BARGAINING EQUILIBRIUM IN A TWO-ECHelon SUPPLY CHAIN WITH A CAPITAL-CONSTRAINED RETAILER

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Abstract. We investigate the bargaining equilibrium in a two-echelon supply chain consisting of a supplier and a capital-constrained retailer. The newsvendor-like retailer can borrow from a bank or use the supplier’s trade credit to fund his business. In the presence of bankruptcy risk for both the supplier and retailer, with a wholesale price contract, we model the player’s strategic interactions under the Nash and Rubinstein bargaining games. In both financing schemes, the Nash bargaining game overcomes the double marginalization effect under the Stackelberg game and achieves supply chain coordination. The Rubinstein bargaining game realizes the Pareto improvement of the supply chain. The player with stronger bargaining power always prefers to initially offer a contract under the Rubinstein bargaining game to obtain greater expected profit. Furthermore, we characterize the conditions under which bargaining power and discount factor affect the bargaining equilibrium. We numerically verify our theoretical results.

1. Introduction. Financial constraints widely exist in today’s supply chain management (see [9, 10, 22, 23, 27]). In real-world transactions, the capital-constrained player generally borrows from an external bank or from the internal supply chain’s players to fund its business (see [11, 20, 31, 54]). Many scholars have shown that many small and medium-sized enterprises (SMEs) often resort to trade credit to mitigate their capital pressure. Trade credit as a short-term financing source is becoming increasingly popular in developing and developed economies (see [27, 46, 56]). Specifically, in current US firms, more than 80% of SMEs utilize trade credit to address their capital constraints (see [3, 38, 39, 44]). Some firms with good reputation.
are more likely to obtain loans from external financial institutions. The survey of Bradley and Rubach [6] of 3561 representative U.S. SMEs shows that approximate 60% of them resort to bank credit to address limited working capital. Different financing sources, however, require capital-constrained firms to pay different interest costs, which directly affects the supply chain players decisions (see [25, 26, 43, 58]). How to effectively make financing and operational decisions is becoming a large challenge in current supply chain management.

Many scholars indicate that the financing cost directly influences the selection of a financing source. With a wholesale price contract, the supplier endowed with full capital often is willing to voluntarily offer trade credit to the capital-constrained retailer. When a reasonable interest rate or wholesale price is charged, the retailer therefore prefers to choose trade credit as his favorable financing source (see [9, 22, 55]). Doing so would benefit all players in the supply chain. Once the supplier charges more, the retailer resorts to bank credit (see [20, 21, 23]). By utilizing bank credit, the retailer reinforces his negotiation power. The retailer can therefore acquire a lower wholesale price from his supplier. To maximize their individual profits, the supplier and retailer would conduct a negotiation (see [2, 51, 52]). Many scholars analyze negotiations among supply chain players, such as the wholesale price contract and the two-part tariff contract (see [29, 31, 36]). Note that most of the studies focus on the negotiation in a decentralized system because the contract is unilaterally determined by the player as the leader (see [1, 41, 48, 61]). However, much empirical evidence suggests that bilateral bargaining processes widely exist in current supply chains (see [13, 60]). For example, Wal-Mart is a dominant buyer for most of its upstream suppliers, including Revlon and Disney. Wal-Mart often wins concessions from its many suppliers. Wal-Mart achieves lower prices and longer delay periods for payment. Suppliers often complain that excess channel profits are obtained by Wal-Mart (see [14, 19]). To increase their profits, suppliers often bargain with Wal-Mart.

