferent to the sequence, because both sellers are weak and they price aggressively regardless of the sequence. Suppose, without loss of generality, that the buyer bargains with seller 1 first in this case. Then, from Proposition 2, equilibrium prices are $(p_1^*(s_1), p_2^*(s_2|s_1)) = (1, \frac{1}{2})$ and $p_2^*(s_2|b) = 1$. Conditioning on each possible realization of the proposers, the buyer's ex ante payoff is found to be:

$$\pi(b|\alpha^L) = (1-\alpha_1)(1-\alpha_2^L) + \alpha_1(1-\alpha_2^L)(1-q)\frac{1}{2} + (1-\alpha_1)\alpha_2^L(1-q)\frac{1}{2}. \tag{4}$$

On the other hand, when faced with the sellers whose bargaining powers are α_1 and $\alpha_2^H = \widehat{\alpha}(q) + \Delta$, the buyer *optimally* negotiates with seller 1 first, resulting in (weakly) *lower* prices $(p_1^*(s_1), p_2^*(s_2|s_1)) = (\frac{1}{2}, \frac{1}{2})$, and $p_2^*(s_2|b) = 1$. Using these prices, the buyer's expected payoff is found to be:

$$\pi(b|\alpha^H) = (1-\alpha_1)(1-\alpha_2^H) + \alpha_1(1-\alpha_2^H)\frac{1}{2} + (1-\alpha_1)\alpha_2^H(1-q)\frac{1}{2}. \tag{5}$$

Comparing (4) and (5), it follows that $\pi(b|\alpha^L) < \pi(b|\alpha^H)$ for all $\Delta \in (0, \frac{\alpha_1}{4+2q(2-3\alpha_1)})$. That is, given $\alpha_1 < \widehat{\alpha}(q)$, the buyer strictly prefers to deal with seller 2 whose bargaining power is $\alpha_2^H = \widehat{\alpha}(q) + \Delta$ rather than $\alpha_2^L = \widehat{\alpha}(q) - \Delta$ so long as Δ is small.

Part (b) of Proposition 6 simply says that when equilibrium trade is efficient, the buyer wants to be in a stronger bargaining position against the sellers. In this case, sequencing does not improve the social surplus or generate a positive strategic effect on the buyer's payoff.

Proposition 6 implies that it may sometimes be in the buyer's best interest to limit her own bargaining power vis-à-vis the sellers. If this power comes from forming buyer alliances and cooperatives, our result says that there may be strategic reasons for the buyer to cap the size of the alliance. Our prediction for the adverse effect of the "buyer power" on the buyer herself is consistent with those in the literature, e.g., Chipty and Snyder (1999), Horn and Wolinsky (1988), and Inderst and Wey (2003), though our reasoning is quite different.[21] By focusing on efficient bilateral negotiations (often through using the Nash Bargaining Solution), these papers show that increased buyer power through mergers is not necessarily beneficial to the buyer, and its benefit crucially depends on the curvature of the value created by the mergers. In contrast, our comparative static result in part (a) underlines the impact of buyer power on the potential for inefficient bargaining with the suppliers while keeping the surplus fixed. In fact, when bargaining is always efficient, part (b) of Proposition 6 reveals that the buyer is always better off having more power.

Proposition 6 also has other important implications for organizational procurement policies, and we next address two such policies.

[21] There is a relatively vast literature on *buyer power*, which is ably surveyed by Inderst and Mazzarotto (2009). Consistent with our model, these authors define buyer power as "the bargaining strength that a buyer has with respect to the suppliers with whom it trades."

5.1 Minimum Purchase Price

One reason why the sellers may price aggressively in our model is that in equilibrium, the buyer always makes the lowest price offer, namely the marginal-cost, 0. While this is the buyer's optimal choice whenever she proposes, it also leaves a large surplus for the sellers to claim. In particular, it may entice the leading seller to disregard price coordination with the follower and target the buyer's entire surplus of 1 instead. The next proposition shows that the buyer can partially control this aggressive behavior by the leader and secure more of the surplus herself by committing to paying a *positive* price.

Proposition 7. (Being a Generous Buyer) *Let $q_i = q$ and $\alpha_i = \alpha$. Suppose that prior to negotiations, the buyer commits to paying at least $w \geq 0$ for each unit she purchases. Then,*

(a) *for $q \in (\frac{1}{2}, 1)$, there exists $\underline{\alpha} \in (0, \widehat{\alpha}(q))$ such that the buyer optimally sets $w > 0$ for all $\alpha \in [\underline{\alpha}, \widehat{\alpha}(q))$.*

(b) *for $q \notin (\frac{1}{2}, 1)$, the buyer optimally sets $w = 0$ for all α.*

Part (a) of Proposition 7 indicates that for strong but imperfect complements, it may be in the buyer's best interest to commit to paying a positive price even when she makes the offers. Consistent with Proposition 6, the buyer intentionally weakens her bargaining position through a minimum payment to better manage the competition between the sellers. It is evident that any positive payment by the buyer will allow the sellers to earn positive profits regardless of who makes the offer while reducing the buyer's own payoff. Thus, to be beneficial to the buyer, any such payment must change the sellers' strategic pricing in the buyer's favor. This is most easily seen with the weak sellers who, as explained before, tend to price aggressively. When the buyer commits to paying at least $w > 0$ per unit, each seller knows that the maximum surplus is $1 - w$ instead of 1. This reduced surplus makes a non-coordinating pricing strategy by the leading seller less attractive, and for an optimally set $w > 0$, it may lead to a coordinating equilibrium in which supply prices are more moderate. Note that an upfront commitment to $w > 0$ is crucial here, because, once the leading seller lowers his price offer, the buyer has a strict incentive to lower her offer to 0 in the second negotiation whenever she proposes.

Part (b) of Proposition 7 is also in line with Proposition 6: when equilibrium trade is efficient irrespective of the sequence, there is no strategic value of a positive purchase price, and hence it is optimally set to be 0.

It is worth noting that a positive price offer is optimal for a powerful buyer given that $\widehat{\alpha}(q) < 0.19$. Hence, our result in part (a) might suggest that even without quality or ethical concerns, participating in a "fair trade" agreement that sets a minimum negotiation price can be in the best interest of powerful buyers.[22] In the same vein, large employers might favor minimum wage regulations when hiring new employees.

5.2 The Make-or-Buy Decision

A critical decision for many industrial buyers is whether to make inputs internally or outsource them from independent suppliers. Conventional wisdom suggests that an input should be made in-house if its internal cost of production is less than the price charged by the outside supplier. This simple criterion would apply if a single input were required for a final product.[23] However, if two complementary inputs are required, as in the present setting, the following result shows that the buyer may optimally outsource an input even if it could be costlessly provided in-house.

