Appendix: The case of n buyers in Section 3.3 (not for publication)

We discuss the relationship between the supplier's profit and the number of buyers in the case of nonpivotal buyers. We assume that the variable and investment costs when the supplier trades with n buyers are $C(n)$ and $F(n)$, respectively. Following the method in the main text, we can derive $\beta(v - T_i) = (1-\beta)(\sum_{j=1}^{n} T_j - C(n) - (\sum_{j\neq i} T_j - C(n-1)))$ for each $i = 1, \ldots, n$. Hence, $T_i^N = \beta v + (1-\beta)(C(n) - C(n-1))$. Summing up T_i^N over i, we have $\sum_{i=1}^{n} T_i^N = n\beta v + n(1-\beta)(C(n) - C(n-1))$. The supplier's profit is

$$\pi_S^N(n) = n\beta v + n(1-\beta)(C(n) - C(n-1)) - C(n) - F(n).$$

The increase in the profit of the supplier from adding one buyer is

$$\begin{aligned} & \pi_S^N(n+1) - \pi_S^N(n) \\ = \;& \beta(v - \Delta C(n+1)) + (1-\beta)n(\Delta C(n+1) - \Delta C(n)) - (F(n+1) - F(n)), \end{aligned}$$

where $\Delta C(m) = C(m) - C(m-1)$ for each $m = 1, \ldots, n$. The second term in this equation represents the cost compensation problem. Note that $\Delta C(n+1) - \Delta C(n)$ is negative if $C(n)$ is concave. Because the buyers are nonpivotal, we must have $\sum_{j\neq i} T_j^N > C(n-1)$. This is given by $Z(n) \equiv (n-1)(\beta v + (1-\beta)C(n)) - (n(1-\beta) + \beta)C(n-1) > 0$.

Next, we discuss the relationship between the supplier's profit and the number of buyers in the case of pivotal buyers. For each buyer $i = 1, \ldots, n$, $\beta(v - T_i) = (1-\beta)(\sum_{j=1}^{n} T_j - C(n))$ or $T_i = \beta v - (1-\beta)\sum_{j\neq i} T_j + (1-\beta)C(n)$. Hence, $T_i^P = (\beta v + (1-\beta)C(n)) \,/\, (n - (n-1)\beta)$ for each $i = 1, \ldots, n$. The profit of the supplier is

$$\pi_S^P(n) = \frac{\beta\,(nv - C(n))}{n - (n-1)\beta} - F(n).$$

The increase in the profit of the supplier from adding one buyer is

$$\begin{aligned} \pi_S^P(n+1) - \pi_S^P(n) = \;& \frac{\beta}{((n+1) - n\beta)(n - (n-1)\beta)} \\ & \times (\beta(v - \Delta C(n+1)) + (1-\beta)(C(n) - n\Delta C(n+1))) \\ & - (F(n+1) - F(n)). \end{aligned}$$

In this equation, the fraction represents the share of the supplier's bargaining power, which is decreasing in n. This generates a negative effect on the supplier's marginal profit. For example, when $C(n)$ is linear, the marginal gross profit is monotonically decreasing in n. Because the buyers are pivotal, we must have $\sum_{j \neq i} T_j^P \leq C(n-1)$. This is given by $Z(n) \leq 0$. Note that $Z(n+1) - Z(n) = \beta(v - \Delta C(n)) + (1-\beta)n(\Delta C(n+1) - \Delta C(n))$. If this is positive (negative), adding one buyer expands the parameter range in which buyers are nonpivotal (pivotal).

Appendix: Bargaining models (not for publication)

We present four sort of sequential bargaining models discussed in Section 5.1. First, following sequential bargaining in Stole and Zwiebel (1996a, b), the supplier negotiates with buyers bilaterally and sequentially. As mentioned in the main text, the results in the main text hold even though we consider this sequential bargaining procedure. Second, following sequential bargaining in Raskovich (2007), the supplier negotiates with buyers bilaterally and sequentially. Third, we consider a sequential bargaining modeled through the Shapley value. Finally, we consider an alternative negotiation process in which the supplier decides to trade with only one buyer.