Our paper is motivated by a real-world case in the sharing economy. Bike sharing is appealing to an increasing number of users. The survey from BDR shows that Mobike, a bike-sharing giant, owned an approximately 40.7% Chinese market share in the first quarter of 2017. The user initially must pay a deposit of RMB299 before riding a bike. The riding fee is RMB1 per hour. Obviously, revenues from riding are insufficient to cover Mobike’s expenses. Specifically, Mobike must invest huge costs to procure bikes and maintain its operations. To alleviate capital pressure, Mobike resorted to external investors. During the period Oct. 2016 to Jun. 2017, an array of big-name companies, such as JOY Capital, Vertex, Hillhose Capital and Foxconn, invested more than $1 bn to develop Mobike (tech.caijing.com.cn). To reduce costs, Mobike chose to purchase bikes from Foxconn beginning in Jan. 2017. Foxconn’s capacity has currently exceeded 5.6 million bikes per year. Mobike’s bike purchase cost per unit has greatly decreased, from approximately RMB3,000 to less than RMB2,000 (hbspcar.com). Foxconn plays double roles in Mobike’s supply chain. How to achieve a win-win result with Foxconn is becoming a large challenge that Mobike faces. Many scholars have investigated joint financing and operational decisions in the supply chain. Buzacott and Zhang [7] find that in a single-period newsvendor model, asset-based financing enables the capital-constrained retailer to earn more returns. Xu and Birge [53] illustrate how a firm’s capital constraints and capital structure affect its inventory decisions. Chern et al. [10] show that
trade credit can not only attract new buyers but also avoid lasting price competition. Trade credit commonly improves supply chain performance but is more expensive for the capital-constrained player. Therefore, in real-world situations, the player with limited capital often funds its business through bank credit financing (BCF) instead of trade credit financing (TCF). This behavior leads to the capital-constrained player’s financing selection between BCF and TCF (see [9, 20, 21]). Numerous studies also concentrate on the coordination of the supply chain with the capital-constrained player (see [15, 27]). To be more specific, Dada and Hu [12] indicate that with BCF, the supply chain can be partially coordinated by designing an effective mechanism. Chen [9] reveals that with a wholesale price contract, a coordinated supply chain is not achieved in either BCF or with TCF.

However, a majority of the above studies on supply chain coordination avoid discussing the bargaining process between the players, particularly for a supply chain with a capital-constrained player. In practice, the bargaining process significantly affects players’ optimal decisions and supply chain coordination (see [18, 19]). More recently, Ma et al. [30] investigate a two-echelon supply chain with risk considerations. They find that there exists a Nash bargaining equilibrium of wholesale price and order quantity. Considering two competing supply chains with uncertain demand, Wu et al. [51] find that the vertical integration strategy in two supply chains is a unique Nash equilibrium over one period, whereas the bargaining strategy on the wholesale price is the Nash equilibrium over infinitely many periods. Feng et al. [16] consider a dynamic bargaining game in which a seller and a buyer bargain over quantity and payment with asymmetric demand information. Baron et al. [2] discuss the effect of bargaining power on the supply chain. When the supply chain is not monopolistic, the coordination can be achieved if the competition between supply chains is intense. However, we note that a majority of supply chain financing studies commonly assume that a trade-credit financing equilibrium exists because the supplier endowed with sufficient capital always prefers to offer trade credit, and
the capital-constrained retailer is always willing to accept it without conditions. Based on such an assumption, studies establish financing equilibrium and supply chain coordination. In practice, when offering loans to the capital-constrained retailer, the bank or dominant supplier requires additional terms to maximize its profit. The retailer also will bargain with the bank or the supplier. For example, the capital-constrained retailer might utilize the banks loans to strengthen its bargaining power. When negotiating with the supplier, the retailer would be able to require a low wholesale price.

Many scholars have studied the financing equilibrium in three capital-constrained scenarios: (1) both the supplier and retailer are capital-constrained (see [24, 43, 57]); (2) only the retailer is capital constrained, whereas the supplier is endowed with full capital (see [9, 20, 22]); and (3) only the supplier is capital constrained, whereas the retailer is endowed with full capital (see [28, 47]). Motivated by the Mobike case, we consider a two-echelon supply chain with a capital-constrained retailer. Following Jing et al. [22] and Chen [9], we investigate the effects of bargaining power and discount rate on the bargaining equilibrium, because the capital-constrained retailer funds his business through bank credit financing or trade credit financing.

Our paper is distinct from the above studies because it considers the bargaining process in a supply chain with a capital-constrained retailer. The retailer can borrow from a bank or use the supplier’s trade credit to satisfy uncertain demand. Our analysis is in sharp contrast to Chen [9], in which the bank and trade credit are compared under the classical wholesale price and revenue sharing contract. With a wholesale price contract, we investigate bargaining equilibrium and supply chain coordination under two bargaining processes instead of the common leader-follower negotiation. In addition, we identify how bargaining power and discount factor affect the bargaining equilibrium under bank credit financing (BCF) and trade credit financing (TCF).