Proposition 8 (Outsourcing). *Suppose that the buyer can costlessly make input 1 in-house, which has no stand-alone value, $q_1 = 1$. Also, suppose that $\alpha_i = \alpha$. Then, the buyer is strictly better off outsourcing both inputs than only input 2 if $q_2 > \frac{\sqrt{5}-1}{2}$ and $\alpha > \frac{1+q_2^2}{1+q_2}$.*

Proposition 8 says that when inputs are strong complements *and* suppliers are powerful bargainers, the "naive" decision of making the zero-cost input in-house while outsourcing the other cannot be optimal for the buyer. In particular, it is strictly better for the buyer to outsource both inputs in this case. The reason is twofold. First, given the high degree of complementarity, the surplus generated by the internal production of input 1 at zero cost is likely to be shared with supplier 2 at the negotiation. Second, we know from Proposition 1 that two powerful suppliers would have the greatest incentives to coordinate and lower their prices. To interpret this result slightly differently, note that for the buyer, internally producing input 1 is equivalent to outsourcing the same input but having all the bargaining power vis-à-vis supplier 1. Proposition 6, however, has informed us that the buyer may sometimes prefer to be in a weaker bargaining position against the sellers, or in this case, outsource input 1 rather than make it in-house.

[22] According to the Fairtrade Foundation of the UK, the minimum price set by the Fairtrade Labelling Organizations International "...is not a fixed price, but should be seen as the lowest possible starting point for price negotiations between producer and purchaser." See www.fairtrade.org.uk.

[23] The make-or-buy decision can, of course, be complicated by various other factors that we ignore here such as asset specificity and incomplete contracts (see, e.g., Williamson (2005) for a recent survey).

Two observations are in order. First, when goods are strong complements and suppliers are powerful bargainers, Proposition 8 implies that the buyer is likely to follow an *all-or-nothing* sourcing strategy. The optimal decision will, however, depend on suppliers' bargaining powers, complementarity, and the total internal cost of production.[24]Second, our finding that the buyer may outsource even without a cost disadvantage complements other strategic explanations for the same phenomenon. For instance, Arya, Mittendorf, and Sappington (2008) have demonstrated that a retail competitor may pay a premium to outsource production to a common supplier in order to raise its rivals' costs through unfavorable supply deals. In contrast, in our model, a single firm outsources production to raise its *own* cost for an input to receive a favorable deal from the other supplier of a complementary input.

6 First- vs. Second-Mover Advantages for Sellers

So far we have focused on the buyer's preference over the negotiation sequence since she is the central agent who initiates the negotiations. It is, however, conceivable that the sellers will also have a preference. In particular, if, all else equal, the sellers expect a higher profit from being the first to negotiate with the buyer than being the second, then they may actively solicit the buyer's business by offering a discount for the right to be the first. If, on the other hand, the sellers expect a greater profit from being the second to negotiate, then no such solicitation should take place. Let $\pi^l(s_i)$ and $\pi^f(s_i)$ denote seller i's expected profits from being the leader or the follower in the negotiations, respectively. Then, we have

Proposition 9 (First- and Second-Mover Advantages). *Let* $q_1 = q_2 = q$ and $\alpha_1 = \alpha_2 = \alpha$. *Then,*

$$\pi^l(s_i) - \pi^f(s_i) \begin{cases} = 0 & if \quad q \leq \frac{1}{2} \\ < 0 & if \quad \frac{1}{2} < q \leq \frac{\sqrt{5}-1}{2} \\ < 0 & if \quad q > \frac{\sqrt{5}-1}{2} \text{ } and \text{ } \alpha < \frac{2-q-q^2}{1+q} \\ > 0 & if \quad q > \frac{\sqrt{5}-1}{2} \text{ } and \text{ } \alpha > \frac{2-q-q^2}{1+q}. \end{cases}$$

According to Proposition 9, there is a first-mover advantage if the sellers are strong bargainers *and* goods are likely to be perfect complements. Otherwise, there is a second-mover

[24]Note that we intentionally assumed in Proposition 8 that the cost of producing input 1 is zero; but the internal cost of both inputs can be some $K \geq 0$, leaving a surplus of $1 - K$ in case of an all in-house production.

advantage, except for when trade is efficient, i.e., $q \leq \frac{1}{2}$, in which case no first- or second-mover advantage exists. Consider, for instance, the case of perfect complements, $q = 1$. From Proposition 1, we know that with perfect complements, the leading seller sets the most aggressive price of 1 because he knows that the follower will have to accommodate by a price of 0, yielding $\pi^l(s_i) = \alpha$ and $\pi^f(s_i) = \alpha(1-\alpha)$. When complementarity is high but imperfect, i.e., $q > \frac{\sqrt{5}-1}{2}$, there is still a first-mover advantage if the leader makes the offer with a sufficiently high probability. Otherwise, there will be a second-mover advantage since the follower can then have a significant chance to claim the buyer's entire surplus if the buyer ends up proposing in the first negotiation.

It is worth comparing our observations from Proposition 9 with those from the standard duopoly theory in which the sellers are price-setters, i.e, $\alpha \to 1$. For complementary products, the IO literature has established the presence of a first-mover advantage for duopolists (e.g., Gal-Or 1985, and Dowrick 1986). This is in line with our result when $q > \frac{\sqrt{5}-1}{2}$. However, a switch to the second-mover advantage occurs in our model as the buyer becomes more powerful so that she is no longer a price-taker. The second-mover advantage also arises in our model when $q \in (\frac{1}{2}, \frac{\sqrt{5}-1}{2}]$ because the second seller can charge a (weakly) higher price than the first.[25]

7 Concluding Remarks

Unlike the standard consumer theory, the buyer is not a simple price-taker in many real examples; rather she is a powerful agent who actively negotiates the price with the sellers. The negotiations grow complicated when there are multiple sellers, because it is often infeasible for all interested parties to meet. In such situations, a key strategic decision for the buyer is how to sequence the bilateral negotiations. In this paper, we have focused on the sellers of complementary goods, and included the possibility that the buyer can be uncertain of her valuations. Our first set of results have revealed that to the extent that equilibrium trade is efficient, the buyer will be neutral to the sequence. We believe that this efficiency reasoning is also the driving force behind the similar "indifference" findings in the literature. When equilibrium trade is inefficient (due to the uncertainty in our model), however, the buyer can

[25] There is an extensive IO literature identifying a second-mover advantage by enriching the standard duopoly model. Most related to our work are the papers with demand uncertainty where the strategic action of the leader has a signaling value, which is not the case in ours. See, e.g., Daughety and Reinganum (1994), Gal-Or (1987), and Mailath (1987).

have a strict preference over the sequence, depending, e.g., on the sellers' bargaining powers.

Our second set of results have revealed that the buyer may sometimes raise her own cost of acquisition to better manage the suppliers' competition. In particular, with complementary goods, securing a low price in one negotiation leaves a large surplus to the seller in the other, encouraging him to be more demanding. To restrain this behavior, we find that the buyer may commit to giving up some of her surplus up front to obtain more favorable prices later. This commitment can manifest itself in the form of a procurement policy such as a minimum purchase price or the outsourcing of an input when it can be made in-house at the same cost.