A sequential bilateral bargaining as in Stole and Zwiebel (1996a, b)

We change the simultaneous bilateral bargaining in the second stage of the basic model to the following sequential bargaining (see Stole and Zwiebel (1996a, b)): First, the first buyer negotiates with the supplier. If the negotiation reaches an agreement, the buyer's payment T_1 is determined; otherwise, no transfer occurs and the buyer exits the game. Observing the outcome of the negotiation, the second buyer negotiates with the supplier. If the negotiation reaches an agreement, the buyer's payment T_2 is determined; otherwise, no transfer occurs and the buyer exits the game.[28]

We verify by the backward application of the Nash bargaining solution that the equilibrium outcome of the sequential bilateral bargaining is the same as that of the simultaneous bilateral bargaining.

The analysis of the second negotiation.

We first analyze bargaining between the second buyer and the supplier, given that the first buyer's payment T_1 is determined. We need to consider the bargaining in the following two cases: one is the case of $T_1 > c$ (the second buyer is nonpivotal) and the other is the case of $T_1 \leq c$ (the second buyer is pivotal).

[28] The order of bargaining does not affect our result.

When $T_1 > c$, the second buyer is nonpivotal. The additional surplus of the trade with the second buyer is $v - ac$. The second buyer pays T_2 to the supplier in a way that satisfies

$$\beta(v - T_2) = (1-\beta)(T_2 - ac) \quad \text{or} \quad T_2 = \beta v + (1-\beta)ac. \tag{26}$$

When $T_1 \le c$, the second buyer is pivotal. The additional surplus of the trade with the second buyer is $(v - T_2) + (T_1 + T_2 - (a+1)c) = v + T_1 - (a+1)c$. The second buyer pays T_2 to the supplier in a way that satisfies

$$\beta(v - T_2) = (1-\beta)(T_1 + T_2 - (a+1)c) \quad \text{or} \quad T_2 = \beta v + (1-\beta)(a+1)c - (1-\beta)T_1. \tag{27}$$

The analysis of the first negotiation

Anticipating that the second negotiation reaches the agreement according to (26) or (27), the first buyer negotiates with the supplier. We need to consider the negotiation in the case in which the second stage transfer is determined according to (26) and the case in which the second stage transfer is determined according to (27). Note that in both cases, the first buyer is pivotal if and only if $T_2 \le c$.

Case 1. Consider the case in which $T_2 = \beta v + (1-\beta)ac$. In this case, by the analysis above, $T_1 > c$ must hold.

(1.1) If $T_2 > c$, then the first buyer is nonpivotal. Note that the condition that the first buyer is pivotal is $\beta v > (1 - (1-\beta)a)c$ because $T_2 = \beta v + (1-\beta)ac$. The additional surplus of the trade with the first buyer is $v - ac$. The first buyer pays T_1 to the supplier in a way that satisfies

$$\beta(v - T_1) = (1-\beta)T_1 - ac \quad \text{or} \quad T_1 = T_2 = \beta v + (1-\beta)ac.$$

Since $\beta v > (1 - (1-\beta)a)c$, then $T_1 > c$. This is consistent with the condition of $T_1 > c$.

(1.2) If $T_2 \le c$, then the first buyer is pivotal. Note that the condition that the first buyer is nonpivotal is $\beta v \le (1 - (1-\beta)a)c$. The additional surplus of the trade with the first buyer is $(v - T_1) + (T_1 + T_2 - (1+a)c) = v + T_2 - (1+a)c$. The first buyer pays T_1 to the supplier in a way that satisfies

$$\beta(v - T_1) = (1-\beta)(T_1 + T_2 - (1+a)c) \quad \text{or} \quad T_1 = \beta^2 v + (1-\beta)(1+a\beta)c.$$

Since $\beta v \leq (1-(1-\beta)a)c$, then $T_1 \leq c$. This is inconsistent with the condition of $T_1 > c$.

In summary, if $\beta v > (1-(1-\beta)a)c$, then it is supported as an equilibrium that $T_1 = T_2 = \beta v + (1-\beta)ac$ $(> c)$ and both buyers are nonpivotal.

Case 2. Consider the case in which $T_2 = \beta v + (1-\beta)(a+1)c - (1-\beta)T_1$. In this case, by the analysis above, $T_1 \leq c$ must hold.