Our work contributes to the literature in three aspects. First, to our knowledge, this paper is among the first to model the strategic interactions of the supply chain with a capital-constrained retailer under the Nash bargaining (NB) and Rubinstein bargaining (RB) processes. Second, with a wholesale price contract, we analytically derive the unique bargaining equilibrium with BCF and TCF and discuss supply chain coordination. Interestingly, we find that under both financing schemes, the NB game overcomes the double marginalization effect of the leader-follower negotiation and achieves supply chain coordination. The RB game realizes a Pareto improvement of the supply chain. Third, we identify the effects of bargaining power and discount rate on bargaining equilibrium and supply chain performance under both financing schemes.

The remainder of the paper is organized as follows. Section 2 introduces notations and our model. Section 3 analyzes bargaining equilibrium with BCF and TCF. Section 4 provides numerical examples. Section 5 summarizes our results and insights. An appendix collects the proofs of all propositions.

2. Model setup. We consider a two-echelon supply chain consisting of one upstream supplier and one capital-constrained retailer. The newsvendor-like retailer can borrow from a bank or use the supplier’s trade credit to fund his business. The retailer orders products from the supplier before the sales season. The supplier produces and delivers the finished products to the retailer at the start of the sales season. The retailer has no additional replenishment opportunity during the sales
season. With a wholesale price contract, the supplier charges the retailer a wholesale price \( w \) per unit purchased. The retailer charges customers a fixed retail price \( p \) per unit sold. For convenience, we refer to the supplier as ‘she’ and the retailer as ‘he’ throughout the paper. Let \( D > 0 \) be the uncertain demand during the sales season. Let \( F(\cdot) \) and \( f(\cdot) \) be the cumulative distribution and probability density functions of \( D \). Let \( h(\cdot) = \frac{f(\cdot)}{F(\cdot)} \) be the increasing failure rate of \( D \) and furthermore \( H(\cdot) = (\cdot)h(\cdot) \) the general increasing failing rate, where \( F(D) = 1 - F(D) \). For tractability, normalize \( p \) to 1 (see [8, 21]). Assume that unsold products have no salvage value (see [9, 16, 20, 33, 37]).

Under BCF, the supplier charges a wholesale price \( w^K_B \). The retailer pays the supplier \( w^K_B q^K_B \) at the beginning of the sales season and pays the bank \( w^K_B q^K_B (1 + r_B) \) at the end of the selling season. Under TCF, the supplier charges a “postponed” wholesale price \( w^K_T \). The retailer pays the supplier \( w^K_T q^K_T \) at the end of the permissible delay period. For simplicity, we assume the selling season overlaps the permissible delay period (see [9, 27]). Table 1 lists the notations in this paper.

| Notation  | Explanation |
|-----------|-------------|
| \( D \)   | Uncertain demand. |
| \( p \)   | Retailer’s retail price per unit, where \( p = 1 \). |
| \( c \)   | Supplier’s production cost per unit, where \( 0 < c < 1 \). |
| \( q^K_0 \) | Supply chain’s optimal order quantity in the centralized case. |
| \( r_B \) | Bank’s interest rate. |
| \( f(\cdot) \) | Probability density function of \( D \). |
| \( F(\cdot) \) | Cumulative distribution function of \( D \). |
| \( w^K_i \) | Supplier’s wholesale price per unit purchased under game \( K \), where \( K = S, N, R \) denotes Stackelberg, Nash bargaining and Rubinstein bargaining game, respectively. The subscript \( i = B, T \) denotes BCF and TCF, respectively. (Decision variable). |
| \( q^K_i \) | Retailer’s order quantity under game \( K \), where \( K = S, N, R \) and \( i = B, T \). (Decision variable). |
| \( \pi_{ij} \) | Player \( j \)’s expected profit under game \( K \), where \( K = S, N, R \) and \( i = B, T \). The subscript \( j = s, r \) denotes the supplier and retailer, respectively. |
| \( \beta \) | Retailer’s bargaining power under Nash bargaining game with TCF. |
| \( \Pi \) | Supply chain’s optimal expected profit. |

Both players are risk neutral and aim to maximize their individual expected profits. The full competition leads to the banks zero expected profit when the retailer borrows from the bank (see [5, 9, 53]). All information is common knowledge and is available at no cost to both players (see [17, 49, 50, 59]). The supplier produces at a constant and identical marginal cost.