At the core of our investigation lies the assumption that the buyer can be uncertain of her valuations. While this fits well with the applications in which it is prohibitively costly for the buyer to discover all her valuations without meeting with the sellers, the cost of information can be low in other applications. For instance, with the recent advent of the internet, an employer may find out much more easily about job candidates through their websites before scheduling a meeting. In such cases, it would be interesting to determine the buyer's incentive to invest in this information prior to negotiations given that her sequencing choice can (partially) signal her valuations to the sellers. Another assumption we have maintained throughout is that goods are complementary. We have done this intentionally here to focus our analysis since the case of substitutes appears to have some qualitative differences that deserve separate investigation.

Appendix A

Proofs of Propositions 1 and 2. Suppose, without loss of generality, that the buyer negotiates with s_i first, and that p_i is the resulting price. When negotiating with s_j, it is clear that the buyer proposes $P_j(b|p_i) = 0$ regardless of p_i. To derive s_j's best price response, $P_j(s_j|p_i)$, let $\overline{q}_i$ denote s_j's belief that $v^i = 0$ conditional on p_i. Note that for any p_i, s_j realizes a sale if and only if

$$\max\{1 - p_i - P_j(s_j|p_i), v^j - P_j(s_j|p_i)\} \geq \max\{v^i - p_i, 0\}.$$

We exhaust two possibilities for p_i. If $p_i \leq \frac{1}{2}$, then $\max\{1-p_i - P_j(s_j|p_i), v^j - P_j(s_j|p_i)\} = 1-p_i - P_j(s_j|p_i)$. Thus, given the two possible realizations of v_i, s_j can either charge a price of $1-p_i$, selling his good only when $v^i = 0$, or charge a price of $\frac{1}{2}$, selling his good with certainty. Comparing his respective payoffs, $\bar{q}_i(1-p_i)$ and $\frac{1}{2}$, from these two pricing options, it follows that $P_j(s_j|p_i) = 1 - p_i$ if $p_i < 1 - \frac{1}{2\overline{q}_i}$, and $P_j(s_j|p_i) = \frac{1}{2}$ if $1 - \frac{1}{2\overline{q}_i} \leq p_i \leq \frac{1}{2}$. Next, consider $p_i > \frac{1}{2}$. Then, since $v^i \leq \frac{1}{2}$, good i is purchased only if the buyer acquires both units. Given this, s_j can either set a coordinating price of $1 - p_i$ and sell his unit with certainty, or he can set a price of $\frac{1}{2}$ and sell only his own unit when $v^j = \frac{1}{2}$. Comparing the respective payoffs, $1 - p_i$ and $(1 - q_j)\frac{1}{2}$, it follows that $P_j(s_j|p_i) = 1 - p_i$ if $\frac{1}{2} < p_i \leq \frac{1+q_j}{2}$, and $P_j(s_j|p_i) = \frac{1}{2}$ if $p_i > \frac{1+q_j}{2}$. To summarize,

$$P_j(s_j|p_i) = \begin{cases} 1 - p_i & if \quad 0 \leq p_i < 1 - \frac{1}{2\overline{q}_i} \\ \frac{1}{2} & if \quad 1 - \frac{1}{2\overline{q}_i} \leq p_i \leq \frac{1}{2} \\ 1 - p_i & if \quad \frac{1}{2} < p_i \leq \frac{1+q_j}{2} \\ \frac{1}{2} & if \quad p_i > \frac{1+q_j}{2}. \end{cases} \tag{A-1}$$

Turning to the first negotiation, note that the buyer would never offer $p_i(b) > \frac{1}{2}$; otherwise she would lose the option of purchasing only good i. A price offer of $p_i(b) = \frac{1}{2}$ can also be ruled out since it will allow s_j to extract all the buyer's surplus by charging $P_j(s_j|\frac{1}{2}) = \frac{1}{2}$. Note also that the lowest price that s_i would charge is $p_i(s_i) = \frac{1}{2}$ (as claimed in Proposition 1), because, given that $P_j(s_j|\frac{1}{2}) = \frac{1}{2}$, this is the highest price that would guarantee a sale. Thus, if $p_i \in [0, \frac{1}{2})$, then s_j would *infer* that the buyer was the proposer in the first negotiation. Next, we show that $p_i(b) = 0$ for all v_i resulting in $\bar{q}_i = q_i$. Note that for $p_i \in [0, \frac{1}{2})$, $p_i(b) = 1 - \frac{1}{2\overline{q}_i}$ is sufficient to induce the lower price response, namely $P_j(s_j|p_i) = \frac{1}{2}$, so long as $1 - \frac{1}{2\overline{q}_i} \geq 0$. If, however, $1 - \frac{1}{2\overline{q}_i} < 0$, then the buyer optimally offers $p_i(b) = 0$ independent of v^i. This means that if $q_i < \frac{1}{2}$, then $\bar{q}_i = q_i$. Suppose $q_i \geq \frac{1}{2}$. In this case, the expected payoff of the buyer with $v^i = \frac{1}{2}$ is $\alpha_j[\frac{1}{2} - p_i(b)] + (1-\alpha_j)[1-p_i(b)]$, which is clearly maximized at $p_i(b) = 0$. This implies that the buyer with $v^i = 0$ cannot do any better than setting $p_i(b) = 0$ either, since $p_i(b) \in (0, \frac{1}{2})$ would reveal her low valuation in equilibrium and result in a response $P_j(s_j|p_i) = 1 - p_i > \frac{1}{2}$. Therefore, in equilibrium, $p_i^*(b) = 0$ and $\overline{q}_i = q_i$, i.e., s_j *cannot* learn anything about v^i from the buyer's price offer, as claimed in Proposition 1. Part (a) of Proposition 2 follows immediately from $\bar{q}_i = q_i$ and $p_j^*(s_j|b) = P_j(s_j|0)$.

To prove part (b) of Proposition 2, we examine the equilibrium pricing by s_i. We have already argued that $p_i(s_i) \geq \frac{1}{2}$. Note that $p_i(s_i) = \frac{1+q_j}{2}$ is the optimal price for s_i in $(\frac{1}{2}, \frac{1+q_j}{2}]$, since, by (A-1), $P_j(s_j|p_i) = 1 - p_i < \frac{1}{2}$, and s_i makes a sale with the same probability q_j, i.e., if $v^j = 0$. Finally, for any price offer in $(\frac{1+q_j}{2}, 1]$, s_i makes a sale with the same probability $(1-\alpha_j)q_j$, i.e., if the buyer is the proposer for good j and $v^j = 0$. This means that $p_i(s_i) = 1$ is the optimal price for s_i in the region $(\frac{1+q_j}{2}, 1]$. In sum, s_i chooses a price among candidates, $\frac{1}{2}$, $\frac{1+q_j}{2}$, and 1, yielding expected payoffs, $\frac{1}{2}$, $\frac{1+q_j}{2}q_j$, and $(1-\alpha_j)q_j$, respectively. Defining $\widehat{\alpha}(q_j)$ as in (3), it is clear that if $\alpha_j < \widehat{\alpha}(q_j)$, then $p_i^*(s_i) = 1$, resulting in $P_j(s_j|p_i^*(s_i)) = \frac{1}{2}$. If, however, $\alpha_j \geq \widehat{\alpha}(q_j)$, then s_i compares payoffs, $\frac{1}{2}$ and $\frac{1+q_j}{2}q_j$, resulting in

$$p_i^*(s_i) = \begin{cases} \frac{1}{2} & if \quad q_j \leq \frac{\sqrt{5}-1}{2} \\ \frac{1+q_j}{2} & if \quad q_j > \frac{\sqrt{5}-1}{2} \end{cases} \quad \text{and } P_j(s_j|p_i^*(s_i)) = \begin{cases} \frac{1}{2} & if \quad q_j \leq \frac{\sqrt{5}-1}{2} \\ \frac{1-q_j}{2} & if \quad q_j > \frac{\sqrt{5}-1}{2} \end{cases}.$$

Finally, the uniqueness of the equilibrium asserted in Proposition 1 follows by construction.