(2.1) If $T_2 > c$, then the first buyer is nonpivotal and the additional surplus of the trade with the first buyer is $v - ac$. The first buyer pays T_1 to the supplier in a way that satisfies

$$\beta(v - T_1) = (1-\beta)(T_1 - ac) \quad \text{or} \quad T_1 = \beta v + (1-\beta)ac.$$

Substituting it into T_2 in (27), we obtain

$$T_1 = \beta v + (1-\beta)ac, \quad T_2 = \beta^2 v + (1-\beta)(1+\beta a)c.$$

Because $T_2 > c$, we obtain the condition that $\beta v > (1-(1-\beta)a)c$. However, this is inconsistent with the condition of $T_1 \leq c$ because $T_1 \leq c$ if and only if $\beta v \leq (1-(1-\beta)a)c$.

(2.2) If $T_2 \leq c$, then the first buyer is pivotal and the additional surplus of the trade with the first buyer is $(v - T_1) + (T_1 + T_2 - (a+1)c) = v + T_2 - (a+1)c$. The first buyer pays T_1 to the supplier in a way that satisfies (we substitute T_2 in (27) into the following equation)

$$\beta(v - T_1) = (1-\beta)(T_1 + T_2 - (a+1)c) = \beta(1-\beta)(v + T_1 - (a+1)c).$$

The equation leads to

$$T_1 = T_2 = \frac{\beta v + (1-\beta)(a+1)c}{2-\beta}.$$

Because $T_2 \leq c$, we obtain the condition that $\beta v \leq (1-(1-\beta)a)c$. This is consistent with the condition of $T_1 \leq c$ because $T_1 \leq c$ if and only if $\beta v \leq (1-(1-\beta)a)c$.

In summary, if $\beta v \leq (1-(1-\beta)a)c$, then it is supported as an equilibrium that $T_1 = T_2 = (\beta v + (1-\beta)(a+1)c)/(2-\beta)$ $(\leq c)$ and both buyers are pivotal.

We can summarize the transfer payments at the equilibrium as follows:

$$T_1 = T_2 = \begin{cases} \beta v + (1-\beta)ac & \text{if } \beta v > (1-(1-\beta)a)c, \\ \dfrac{\beta v + (1-\beta)(a+1)c}{2-\beta} & \text{if } \beta v \leq (1-(1-\beta)a)c. \end{cases}$$

These transfer payments by the buyers are equal to those derived in the main text.

A sequential bilateral bargaining as in Raskovich (2007)

We now consider the following sequential bargaining (see Raskovich (2007)): First, the first buyer negotiates with the supplier. Bargaining takes the simple form that one agent chosen at random makes a take-it-or-leave-it offer to the other. If the supplier is chosen to be the proposer with probability β, the first buyer with probability $1-\beta$. If the negotiation reaches an agreement, the buyer's payment T_1 is determined; otherwise, no transfer occurs and the buyer exits the game. Observing the outcome of the negotiation, the second buyer negotiates with the supplier. The bargaining procedure is similar to the first one. If the negotiation reaches an agreement, the buyer's payment T_2 is determined; otherwise, no transfer occurs and the buyer exits the game. We consider two cases concerning the compliance for the agreements: (i) the supplier cannot abandon the first agreement even though the total payment, $T_1 + T_2$, is smaller than the total variable cost, $(1+a)c$; (ii) the supplier can abandon the first agreement if the total payment, $T_1 + T_2$, is smaller than the total variable cost, $(1+a)c$. We show that the expected payoffs in the two cases are the same.

Case (i) We first analyze bargaining between the second buyer and the supplier. Given the outcome of the bargaining, we then examine the bargaining among the first buyer and the supplier.