3. Equilibrium analysis. Suppose the players share the profit of the supply chain through the negotiations. In practice, we can observe many similar scenarios in which the buyers and sellers sit together to negotiate a certain contract. In real-world transactions, the players occasionally simultaneously offer their contracts, or one player occasionally initially offers its contract. Hence, we naturally consider two types of bargaining processes to capture different negotiations. In numerous studies, the Nash bargaining process initiated by Nash Jr [35] is used to depict a negotiation in which both players simultaneously offer the contract. The Rubinstein bargaining process, initially presented by Rubinstein [42], is often applied to address the sequential negotiation.
3.1. Nash bargaining game (NB game). In a two-echelon supply chain, the downstream retailer is capital-constrained. He can borrow loans to fund his order. In BCF, the retailer borrows loans from a bank. With a wholesale price contract, the retailer therefore has the same bargaining power as the supplier. Both players simultaneously negotiate to maximize \((\pi_{Br}^{N} - d_1)(\pi_{Bs}^{N} - d_2)\), where \((d_1, d_2)\) is the disagreement point under the NB game. The NB model with BCF is

\[
\max_{c \leq w_B^{N} \leq 1, q_B^{N} \geq 0} G_1(w_B^{N}, q_B^{N}) = \left[ \int_{0}^{w_B^{N}} \bar{F}(y)dy - w_B^{N}q_B^{N} - d_1 \right] \left[ (w_B^{N} - c)q_B^{N} - d_2 \right]
\]

where \((d_1 = \pi_{Br}^{S}, d_2 = \pi_{Bs}^{S})\) are the retailer's and supplier's reserved expected profits under the Stackelberg game with BCF, respectively. See Jing et al. [20] for \((\pi_{Br}^{S}, \pi_{Bs}^{S})\), in which \(\pi_{Br}^{S} = \mathbb{E}\{\min(D, q_B^{S}) - w_B^{S}q_B^{S}(1 + r_B^{S})\}^+\) and \(\pi_{Bs}^{S} = (w_B^{S} - c)q_B^{S}\), where \(q_B^{S}, w_B^{S}\) and \(r_B^{S}\) satisfy \(\bar{F}(q_B^{S}) - q_B^{S}f(q_B^{S}) = c, w_B^{S} = \bar{F}(q_B^{S}), \) and \(w_B^{S}q_B^{S} = \mathbb{E}\{w_B^{S}q_B^{S}(1 + r_B^{S}), \min(D, q_B^{S})\}\), respectively.

In TCF, the retailer uses the supplier’s trade credit to help order. Therefore, the retailer’s bargaining power is weak relative to the supplier. Let \(\beta \in (0, 1/2)\) represent the retailer’s bargaining power. Correspondingly, the supplier’s bargaining power is \(1 - \beta\). The smaller the value of \(\beta\), the weaker the retailer’s bargaining is than the supplier’s. The NB model with TCF is

\[
\max_{c \leq w_T^{N} \leq 1, q_T^{N} \geq 0} G_2(w_T^{N}, q_T^{N}) = \left[ \int_{0}^{w_T^{N}} \bar{F}(y)dy - d_3 \right] \left[ \int_{0}^{w_T^{N}} \bar{F}(y)dy - cq_T^{N} - d_4 \right]^{1-\beta},
\]

where \((d_3 = \pi_{Tr}^{S}, d_4 = \pi_{Ts}^{S})\) are the retailer’s and supplier’s reserved expected profits under the Stackelberg game with TCF, respectively. See Jing et al. [20] for \((\pi_{Tr}^{S}, \pi_{Ts}^{S})\), in which \(\pi_{Tr}^{S} = \mathbb{E}\{\min(D, q_T^{S}) - w_T^{S}q_T^{S}\}^+\) and \(\pi_{Ts}^{S} = \mathbb{E}\{w_T^{S}q_T^{S}, \min(D, q_T^{S})\} - cq_T^{S}\) satisfy \(H(q_T^{S}(w_T^{S})) = 1 \) and \(w_T^{S} = 1\), respectively.

**Proposition 1.**

(i) In BCF, there exists a unique NB equilibrium of \((w_B^{N*}, q_B^{N*})\), where \(q_B^{N*} = \bar{F}^{-1}(c) = q^0\) and \(w_B^{N*} = \frac{cq_B^{N*} + \int_{0}^{w_B^{N*}} \bar{F}(y)dy + d_2 - d_1}{2}\). The retailer’s and supplier’s expected profits are \(\pi_{Br}^{N*} = d_1 + \frac{1}{2} \left( \int_{0}^{w_B^{N*}} \bar{F}(y)dy - cq_B^{N*} - d_1 - d_2 \right) > d_1 \) and \(\pi_{Bs}^{N*} = d_2 + \frac{1}{2} \left( \int_{0}^{w_B^{N*}} \bar{F}(y)dy - cq_B^{N*} - d_1 - d_2 \right) > d_2\), respectively.