■

Proof of Proposition 3. Recall that the efficient trade occurs in our model whenever the buyer purchases both goods with certainty, resulting in expected social surplus, $SS = 1$. Suppose that s_i is approached first. Then, the expected equilibrium social surplus is given by

$$\begin{aligned} SS_{ij} &= (1-\alpha_i)(1-\alpha_j) + \alpha_i(1-\alpha_j)\left[q_j + (1-q_j)\left(\frac{1}{2} + \frac{1}{2}\mathbf{1}(p_i^*(s_i) \leq \frac{1}{2})\right)\right] + \qquad \text{(A-2)} \\ &+(1-\alpha_i)\alpha_j\left[q_i + (1-q_i)\left(\frac{1}{2} + \frac{1}{2}\mathbf{1}(p_j^*(s_j|b) \leq \frac{1}{2})\right)\right] + \\ &+\alpha_i\alpha_j\left[q_j\mathbf{1}(p_i^*(s_i) + p_j^*(s_j|s_i) \leq 1) + (1-q_j)\left(\frac{1}{2} + \frac{1}{2}\mathbf{1}(p_i^*(s_i) \leq \frac{1}{2})\right)\right], \end{aligned}$$

where $\mathbf{1}(\cdot)$ stands for the indicator function. The first term for SS_{ij} accounts for the possibility that the buyer is the proposer in both negotiations, in which case she purchases both goods with certainty at 0 price. The second term accounts for the possibility of s_i being the proposer in the first negotiation and the buyer in the second. Then, the buyer purchases both goods whenever $v^j = 0$ and purchases only good j if $v^j = \frac{1}{2}$ and $p_i^*(s_i) > \frac{1}{2}$. Similarly, the third term accounts for the possibility of s_j being the proposer in the second negotiation and the buyer in the first. Finally, the last term accounts for the sellers making price offers in each negotiation. Since $p_i^*(s_i) \geq \frac{1}{2}$, for $v^j = 0$, the buyer will purchase both goods if the sum of the prices does not exceed 1. For $v^j = \frac{1}{2}$, the buyer will opt for purchasing good j only if $p_i^*(s_i) > \frac{1}{2}$. Taking into account the equilibrium prices derived in Proposition 2, it is straightforward to verify that $SS_{12} = SS_{21} = 1$ whenever $q_i \notin (\frac{1}{2}, 1)$ for $i = 1, 2$. Otherwise, if $q_i \in (\frac{1}{2}, 1)$ for some i, then $p_j^*(s_j|b) = 1$ and from equation (A-2) it is straightforward to verify that $SS_{ij}^* < 1$. Thus, trade is efficient independent of the sequence if and only if $q_i \notin (\frac{1}{2}, 1)$ for $i = 1, 2$, or equivalently, $\widehat{\alpha}(q_i) = 0$ by Proposition 2.

Consider now the buyer's equilibrium expected payoff from approaching s_i first.

$$\begin{aligned} \pi_{ij}(b) \;=\;& (1-\alpha_i)(1-\alpha_j) + \alpha_i(1-\alpha_j)\left[q_j(1-p_i^*(s_i)) + (1-q_j)\frac{1}{2}\right] + \\ &+\alpha_j(1-\alpha_i)\left[q_i(1-p_j^*(s_j|b)) + (1-q_i)\frac{1}{2}\right] + \alpha_i\alpha_j(1-q_j)\left[\frac{1}{2} - p_j^*(s_j|s_i)\right]. \end{aligned} \tag{A-3}$$

If the buyer is the proposer in both negotiations, captured by the first term in equation (A-3), then she realizes a payoff of 1. If the buyer is a proposer only in the second period, she gets a payoff of $1 - p_i^*(s_i)$ if $v^j = 0$ since then she purchases both goods. If instead, $v^j = \frac{1}{2}$, she can ensure a payoff of $\frac{1}{2}$. Similarly, the third term accounts for the possibility of s_j being a proposer in the second negotiation and the buyer in the first. Finally, if the sellers are proposers in both negotiations, the buyer can realize a positive payoff only if $v^j = \frac{1}{2}$ and the second seller charges a price lower than $\frac{1}{2}$ resulting in a payoff of $\frac{1}{2} - p_j^*(s_j|s_i)$. It is straightforward to verify that for $q_i \notin (\frac{1}{2}, 1)$ and $i = 1, 2$ we have $\pi_{12}(b) = \pi_{21}(b)$. ■

Proof of Proposition 4. Let $q_1 = q_2 = q \in (\frac{1}{2}, 1)$ and $\alpha_1 < \alpha_2$. We prove both parts together. Suppose that $\alpha_1 < \alpha_2 < \widehat{\alpha}(q)$. Then, given the equilibrium prices from Proposition 2 and equation (A-3), it follows that $\pi_{12}(b) - \pi_{21}(b) = 0$. Moreover, from equation (A-2), $SS_{12} - SS_{21} = 0$ in this case.

Next, suppose that $\alpha_1 < \widehat{\alpha}(q) \leq \alpha_2$. Then, Proposition 2 and equation (A-3) result in $\pi_{12}(b) - \pi_{21}(b) = \alpha_1(1-\alpha_2)q(1-p_1^*(s_1)) + \alpha_1\alpha_2(1-q)[p_1^*(s_1) - \frac{1}{2}] > 0$ since $p_1^*(s_1) \geq \frac{1}{2}$. Therefore, the buyer is strictly better off approaching s_1 first. Moreover, from equation (A-2), $SS_{12} - SS_{21} = \alpha_1(1-\alpha_2)\frac{1}{2}\mathbf{1}(p_1^*(s_1) \leq \frac{1}{2}) + \alpha_1\alpha_2[q + (1-q)\frac{1}{2}\mathbf{1}(p_1^*(s_1) \leq \frac{1}{2})] > 0$.