Given that the first buyer's payment T_1 is determined, we consider the negotiation between the second buyer and the supplier. If the second buyer is chosen to be the proposer, T_2 is accepted by the supplier if and only if $T_2 \geq ac$. This compensates the additional variable cost of the supplier. If the supplier is chosen to be the proposer, T_2 is accepted by the second buyer if and only if $T_2 \leq v$. The second buyer pays T_2 to the supplier in a way that satisfies

$$T_2^* = \begin{cases} ac & \text{if the second buyer is the proposer,} \\ v & \text{if the supplier is the proposer.} \end{cases}$$

The expected payoff of the supplier in case (i), denote it $\pi_S^{II(\mathrm{i})}(T_1)$, is given as

$$\pi_S^{II(\mathrm{i})}(T_1) = T_1 + T_2^* - (1+a)c = T_1 + (1-\beta)ac + \beta v - (1+a)c = T_1 + \beta v - (1+\beta a)c.$$

Assuming that the second negotiation reaches the agreement mentioned above, the first buyer negotiates with the supplier.

If the first buyer is chosen to be the proposer, T_1 is accepted by the supplier if and only if

$$\pi_S^{II(\mathrm{i})}(T_1) \geq \beta(v-c).$$

The right-hand side is the expected payoff of the supplier when it rejects the offer by the first buyer.[29] If the supplier is chosen to be the proposer, T_1 is accepted by the first buyer if and only if $T_1 \leq v$. The first buyer pays T_1 to the supplier in a way that satisfies

$$T_1^* = \begin{cases} (1-(1-a)\beta)c & \text{if the first buyer is the proposer,} \\ v & \text{if the supplier is the proposer.} \end{cases}$$

The expected payoff of the supplier is given as

$$\pi_S^{II(\mathrm{i})}(T_1^*) = (1-\beta)(1-(1-a)\beta)c + \beta v + \beta v - (1+\beta a)c = 2\beta v - \beta(2-(1-a)\beta)c.$$

Case (ii) Given that the first buyer's payment T_1 is determined, we consider the negotiation between the second buyer and the supplier. We need to consider the following two cases: one is the case of $T_1 \geq c$ and the other is the case of $T_1 < c$.

When $T_1 \geq c$, if the second buyer is chosen to be the proposer, T_2 is accepted by the supplier if and only if $T_2 \geq ac$. This compensates the additional variable cost of the supplier. If the

[29] Given that the supplier rejects, if the second buyer is chosen to be the proposer, T_2 is accepted by the supplier if and only if $T_2 \geq c$. This compensates the variable cost of the supplier. If the supplier is chosen to be the proposer, T_2 is accepted by the second buyer if and only if $T_2 \leq v$. The expected payoff of the supplier is $(1-\beta)c + \beta v - c = \beta(v-c)$.

supplier is chosen to be the proposer, T_2 is accepted by the second buyer if and only if $T_2 \leq v$. The second buyer pays T_2 to the supplier in a way that satisfies

$$T_2^* = \begin{cases} ac & \text{if the second buyer is the proposer,} \\ v & \text{if the supplier is the proposer.} \end{cases}$$

When $T_1 \geq c$, the expected payoff of the supplier is given as

$$T_1 + (1-\beta)ac + \beta v - (1+a)c = T_1 + \beta v - (1+\beta a)c.$$

When $T_1 < c$, if the second buyer is chosen to be the proposer, T_2 is accepted by the supplier if and only if $T_2 \geq (1+a)c - T_1$. This compensates the total variable cost of the supplier. If this inequality does not hold, the supplier abandons to produce its goods for the buyers. If the supplier is chosen to be the proposer, T_2 is accepted by the second buyer if and only if $T_2 \leq v$. The second buyer pays T_2 to the supplier in a way that

$$T_2^* = \begin{cases} (1+a)c - T_1 & \text{if the second buyer is the proposer,} \\ v & \text{if the supplier is the proposer.} \end{cases}$$

When $T_1 < c$, the expected payoff of the supplier is given as

$$T_1 + (1-\beta)((1+a)c - T_1) + \beta v - (1+a)c = \beta T_1 + \beta v - \beta(1+a)c.$$

We can summarize the expected payoff of the supplier in case (ii), denote it $\pi_S^{II(\text{ii})}(T_1)$, as follows:

$$\pi_S^{II(\text{ii})}(T_1) = \begin{cases} T_1 + \beta v - (1+\beta a)c, & \text{if } T_1 \geq c, \\ \beta T_1 + \beta v - \beta(1+a)c, & \text{if } T_1 < c. \end{cases}$$