(ii) In TCF, there exists a unique NB equilibrium of \((w_T^{N*}, q_T^{N*})\), where \(q_T^{N*} = \bar{F}^{-1}(c) = q^0\) and \(w_T^{N*} \) satisfies \(\int_{0}^{w_T^{N*}} \bar{F}(y)dy - \beta \int_{0}^{\frac{q_T^{N*}}{q_T^{S}}} \bar{F}(y)dy + \beta cq_T^{N*} + \beta d_4 + (\beta - 1)d_3 = 0\). The retailers and suppliers expected profits are \(\pi_{Tr}^{N*} = d_3 + \beta \left( \int_{0}^{\frac{q_T^{N*}}{q_T^{S}}} \bar{F}(y)dy - cq_T^{N*} - d_3 - d_4 \right) > d_3 \) and \(\pi_{Ts}^{N*} = d_4 + (1 - \beta) \left( \int_{0}^{w_T^{N*}} \bar{F}(y)dy - cq_T^{N*} - d_3 - d_4 \right) > d_4\), respectively.

(iii) \(\frac{d_{N*}}{q_T^{N*}} \leq 0\).

Note that \(q_B^{N*} = q_T^{N*} = q^0\), so the NB game, either with BCF or with TCF, orders the supply chain optimal order quantity. Each player profits from the NB game. For example, with BCF, \(\pi_{Br}^{N*} > d_1 = \pi_{Br}^{S}\) and \(\pi_{Bs}^{N*} > d_2 = \pi_{Bs}^{S}\). In TCF, \(\pi_{Tr}^{N*} > d_3 = \pi_{Tr}^{S}\) and \(\pi_{Ts}^{N*} > d_4 = \pi_{Ts}^{S}\). In a decentralized system, the player aims to maximize its own individual expected profit. Comparatively, under a bargaining
process, the player initially focuses on how to create greater total expected profit. Then, designing a reasonable splitting overcomes the double marginalization effect under the Stackelberg game. Therefore, supply chain coordination would likely be achieved in a bargaining process. In TCF, the supplier actually bears all of the financing risks of the supply chain. The supplier as a Stackelberg leader therefore requires the entire expected profit to make up for her risks. By setting the wholesale price, the supplier makes the retailer’s expected profit equal to zero. In this scenario, the retailer will not be willing to order (see [20]). However, through bargaining with the supplier, the retailer can obtain a low wholesale price to earn a positive profit. Note that with TCF, the supplier can earn more profit with TCF than with BCF, i.e., \( \pi^{T^*}_S > \pi^{B^*}_S \). The stronger the player’s bargaining power determines the allocation of the expected profit of the supply chain with TCF. The supplier therefore prefers to offer TCF. In this case, the influence of bargaining power is negligible. When \( c_1 \leq c < 1 \), the supplier’s profit reduces. The supplier’s profit reduces. The supplier’s profit reduces.

**Proposition 2.**

(i) \( w^N_B \leq w^S_B \) and \( q^N_B > q^S_B \);

(ii) \( w^T_N \leq w^S_T \) and \( q^N_T > q^S_T \) when \( 0 \leq c < f(H^{-1}(1)) \) and \( q^N_T \leq q^S_T \) when \( f(H^{-1}(1)) \leq c \leq 1 \).

The NB game, either with BCF or with TCF, leads to a lower wholesale price than does the Stackelberg game. In BCF, the retailers optimal order quantity under the NB game is greater than under the Stackelberg game. From Proposition 1(i), in which \( q^N_B = q^B_s \), the NB game creates greater profit for the supply chain relative to the Stackelberg game. In TCF, the retailer’s optimal order quantity under the NB game is decreasing in the production cost. Although the product cost exceeds a certain value, the retailer orders less under the NB game than under the Stackelberg game. Because \( q^N_T = q^T_s \), the NB game nevertheless creates greater profit for the supply chain relative to the Stackelberg game.