Finally, suppose that $\widehat{\alpha}(q) \leq \alpha_1 < \alpha_2$. Then, by Proposition 2, $p_1^*(s_1) = p_2^*(s_2)$ and

$p_1^*(s_1|\sigma_2^*) = p_2^*(s_2|\sigma_1^*)$. Using equation (A-3), we find that $\pi_{12}(b) - \pi_{21}(b) = (\alpha_1 - \alpha_2)q\left[1 - p_1^*(s_1)\right] < 0$. Thus, the buyer will choose to negotiate with s_2 first. Moreover, from equation (A-2), $SS_{12} - SS_{21} = (\alpha_1 - \alpha_2)\frac{1}{2}\mathbf{1}(p_1^*(s_1) \leq \frac{1}{2}) \leq 0$. ■

Proof of Proposition 5. Let $\alpha_1 = \alpha_2 = \alpha$ and $q_1 \notin (\frac{1}{2}, 1)$ and $q_2 \in (\frac{1}{2}, 1)$. From Proposition 2, $\widehat{\alpha}(q_1) = 0$ and $\widehat{\alpha}(q_2) > 0$. Depending on α, we consider three subcases:

$\underline{\alpha \geq \widehat{\alpha}(q_2) \text{ and } q_2 \in (\frac{1}{2}, \frac{\sqrt{5}-1}{2}]}$: Then, by equation (A-3), $\pi_{12}(b) - \pi_{21}(b) = \alpha(1-\alpha)\frac{q_2}{2} > 0$.

$\underline{\alpha \geq \widehat{\alpha}(q_2) \text{ and } q_2 \in (\frac{\sqrt{5}-1}{2}, 1)}$: Then, by equation (A-3), $\pi_{12}(b) - \pi_{21}(b) = \alpha^2(1-q_2)\frac{q_2}{2} > 0$.

$\underline{\alpha < \widehat{\alpha}(q_2)}$: Then, by equation (A-3), $\pi_{12}(b) - \pi_{21}(b) = 0$.

Hence, the buyer strictly prefers to first negotiate over product 1 for $\alpha \geq \widehat{\alpha}(q_2)$, and she is indifferent to the sequence for $\alpha < \widehat{\alpha}(q_2)$. ■

Proof of Proposition 6.

a) Suppose that $q_i = q \in (\frac{1}{2}, 1)$, and that $\alpha_2^L = \widehat{\alpha}(q) - \Delta$, and $\alpha_2^H = \widehat{\alpha}(q) + \Delta$. We distinguish two cases for α_1:

- $\underline{\alpha_1 < \widehat{\alpha}(q)}$: From Proposition 4, the buyer is indifferent to the sequence under $\alpha^L = (\alpha_1, \alpha_2^L)$. Using equilibrium prices in Proposition 2, the buyer's expected payoff is found to be:

$$\pi_{12}(b|\alpha^L) = \pi_{21}(b|\alpha^L) = (1-\alpha_1)(1-\alpha_2^L) + \alpha_1(1-\alpha_2^L)(1-q)\frac{1}{2} + (1-\alpha_1)\alpha_2^L(1-q)\frac{1}{2}.$$

  - Under $\alpha^H = (\alpha_1, \alpha_2^H)$, Proposition 4 implies that the buyer optimally visits s_1 first. From Proposition 2 and equation (A-3), we have the following expected payoffs.
  - $q \in (\frac{1}{2}, \frac{\sqrt{5}-1}{2}] \Longrightarrow p_1^*(s_1) = p_2^*(s_2|s_1) = \frac{1}{2}$, yielding

$$\pi_{12}(b|\alpha^H) = (1-\alpha_1)(1-\alpha_2^H) + \alpha_1(1-\alpha_2^H)\frac{1}{2} + (1-\alpha_1)\alpha_2^H(1-q)\frac{1}{2}.$$

  - $q \in (\frac{\sqrt{5}-1}{2}, 1) \Longrightarrow p_1^*(s_1) = \frac{1+q}{2}$ and $p_2^*(s_2|s_1) = \frac{1-q}{2}$, yielding

$$\pi_{12}(b|\alpha^H) = (1-\alpha_1)(1-\alpha_2^H) + \alpha_1(1-\alpha_2^H)\frac{1-q^2}{2} + (1-\alpha_1)\alpha_2^H\frac{1-q}{2} + \alpha_1\alpha_2^H q\frac{1-q}{2}.$$

  A simple algebra shows that $\pi_{12}(b|\alpha^L) = \pi_{21}(b|\alpha^L) < \pi_{12}(b|\alpha^H)$ for any $\Delta \in (0, \overline{\Delta})$, where

$$\overline{\Delta} = \begin{cases} \frac{\alpha_1}{4+2q(2-3\alpha_1)} & if \quad q \in (\frac{1}{2}, \frac{\sqrt{5}-1}{2}] \\ \frac{\alpha_1 q(1-q)}{2+2q(1-2\alpha_1)} & if \quad q \in (\frac{\sqrt{5}-1}{2}, 1). \end{cases}$$

Clearly, $\overline{\Delta} > 0$. Moreover, it is readily verified that $\widehat{\alpha}(q) - \overline{\Delta} > 0$ and $\widehat{\alpha}(q) + \overline{\Delta} < 1$.

- $\underline{\alpha_1 > \widehat{\alpha}(q)}$: Under α^L, the buyer optimally visits s_2 first. Suppose that $\alpha_2^H < \alpha_1$, in which case the buyer optimally visits s_1 first. Then,

  - $q \in (\frac{1}{2}, \frac{\sqrt{5}-1}{2}] \Longrightarrow$

$$\pi_{21}(b|\alpha^L) = (1-\alpha_1)(1-\alpha_2^L) + \alpha_1(1-\alpha_2^L)(1-q)\frac{1}{2} + (1-\alpha_1)\alpha_2^L\frac{1}{2},$$

and

$$\pi_{12}(b|\alpha^H) = (1-\alpha_1)(1-\alpha_2^H) + \alpha_1(1-\alpha_2^H)\frac{1}{2} + (1-\alpha_1)\alpha_2^H(1-q)\frac{1}{2}.$$

Comparing the two payoffs, it follows that $\pi_{21}(b|\alpha^L) < \pi_{12}(b|\alpha^H)$ for any $\Delta \in (0, \overline{\Delta})$, where $\overline{\Delta} = \frac{q(\alpha_1 - \hat{\alpha}(q))}{2+q(1-2\alpha_1)} > 0$. It is easily shown that $\hat{\alpha}(q) - \overline{\Delta} > 0$ and $\hat{\alpha}(q) + \overline{\Delta} < \alpha_1$.