Assuming that the second negotiation reaches the agreement mentioned above, the first buyer negotiates with the supplier. If the first buyer is chosen to be the proposer, T_1 is accepted by the supplier if and only if

$$\pi_S^{II(\text{ii})}(T_1) \geq \beta(v-c).$$

If the supplier is chosen to be the proposer, T_1 is accepted by the first buyer if and only if $T_1 \leq v$. The first buyer pays T_1 to the supplier in a way that satisfies

$$T_1^* = \begin{cases} ac & \text{if the first buyer is the proposer,} \\ v & \text{if the supplier is the proposer.} \end{cases}$$

The expected payoff of the supplier is given as

$$\begin{aligned}\pi_S^{II(\mathrm{ii})}(T_1^*) &= (1-\beta)(\beta ac + \beta v - \beta(1+a)c) + \beta(v + \beta v - (1+\beta a)c) \\ &= 2\beta v - \beta(2-(1-a)\beta)c.\end{aligned}$$

The payoff is equal to that in the first case.

To clarify the difference between the payoffs in the two bargaining procedures, we compare the payoff in this appendix and that in the main text when the buyers are nonpivotal (see (7)). The difference between them is

$$\pi_S^{II(\mathrm{ii})}(T_1^*) - \pi_S^N = (1-\beta)^2(1-a)c \geq 0.$$

$(1-\beta)^2$ is the probability that the two buyers are the proposers. When the two buyers are the proposers *ex post*, they fully compensate the variable cost of the supplier, $(1+a)c$. That compensation does not occur when the bargaining procedure follows that in Stole and Zwiebel (1996a, b). When the buyers are nonpivotal, they compensate only $2ac$. $(1-a)c$ is the difference between them. The way to split the net gain from the trade follows the predetermined proportion $\beta : 1-\beta$ in Stole and Zwiebel (1996a, b). The two possible events that the buyer is the proposer and that the supplier is the proposer are merged by the predetermined proportion $\beta : 1-\beta$. The merged bargaining process eliminates the possibility that the two buyers fully compensate the variable cost of the supplier, $(1+a)c$.

Sequential bargaining modeled through the Shapley value

We consider bargaining as modeled through the probabilistic value, a generalization of the Shapley value.[30] Each player comes to negotiate in a given order and receives the marginal surplus from his/her arrival. The marginal surplus of the arrival may depend on the order of arrival, which is stochastically determined. Although the Shapley value assumes that the probability of each arrival order is symmetric, the probabilistic value extends it to asymmetric arrival probabilities. We establish an arrival probability that reflects the bargaining powers of the

[30] See Weber (1988) for more detail on the probabilistic value.

players and calculate each player's share of the bargaining surplus according to the probabilistic value. As in the text, we assume that in each bilateral negotiation, the supplier and a buyer receive $\beta \in [0,1]$ and $1-\beta$ of the bargaining surplus, respectively.

First, we examine the case in which the supplier negotiates with buyer i only. A natural characteristic function in this case, denoted by $V^I : 2^{\{S,i\}} \rightarrow \mathbb{R}_+$, is defined as $V^I(\emptyset) = 0$, $V^I(j) = 0$ for each $j \in \{S,i\}$, and $V^I(S,i) = v - c$. There are two orders of arrival: Buyer i arrives first, followed by the supplier, and the supplier arrives first, followed by buyer i. The probability of the former is assumed to be β and that of the latter is assumed to be $1-\beta$. Then, the supplier and buyer i respectively receive β and $1-\beta$ of $v-c$. The probabilistic value of the supplier, SV_S^I, and that of buyer i, SV_i^I, are $SV_S^I = \beta(v-c)$ and $SV_i^I = (1-\beta)(v-c)$, respectively.