Thus far, we have separately derived the equilibrium in the supply chain under BCF and TCF. However, BCF and TCF both being viable naturally poses the interesting question of which financing channel is better off for the supplier. From the supplier’s perspective, the supplier is willing to offer trade credit to the retailer if and only if \( \pi^{N^*}_T > \pi^{B^*}_T \). Next, we will identify the conditions for BCF and TCF to obtain equilibrium.

**Proposition 3.**

There exists a unique \( c_1 \in (0, 1) \) and \( \beta_1 \in (0, 1/2) \) under the NB game: (i) when \( 0 \leq c < c_1 \), then \( \pi^{N^*}_T > \pi^{B^*}_T \), and the supplier prefers to offer TCF; (ii) when \( c_1 \leq c < 1 \) and \( 0 < \beta < \beta_1 \), then \( \pi^{N^*}_T > \pi^{B^*}_T \), and the supplier prefers to offer TCF; (iii) when \( c_1 \leq c < 1 \) and \( \beta_1 \leq \beta < 1/2 \), then \( \pi^{N^*}_T \leq \pi^{B^*}_T \), and the supplier prefers not to offer TCF.

Whether to offer trade credit for the supplier depends upon the supplier’s expected profit with BCF and TCF. The supplier prefers to offer TCF when \( \pi^{N^*}_T > \pi^{B^*}_T \). With TCF, the supplier will lose \( cq^N_T - \min(D, q^N_T) \) if the retailer goes bankrupt. Otherwise, the supplier will earn \( \min(D, q^N_T) - cq^N_T \). Note that the supplier’s expected profit is monotonically decreasing in \( c \). Therefore, there always exists a critical threshold value \( c_1 \) to determine the supplier’s preference. When \( 0 \leq c < c_1 \), the supplier can earn more profit with TCF than with BCF, i.e., \( \pi^{N^*}_T > \pi^{B^*}_T \). The supplier therefore prefers to offer TCF. In this case, the influence of bargaining power is negligible. When \( c_1 \leq c < 1 \), the supplier’s profit reduces. The supplier’s
strong bargaining power leads to \( \pi^{N*}_{T}s > \pi^{N*}_{Bs} \). In this case, the influence of bargaining power is prominent. Stronger bargaining power can lead to acquiring a greater part of the total surplus (see [3, 4, 40, 44]). Therefore, the supplier prefers to offer trade credit; otherwise the supplier prefers not to offer TCF because \( \pi^{N*}_{T}s \leq \pi^{N*}_{Bs} \).

### 3.2. Rubinstein bargaining game (RB game)

In this section, the RB game is considered to capture the alternating-offer negotiation process. In our proposed two-echelon supply chain, one player, either the supplier or retailer, initially offers a wholesale price contract \((w_1^R, q_1^R)\) to the other player. The latter responds with either acceptance or rejection. If the proposed contract is accepted, then the game is ended and the contract is executed. Both players receive the agreed profits \((\pi^R_s, \pi^R_r) = (x_{s1}, x_{r1})\), where \((x_{s1}, x_{r1})\) are the supplier’s and retailer’s expected profit in round 1, respectively. If the contract is rejected, the players conduct the next round and exchange roles to offer a new contract \((w_2^R, q_2^R)\). If the new contract is accepted, then both players receive the agreed profits \((\pi^R_s, \pi^R_r) = (\delta_s x_{s2}, \delta_r x_{r2})\), where the constant \(0 < \delta_s, \delta_r < 1\) represents the supplier’s and retailer’s discount factors in the negotiation, respectively, and \((x_{s2}, x_{r2})\) are the supplier’s and retailer’s expected profits in round 2, respectively.

With a wholesale price contract, the retailer with BCF has the same bargaining power as the supplier. Both the supplier and retailer have the same right to initially offer a contract. In TCF, the supplier offers trade credit to the retailer. Furthermore, she possesses stronger bargaining power. Hence, the supplier might choose whether first to offer a contract in the alternating-offer negotiation.