  - $q \in (\frac{\sqrt{5}-1}{2}, 1) \Longrightarrow$

$$\pi_{21}(b|\alpha^L) = (1-\alpha_1)(1-\alpha_2^L) + \alpha_1(1-\alpha_2^L)(1-q)\frac{1}{2} + (1-\alpha_1)\alpha_2^L\frac{1-q^2}{2} + \alpha_1\alpha_2^L(1-q)q\frac{1}{2},$$

and

$$\pi_{12}(b|\alpha^H) = (1-\alpha_1)(1-\alpha_2^H) + \alpha_1(1-\alpha_2^H)(1-q^2)\frac{1}{2} + (1-\alpha_1)\alpha_2^H(1-q)\frac{1}{2} + \alpha_1\alpha_2^H(1-q)q\frac{1}{2}.$$

Comparing the two payoffs, it follows that $\pi_{21}(b|\alpha^L) < \pi_{12}(b|\alpha^H)$ for any $\Delta \in (0, \overline{\Delta})$, where $\overline{\Delta} = \frac{q(1-q)(\alpha_1 - \hat{\alpha}(q))}{2+q^2+q(1-4\alpha_1)} > 0$, satisfying $\hat{\alpha}(q) - \overline{\Delta} > 0$ and $\hat{\alpha}(q) + \overline{\Delta} < \alpha_1$.

b) Suppose that $q_i = q \notin (\frac{1}{2}, 1)$. From Proposition 3, we know that the buyer is indifferent to the negotiation order, and by equation (A-3), her payoff is

$$\pi_{12}(b|\alpha_2) = \pi_{21}(b|\alpha_2) = (1-\alpha_1)(1-\alpha_2) + \alpha_1(1-\alpha_2)[q(1-p_1^*(s_1)) + (1-q)\frac{1}{2}] + \alpha_2(1-\alpha_1)[q(1-p_1^*(s_1)) + (1-q)\frac{1}{2}].$$

where $p_1^*(s_1) = p_2^*(s_2) = p_1^*(s_1|\sigma_2^*) = p_2^*(s_2|\sigma_1^*)$ for $q \notin (\frac{1}{2}, 1)$ by Proposition 2. Then, simple algebra shows that the r.h.s. is decreasing in α_2, establishing part (b). ■

Proof of Proposition 7. Let $q_i = q$ and $\alpha_i = \alpha$. Suppose that prior to negotiations, the buyer commits to paying at least $w \geq 0$ for each unit she purchases. Also, suppose, without loss of generality, that the buyer negotiates with s_i first. First we show that $w \geq \frac{1}{2}$ cannot optimal for the buyer. Under $w \geq \frac{1}{2}$, the buyer realizes a 0 payoff if she is the proposer in both negotiations. If she is the proposer only in the first negotiation, s_j extracts the remaining surplus by charging $P_j(s_j|w) = \begin{cases} 1-w & if \quad \frac{1}{2} \leq w \leq \frac{1+q}{2} \\ \frac{1}{2} & if \quad w > \frac{1+q}{2} \end{cases}$. Therefore, the only possible benefit from committing to $w \geq \frac{1}{2}$ is to induce a lower price by s_i. The lowest price offered by s_i is $P_i(s_i) = 1-w$ requiring $\alpha\frac{1}{2} < 1-w$ since from equation (A-1) we know that $\frac{1}{2}$ is accepted with certainty if s_j is the proposer in the second negotiation. From equation (A-1), $p_i(s_i) = 1-w$ results in a price response $P_j(s_j|1-w) = w$. Thus, the highest possible payoff for the buyer from setting $w \geq \frac{1}{2}$ is $\pi(b|w \geq \frac{1}{2}) = \alpha(1-\alpha)(1-q)(w-\frac{1}{2}) + \alpha^2(1-q)(w-\frac{1}{2})$. From equation (A-3), it is readily verified that $\pi(b|w=0) > \alpha(1-\alpha)(1-q) > \pi(b|w \geq \frac{1}{2})$ for all q and $\alpha\frac{1}{2} < 1-w$, establishing that the optimal $w < \frac{1}{2}$.

Next, consider $w \in [0, \frac{1}{2})$. Given (A-1), if s_i anticipates s_j making an offer in the second negotiation, she will choose between $p_i(s_i) \in \{\frac{1}{2}, \frac{1+q}{2}\}$. If, instead, s_i anticipates the buyer making an offer, then s_i has a chance of realizing a sale by setting $p_i(s_i) = 1-w$. Thus, s_i has three candidates for his optimal price: $p_i(s_i) \in \{\frac{1}{2}, \frac{1+q}{2}, 1-w\}$. While the price of $\frac{1}{2}$ is accepted with certainty, independent of who makes the offer in the second negotiation, the probability of acceptance of $1-w$ and $\frac{1+q}{2}$ depend on their relative magnitudes. If $w < (1-q)\frac{1}{2}$, then $\frac{1+q}{2}$ is accepted with probability q, and $1-w$ is accepted with probability $(1-\alpha)q$. If $w > (1-q)\frac{1}{2}$, then $\frac{1+q}{2}$ is accepted with probability $\alpha q\frac{1+q}{2}$, and $1-w$ is accepted with probability q. We now consider two regions for q as stated in the proposition.

(a) $q \in (\frac{1}{2}, 1)$: Since our goal is to establish the optimality of $w > 0$, we restrict attention to $w \in [0, \frac{1-q}{2})$. In this case, $p_i(s_i) = \frac{1}{2}$ is accepted with probability 1, $p_i(s_i) = \frac{1+q}{2}$ is accepted with probability q, and $p_i(s_i) = 1-w$ is accepted with probability $(1-\alpha)q$. Comparing s_i's payoff under these prices, we can derive the equilibrium prices (which reduce to those in Proposition 2 for $w = 0$):

$$p_j^*(s_j|b) = \begin{cases} 1-w & if \quad q > \frac{1}{2(1-w)} \\ \frac{1}{2} & if \quad q \leq \frac{1}{2(1-w)} \end{cases}.$$

$$(p_i^*(s_i), p_j^*(s_j|s_i)) = \begin{cases} (1-w, \frac{1}{2}) & if \quad \alpha < \hat{\alpha}(q,w) \\ (\frac{1+q}{2}, \frac{1-q}{2}) & if \quad \alpha \geq \hat{\alpha}(q,w) \text{ and } q > \frac{\sqrt{5}-1}{2} \\ (\frac{1}{2}, \frac{1}{2}) & if \quad \alpha \geq \hat{\alpha}(q,w) \text{ and } q \leq \frac{\sqrt{5}-1}{2} \end{cases}$$

where $\hat{\alpha}(q,w) = \begin{cases} 0 & if \quad q \leq \frac{1}{2(1-w)} \\ 1-\frac{1}{2q(1-w)} & if \quad q \in (\frac{1}{2(1-w)}, \frac{\sqrt{5}-1}{2}\ ] \\ 1-\frac{1+q}{2(1-w)} & if \quad q > \frac{\sqrt{5}-1}{2} \end{cases}$.