Second, we examine the case in which the supplier negotiates with two buyers. Because there are three players (the supplier, buyer 1, and buyer 2), there are $3! = 6$ orders. The probability that the supplier is the first arriver and the probability that buyer i ($i = 1,2$) is the first arriver are assumed to be $(1-\beta)/(1+\beta)$ and $\beta/(1+\beta)$, respectively.[31] We can naturally define a characteristic function $V^{II} : 2^{\{S,1,2\}} \rightarrow \mathbb{R}_+$ that describes the group benefits from negotiating, where S, 1, and 2 represent the supplier, buyer 1, and buyer 2, respectively, as follows. We normalize $V^{II}(\emptyset) = 0$. None of the players can benefit alone; hence, $V^{II}(i) = 0$ for each $i \in \{S,1,2\}$. Buyers 1 and 2 can earn nothing; hence, $V^{II}(1,2) = 0$. Groups of the supplier and at least one buyer generate a surplus; hence, $V^{II}(S,i) = v - c$ ($i = 1,2$) and $V^{II}(S,1,2) = 2v - (1+a)c$. The marginal contribution of player i to a set of arriving players T, such that $i \notin T$, is given by $V^{II}(T \cup \{i\}) - V^{II}(T)$.

[31] In this assignment of the probabilities, for each bilateral negotiation, the supplier and buyer receive β and $1-\beta$ of the surplus, respectively; hence, the probabilities reflect their respective bargaining powers.

The expected marginal contribution of player i is defined as the probabilistic value, SV_j^{II} ($j = S, 1, 2$). The supplier's expected contribution, SV_S^{II}, is

$$\begin{aligned} SV_S^{II} &= \frac{1-\beta}{1+\beta}(V^{II}(S) - V^{II}(\emptyset)) + \sum_{i=1}^{2} \frac{\beta(1-\beta)}{1+\beta}(V^{II}(S,i) - V^{II}(i)) \\ &\qquad + \frac{2\beta^2}{1+\beta}(V^{II}(S,1,2) - V^{II}(1,2)) \\ &= 2\beta v - \frac{2\beta(1+a\beta)c}{1+\beta}. \end{aligned}$$

Based on these analyses, we examine the optimal number of buyers with whom the supplier can negotiate. When the supplier negotiates with one buyer, its payoff is

$$\pi_S^{I,SV} \equiv SV_S^I - F = \beta(v-c) - F. \tag{28}$$

When it trades with two buyers, its payoff is

$$\pi_S^{II,SV} \equiv SV_S^{II} - dF = 2\beta v - \frac{2\beta(1+a\beta)c}{1+\beta} - dF. \tag{29}$$

Subtracting (29) from (28) yields

$$\pi_S^{I,SV} - \pi_S^{II,SV} = -\beta v + \frac{\beta(1+\beta-2\beta(1-a))}{1+\beta}c + (d-1)F. \tag{30}$$

We examine whether there is an exogenous parameter within which the supplier would choose to trade with one buyer. The supplier chooses to trade with one buyer if and only if $\pi_S^{I,SV} - \pi_S^{II,SV} \geq 0$ and $\pi_S^{I,SV} \geq 0$. We have

$$\pi_S^{I,SV} - \pi_S^{II,SV} \geq 0 \text{ if and only if } F \geq \frac{\beta((1+\beta)(v-c) + 2\beta(1-a)c)}{(d-1)(1+\beta)}$$

and

$$\pi_S^{I,SV} \geq 0 \text{ if and only if } \beta(v-c) \geq F.$$

Thus,

$$\beta(v-c) \geq F \geq \frac{\beta((1+\beta)v - c - \beta(2a-1)c)}{(d-1)(1+\beta)}. \tag{31}$$

The supplier chooses one buyer only if the subtraction of the right-hand side of (31) from the left-hand side of (31) is not negative. Hence, the supplier chooses one buyer only if

$$d \geq \underline{d}^{SV} \equiv \frac{2((1+\beta)v - (1+a\beta)c)}{(1+\beta)(v-c)} = 2 + \frac{2(1-a)\beta c}{(1+\beta)(v-c)} \tag{32}$$

Note that since $0 \leq a \leq 1$, $\underline{d}^{SV} \geq 2$ with equality if $a = 1$. Therefore, condition (32) holds if and only if $a = 1$ and $d = 2$.

According to the analysis above, if there exists an exogenous parameter at which the supplier chooses to trade with one buyer, then $a = 1$ and $d = 2$. However, when $a = 1$ and $d = 2$, the supplier is indifferent to trading with one or two buyers. Therefore, in the bargaining procedure based on the probabilistic value, the supplier rarely trades with only one buyer, irrespective of the supplier's bargaining power.

An alternative bargaining procedure when the supplier decides to trade with only one buyer

In the basic model, we assume that the supplier does not trade with new buyers when it has decided to trade with only one partner. We change this assumption as follows. In the first stage, the supplier determines its production capacity, choosing between one or two units. If it sets a two-unit capacity, the subsequent stages are the same as those in the basic model. If it sets a one-unit capacity, in the second stage, the supplier sequentially and bilaterally negotiates with two buyers until it reaches an agreement with one of the buyers. First, the supplier and one of the buyers negotiate bilaterally. If they reach a contractual agreement, the supplier goes to the third stage and decides whether to execute the contract; otherwise, the supplier and the other buyer negotiate bilaterally in the next period. Similarly, if the supplier reaches an agreement with the second buyer, it decides to execute the contract as above; otherwise, the supplier once again negotiates bilaterally with the first buyer. This process continues until the supplier and one of the buyers reach an agreement or a finite final period is reached.

We can verify by the backward application of the Nash bargaining solution that setting a one-unit capacity is more beneficial for the supplier than in the basic model. Without loss of generality, we assume that there is an even number of periods T and the supplier negotiates with buyer 1 (2) in any odd (even) period (if necessary). We first apply the Nash bargaining solution to the negotiation with buyer 2 in the final period (Tth period). If the supplier and buyer 2 fail to negotiate, then they have nothing. Hence, the Nash bargaining solution assigns payoffs of $s_T \equiv \beta(v-c)$ to the supplier and $(1-\beta)(v-c)$ to buyer 2. Given this outcome, we then apply the solution to the negotiation with buyer 1 in period $T-1$. If the supplier and buyer 1 fail to negotiate in this period, the supplier obtains s_T and buyer 1 obtains nothing because in the final period, the supplier and buyer 2 reach an agreement. Hence, in the negotiation during period $T-1$, the surplus of the negotiation is $v-c-s_T$. At the Nash bargaining solution, the supplier obtains $s_{T-1} \equiv \beta(v-c-s_T)+s_T$ and buyer 1 obtains $(1-\beta)(v-c-s_T)$. We can apply this logic iteratively until period 1. In general, in period $t \in \{1,\ldots,T-1\}$, anticipating the bargaining outcome of period $t+1$, the supplier and the buyer split the surplus $v-c-s_{t+1}$ and the supplier obtains $s_t \equiv \beta(v-c)+(1-\beta)s_{t+1}$ at the Nash bargaining solution. According to the analysis, we have

$$s_t = \beta(v-c)+(1-\beta)s_{t+1} \text{ for all } t \in \{1,\ldots,T-1\} \quad \text{and} \quad s_T = \beta(v-c).$$

According to these equations, the supplier obtains

$$\begin{aligned} s_1 &= \beta(v-c)+\sum_{t=1}^{T-1}(1-\beta)^t\beta(v-c) = \beta(v-c)\left(1+\sum_{t=1}^{T-1}(1-\beta)^t\right) \\ &= \beta(v-c)\left(\frac{1-(1-\beta)^T}{\beta}\right) \end{aligned}$$

in the first period at the Nash bargaining solution. Clearly, s_1 is greater than $\beta(v-c)$, which is the payoff to the supplier when it negotiates with one buyer in the basic model.[32] Therefore, the bargaining procedure strengthens the supplier's bargaining power and setting a one-unit capacity is more beneficial to the supplier than in the basic model.

[32]In this setting, longer periods strengthen the incentive to trade with one buyer since $\lim_{T\to\infty} s_1 = v-c$.

Appendix: Buyer competition in Section 5.3 (not for publication)

As in the main analyses, we solve the simultaneous bilateral negotiation between the supplier and the buyers by the Nash bargaining solution. The bargaining procedure is consistent with that in Marshall and Merlo (2004).