Note that for $w < \frac{1-q}{2}$, we have $q(1-w) > q\frac{1+q}{2}$ for all q. Therefore, $q' = \frac{1}{2(1-w)} < \frac{\sqrt{5}-1}{2} = q''$ since q' solves $\frac{1}{2} = q'(1-w)$ and q'' solves $\frac{1}{2} = q''\frac{1+q''}{2}$. Since the equilibrium pricing depends on q, we consider two subcases:

- $q \in (\frac{1}{2}, \frac{\sqrt{5}-1}{2}\ ]$: In this case, if $\alpha < \hat{\alpha}(q,0)$, the equilibrium will be one of non-coordination. Let $\underline{w}(\alpha,q) = 1-\frac{1}{2q(1-\alpha)}$ denote the minimum price that induces coordination by the sellers. Note that $\underline{w}(\alpha,q) < \frac{1-q}{2}$ since $q < \frac{\sqrt{5}-1}{2}$ implies that $\frac{1}{2q(1-\alpha)} > \frac{1}{2} > \frac{q(1+q)}{2}$. The equilibrium pricing in this case is $(p_i^*(s_i), p_j^*(s_j|s_i)) = (\frac{1}{2}, \frac{1}{2})$ and $p_j^*(s_j|b) = 1-w$ since $q(1-w) > \frac{1}{2}$. Thus, the buyer's payoff is

$$\pi(b|w=0) = (1-\alpha)^2 + \alpha(1-\alpha)(1-q)\frac{1}{2} + \alpha(1-\alpha)(1-q)\frac{1}{2} = (1-\alpha)(1-q\alpha).$$

$$\begin{aligned} \pi[b|w \quad &\geq \quad \underline{w}(\alpha,q)] = (1-\alpha)^2(1-2w) + \alpha(1-\alpha)(\frac{1}{2}-w) + \alpha(1-\alpha)(1-q)(\frac{1}{2}-w) \\ &= \quad \frac{(1-\alpha)(2-q\alpha)(1-2w)}{2}. \end{aligned}$$

Comparing the two payoffs, it follows that $\pi[b|w \geq \underline{w}(\alpha,q)] > \pi(b|w=0)$ for $w < \frac{\alpha q}{2(2-q\alpha)}$. Thus, there exists a $w > 0$ that strictly increases the buyer's payoff whenever $\underline{w}(\alpha,q) < \frac{\alpha q}{2(2-q\alpha)}$. Note that $\frac{\alpha q}{2(2-q\alpha)}$ is increasing in α and $\underline{w}(\alpha,q)$ is decreasing in α. Moreover, $\underline{w}(\hat{\alpha}(q,0),q) = 0$. Therefore, there exists $\alpha^c(q)$ such that for $\alpha \in (\alpha^c(q), \hat{\alpha}(q,0))$, we have $\pi[b|w = \underline{w}(\alpha,q)] > \pi(b|w=0)$.

- $q \in (\frac{\sqrt{5}-1}{2}, 1)$: In this case, for $\alpha < \hat{\alpha}(q,0)$, $\underline{w}(\alpha,q) = 1-\frac{1+q}{2(1-\alpha)} < \frac{(1-q)}{2}$. The equilibrium prices are $(p_i^*(s_i), p_j^*(s_j|s_i)) = (\frac{1+q}{2}, \frac{1-q}{2})$. In addition, $p_j^*(s_j|b) = 1-w$. Then,

$$\begin{aligned} \pi(b|w \quad &\geq \quad \underline{w}(\alpha,q)) = (1-\alpha)^2(1-2w) + \alpha(1-\alpha)\left[\frac{(1-q)^2}{2} - w\right] \\ &+\alpha(1-\alpha)(1-q)(\frac{1}{2}-w) + \alpha^2 q(1-q)\frac{1}{2}. \end{aligned}$$

Trivial algebra reveals that $\pi(b|w \geq \underline{w}(\alpha,q)) > \pi(b|w=0)$ for $w < \frac{\alpha(1-q)q}{2(1-\alpha)(2-q\alpha)}$. Thus, there exists a $w > 0$ that strictly increases the buyer's payoff whenever $\underline{w}(\alpha,q) < \frac{\alpha(1-q)q}{2(1-\alpha)(2-q\alpha)}$. Note that $\frac{\alpha(1-q)q}{2(1-\alpha)(2-q\alpha)}$ is increasing in α and $\underline{w}(\alpha,q)$ is decreasing in α. Moreover, $\underline{w}(\hat{\alpha}(q,0),q) = 0$. Therefore, there exists $\alpha^c(q)$ such that for $\alpha \in (\alpha^c(q), \hat{\alpha}(q,0))$, we have $\pi(b|w=\underline{w}(\alpha,q)) > \pi(b|w=0)$.

(b) $q \notin (\frac{1}{2},1)$: For $q \leq \frac{1}{2}$, it follows that $(p_i^*(s_i), p_j^*(s_j|s_i)) = (\frac{1}{2},\frac{1}{2})$ and $p_j^*(s_j|b) = \frac{1}{2}$ for all $w \in [0,\frac{1}{2})$ since $\frac{1}{2} > \frac{1}{2}(1-w) > q(1-w)$. The buyer's payoff is $\pi(b|w) = (1-\alpha)^2(1-2w) + 2\alpha(1-\alpha)(\frac{1}{2}-w)$, and it is decreasing in w. For $q=1$, we obtain $(p_i^*(s_i), p_j^*(s_j|s_i)) = \begin{cases} (1-w,w) & if \quad w \leq 1-\alpha \\ (1,0) & if \quad w > 1-\alpha \end{cases}$ and $p_j^*(s_j|b) = \begin{cases} 1-w & if \quad w \leq 1-\alpha \\ 1 & if \quad w > 1-\alpha \end{cases}$. The buyer's payoff is $\pi(b|w) = (1-\alpha)^2(1-2w)$. Thus, the buyer's optimal choice is $w=0$ for $q \notin (\frac{1}{2},1)$. ■

Proof of Proposition 8. Let $q_1 = 1$ and $q_2 \in (\frac{\sqrt{5}-1}{2},1)$. If the buyer makes input 1 and outsources only input 2, then $p_2^*(s_2) = 1$, in which case the buyer's expected payoff is $\pi^{Make}(b) = 1-\alpha$. Suppose now that she outsources both inputs. Then, by Proposition 5, the buyer first negotiates for input 1, leading to an expected payoff:

$$\pi^{Out}(b) = (1-\alpha)^2 + \alpha(1-\alpha)\frac{1-q_2^2}{2} + \alpha^2(1-q_2)\frac{q_2}{2}.$$

Then,

$$\pi^{Out}(b) - \pi^{Make}(b) = \frac{\alpha}{2}(1+q_2)\left(\alpha - \frac{1+q_2^2}{1+q_2}\right),$$

which implies that $\pi^{Out}(b) - \pi^{Make}(b) > 0$ if $\alpha > \frac{1+q_2^2}{1+q_2}$. ■

Proof of Proposition 9. Let $q_1 = q_2 = q$ and $\alpha_1 = \alpha_2 = \alpha$. Given Proposition 2, we have the following payoffs:

$$\pi^l(s_i) = \begin{cases} \alpha(1-\alpha)q & if \quad \alpha < \widehat{\alpha}(q) \\ \alpha q\frac{1+q}{2} & if \quad \alpha \geq \widehat{\alpha}(q) \text{ and } q > \frac{\sqrt{5}-1}{2} \\ \alpha\frac{1}{2} & if \quad \alpha \geq \widehat{\alpha}(q) \text{ and } q \leq \frac{\sqrt{5}-1}{2} \end{cases}$$

and

$$\pi^f(s_i) = \begin{cases} \alpha\left[(1-\alpha)q + \alpha(1-q)\frac{1}{2}\right] & if \quad \alpha < \widehat{\alpha}(q) \\ \alpha\left[1-\alpha+\alpha(1-q)\frac{1}{2}\right] & if \quad \alpha \geq \widehat{\alpha}(q) \text{ and } q > \frac{\sqrt{5}-1}{2} \\ \alpha\left[(1-\alpha)p_i^*(s_i|\sigma_j=b) + \alpha\frac{1}{2}\right] & if \quad \alpha \geq \widehat{\alpha}(q) \text{ and } q \leq \frac{\sqrt{5}-1}{2}. \end{cases}$$