First, we analyze the final stage. There are n $(n \leq \bar{n})$ competing buyers and $(w_i)_{i=1}^n$ is the tuple of the wholesale prices. The inverse demand function for the final product is given by $p(\sum_{i=1}^n q_i) = \alpha - \sum_{i=1}^n q_i$, where α is a positive constant and q_i is the quantity of buyer i. The profit of buyer i $(i = 1, \dots, n)$ and the supplier's profit excluding the sunk costs, $\pi_i^n(w_1, \dots, w_n)$ and $\pi_S^n(w_1, \dots, w_n)$, are

$$\begin{aligned} \pi_i^n(w_1, \dots, w_n) &= \left(\frac{\alpha - nw_i + \sum_{j \neq i} w_j}{n+1} \right)^2, \\ \pi_S^n(w_1, \dots, w_n) &= \sum_{i=1}^n w_i \left(\frac{\alpha - nw_i + \sum_{j \neq i} w_j}{n+1} \right). \end{aligned}$$

We next solve the negotiation stage by the Nash bargaining solution. Each buyer's disagreement payoff is zero because it cannot produce the product without inputs. The supplier has outside options. Even if it cannot agree to a negotiation with buyer i, it trades with other buyers. The supplier's disagreement payoff of the negotiation with buyer i is

$$\pi_S^{n-1}((w_j)_{j \neq i}) = \sum_{j \neq i} w_j \left(\frac{\alpha - (n-1)w_j + \sum_{k \neq j,i} w_k}{n} \right).$$

The Nash bargaining solution to the negotiation between the supplier and buyer i is given by

$$w_i^* \in \arg\max_{w_i} \quad \beta \ln \left[\pi_S^n(w_1, \dots, w_n) - \pi_S^{n-1}((w_j)_{j \neq i}) \right] + (1-\beta) \ln \pi_i^n(w_1, \dots, w_n). \tag{33}$$

The partial differential of (33) with respect to w_i leads to

$$\begin{aligned} \beta \frac{1}{\pi_S^n(w_1, \dots, w_n) - \pi_S^{n-1}((w_j)_{j \neq i})} \left(\frac{\alpha - 2nw_i + \sum_{j \neq i} w_j}{n+1} + \sum_{j \neq i} \frac{w_j}{n+1} \right) \\ +2(1-\beta) \left(\frac{n}{\alpha - nw_i + \sum_{j \neq i} w_j} \right) = 0. \end{aligned} \tag{34}$$

Focusing on the symmetric solution ($w^* = w_k^*$ for all k) and substituting $w_k = w^*$ for all k in (34) yields

$$w^* = \frac{\beta\alpha}{2}.$$

The profits of each buyer i and that of the supplier excluding sunk costs are given by

$$\pi_i^n((w^*)_{j=1}^n) = \frac{(2-\beta)^2\alpha^2}{4(n+1)^2}, \quad \pi_S^n((w^*)_{j=1}^n) = \frac{\beta(2-\beta)\alpha^2 n}{4(n+1)}.$$

Finally, we solve for the optimal number of buyers. The net profit of the supplier is

$$\frac{\beta(2-\beta)a^2 n}{4(n+1)} - F(n).$$

We assume that $F(n) = nf$, where f is a positive constant. The following figure shows the marginal gain from increasing in n and the marginal sunk cost from increasing in n (see Figure below). We easily determine that the marginal gain from increasing the number of trading buyers decreases and that the weaker is the bargaining power of the supplier, the smaller is the optimal number of buyers. This is because increasing the number of trading buyers generates a business stealing effect, as in standard Cournot competition, which diminishes the marginal gain from increasing in n. This effect in itself weakens the incentive of the supplier to increase the number of trading buyers although the basic model does not have such an effect.

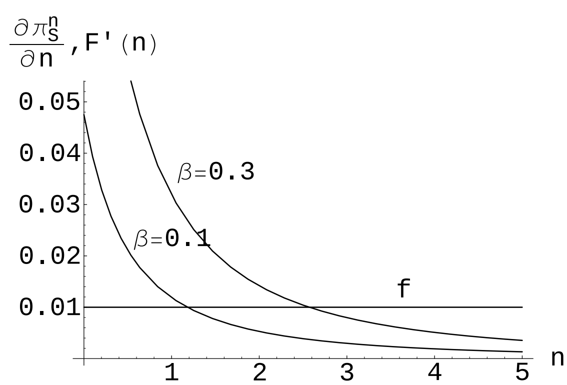

Figure: The marginal gain and the marginal sunk cost.