For $q \leq \frac{1}{2}$, since $\widehat{\alpha}(q) = 0$, and $p_i^*(s_i|\sigma_j=b) = \frac{1}{2}$, we have $\pi^l(s_i) - \pi^f(s_i) = 0$. Suppose $q > \frac{1}{2}$. If $\alpha < \widehat{\alpha}(q)$, then $\pi^l(s_i) - \pi^f(s_i) = -\alpha^2(1-q)\frac{1}{2} < 0$. If $\alpha \geq \widehat{\alpha}(q)$ and $q \leq \frac{\sqrt{5}-1}{2}$, then

$\pi^l(s_i) - \pi^f(s_i) = -\alpha(1-\alpha)\frac{1}{2} < 0$. Thus, $\pi^l(s_i) - \pi^f(s_i) < 0$ if $\frac{1}{2} < q < \frac{\sqrt{5}-1}{2}$. Now, suppose that $\alpha \geq \widehat{\alpha}(q)$ and $q > \frac{\sqrt{5}-1}{2}$. Then, $\widehat{\alpha}(q) = \frac{1-q}{2}$, and $\pi^l(s_i) - \pi^f(s_i) = \alpha\frac{1+q}{2}[\alpha - \frac{2-q-q^2}{1+q}] =^{sign} \alpha - \frac{2-q-q^2}{1+q}$. It is straightforward to check that $\frac{2-q-q^2}{1+q} \geq \frac{1-q}{2}$. ■

Appendix B

As mentioned in the text, all of our results would remain qualitatively the same if we assumed a more general support for valuations. In particular, let $\Pr\{v^i = 0\} = q_i \in [0,1]$ and $\Pr\{v^i = v\} = 1 - q_i$, where $v \in [0, \frac{1}{2}]$. Then, we can state the following generalization of equilibrium characterization in Proposition 1, where $v = \frac{1}{2}$. Since the proof is also very similar to that of Proposition 1, we omit it here.

Proposition B1. *Suppose that the buyer negotiates with supplier i first. Then, there exists a unique (perfect Bayesian) equilibrium and it is characterized by these prices:*

(a) *the buyer proposes to pay the marginal cost in both negotiations: $p_i^*(b) = p_j^*(b|\sigma_i^*) = 0$;*

(b) *if the buyer makes the offer for product i, then seller j sets a price,*

$$p_j^*(s_j|b) = \begin{cases} 1 & if \quad q_i > 1-v \\ 1-v & if \quad q_i \leq 1-v, \end{cases}$$

(c) *if seller i makes the offer for product i, then the sellers set prices*

$$\left(p_i^*(s_i), p_j^*(s_j|s_i)\right) = \begin{cases} (1, v) & if \quad \alpha_j < \widehat{\alpha}(q_j, v) \\ (1-(1-q_j)v, (1-q_j)v) & if \quad \alpha_j \geq \widehat{\alpha}(q_j, v) \text{ and } q_j > \widehat{q}(v) \\ (1-v, v) & if \quad \alpha_j \geq \widehat{\alpha}(q_j, v) \text{ and } q_j \leq \widehat{q}(v), \end{cases}$$

where

$$\widehat{q}(v) \equiv \frac{\sqrt{(1-v)(1+3v)} - (1-v)}{2v} \text{ and } \widehat{\alpha}(q, v) \equiv \begin{cases} 0 & if \quad q \leq 1-v \\ 1 - \frac{1-v}{q} & if \quad 1-v < q \leq \widehat{q}(v) \\ (1-q)v & if \quad q > \widehat{q}(v), \end{cases}$$

satisfying $\widehat{q}(v) \in (1-v, 1)$.

Lemma B1. *Suppose that unlike in our present setting, the buyer has to make her purchases as she negotiates with the sellers, and that the purchasing history is public. Let the buyer negotiate with seller i first. Then, in equilibrium there is a strictly positive probability of the buyer acquiring both goods but receiving a negative payoff. In particular, the sum of the sellers' equilibrium prices exceeds her maximum surplus, namely $p_i^*(s_i) + p_j^*(s_j|\phi_i^* = 1) > 1$, where $\phi_i \in \{0,1\}$ denotes the buyer's purchasing decision for good i.*

Proof. Let the buyer negotiate with seller i first, and $\phi_i \in \{0,1\}$ be her purchasing decision. Then, seller j's best response is given by

$$p_j(s_j|\phi_i = 0) = \frac{1}{2} \text{ and } p_j(s_j|\phi_i = 1) = \begin{cases} \frac{1}{2} & if \quad \tilde{q}_i \leq \frac{1}{2} \\ 1 & if \quad \tilde{q}_i > \frac{1}{2}. \end{cases}$$

where $\tilde{q}_i = \Pr(v_i = 0|\phi_i = 1)$. Next, note that if the buyer accepts a price offer $p_i(s_i)$ by seller i in the first negotiation, she receives an expected payoff:

$$\max\{1 - \alpha_j p_j(s_j|\phi_i = 1) - p_i(s_i), v_i - p_i(s_i)\} = \max\{1 - \alpha_j p_j(s_j|\phi_i = 1), v_i\} - p_i(s_i),$$

whereas if she rejects $p_i(s_i)$, then her expected payoff in the second negotiation is $(1 - \alpha_j)(1 - q_j)\frac{1}{2}$.

Comparing the two payoffs for the buyer, it can be seen that a price offer of $\underline{p}_i(s_i) = 1 - \alpha_j p_j(s_j|\phi_i = 1) - (1 - \alpha_j)(1 - q_j)\frac{1}{2}$will be accepted by the buyer with probability 1. Therefore, in equilibrium $p_i^*(s_i) \geq \underline{p}_i(s_i)$. Moreover, if in equilibrium the buyer purchases good i, then

$$p_i^*(s_i) + p_j^*(s_j|\phi_i^* = 1) \geq \underline{p}_i(s_i) + p_j^*(s_j|\phi_i^* = 1) \geq 1 + (1 - \alpha_j)[p_j(s_j|\phi_i = 1) - (1 - q_j)\frac{1}{2}] > 1.$$

Note that in equilibrium, $p_i^*(s_i)$ must be accepted with a positive probability. Otherwise, seller i would have a profitable deviation to $\underline{p}_i(s_i)$ which would be accepted with certainty. Similarly, $p_j^*(s_j|\phi_i^* = 1)$ is accepted with a positive probability as well, precluding a profitable deviation by seller j to $\frac{1}{2}$. Since, in addition, both sellers end up proposing with probability $\alpha_i \alpha_j > 0$, there is a strictly positive probability that the buyer acquires both goods but realizes an ex-post negative payoff. ■

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