**Proposition 4.**

(i) if the supplier initially offers a wholesale price contract, then there exists a unique subgame perfect equilibrium of \((w_B^R, q_B^R)\) that is accepted immediately by the retailer, in which \(q_B^R = q^0\) and \(w_B^R\) satisfies \(m - \int_0^{q_B^R} \bar{F}(y) dy - w_B^R q_B^R = 0\), where \(m = \max\{\pi^S_{Br}, \delta_r (1 - \max\{\pi^S_{Bs}, \delta_s (1 - m)\})\}, \pi^R_{Bs} = \Pi - m\), and \(\pi^R_{Br} = m.\ \Pi = \int_0^{q^0} \bar{F}(y) dy - cq^0.\)

(ii) if the retailer initially offers a wholesale price contract, then there exists a unique subgame perfect equilibrium of \((w_B^R, q_B^R)\) that is accepted immediately by the supplier, where \(q_B^R = q^0\) and \(w_B^R\) satisfies \(\Pi - n - \int_0^{q_B^R} \bar{F}(y) dy - w_B^R q_B^R = 0\), where \(n = \max\{\pi^S_{Bs}, \delta_s (1 - \max\{\pi^S_{Br}, \delta_r (1 - n)\})\}, \pi^R_{Bs} = n\), and \(\pi^R_{Br} = \Pi - n.\)

The RB game with BCF orders the supply chain optimal order quantity. In BCF, regardless of whether the supplier or the retailer initially offers a contract, there always exists a unique optimal wholesale price contract to be agreed immediately in the first round, which avoids the potential loss in the next round.

**Proposition 5.**

In BCF, if the supplier initially offers a wholesale price contract,

(i) when \(0 < \delta_s \leq \frac{\pi^S_{Br}}{\pi^S_{Bs}}\) and \(0 < \delta_r < \frac{\pi^S_{Br}}{\pi^S_{Bs}}\), then \(w_B^R\) satisfies \(\pi^S_{Br} \int_{\pi^S_{Bs}}^{\pi^S_{Br}} \bar{F}(y) dy - w_B^R q_B^R = 0, \pi^R_{Bs} = \Pi - \pi^S_{Bs} > \pi^S_{Bs}, \) and \(\pi^R_{Br} = \pi^S_{Br}.\)

(ii) when \(0 < \delta_s \leq \frac{\pi^S_{Br}}{\pi^S_{Bs}}(1 - \frac{\pi^S_{Br}}{\pi^S_{Bs}})\) and \(\frac{\pi^S_{Br}}{\pi^S_{Bs}} < \delta_r < 1,\) then \(w_B^R\) satisfies \(\delta_r (\Pi - \pi^S_{Bs}) \int_{\pi^S_{Bs}}^{\pi^S_{Br}} \bar{F}(y) dy = 0, \pi^R_{Bs} = \Pi - \delta_r (\Pi - \pi^S_{Bs}) > \pi^S_{Bs}, \) and \(\pi^R_{Br} = \delta_r (\Pi - \pi^S_{Bs}) > \pi^S_{Br}.\)
(iii) when \( \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} - \delta_{s} < 1 \) and \( 0 < \delta_{r} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \), then \( w^{R_{s}}_{T} \) satisfies \( \pi^{s}_{T_{r}} - \int_{0}^{\pi^{s}_{T_{r}}} F(y)dy - w^{R_{s}}_{T} q^{R_{s}}_{T} = 0, \pi^{R_{r}}_{T_{r}} = \Pi - \pi^{s}_{T_{r}} > \pi^{s}_{T_{r}}, \) and \( \pi^{R_{r}}_{T_{r}} = \pi^{s}_{T_{r}}. \)

(iv) when \( \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} - \delta_{s} < 1 \) and \( 0 < \delta_{r} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \), then \( w^{R_{s}}_{T} \) satisfies \( \delta_{s}(1-\delta_{s})\Pi - \int_{0}^{\pi^{s}_{T_{r}}} F(y)dy - w^{R_{s}}_{T} q^{R_{s}}_{T} = 0, \pi^{R_{r}}_{T_{r}} = \frac{\delta_{s}(1-\delta_{s})}{1-\delta_{s}, \delta_{s}} \Pi > \pi^{s}_{T_{r}}, \) and \( \pi^{R_{r}}_{T_{r}} = \frac{\delta_{s}(1-\delta_{s})}{1-\delta_{s}, \delta_{s}} \Pi > \pi^{s}_{T_{r}}. \)

Proposition 6.
In BCF, if the retailer initially offers a wholesale price contract,

(i) when \( 0 < \delta_{s} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \) and \( 0 < \delta_{r} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \), then \( w^{R_{s}}_{T} \) satisfies \( \Pi - \pi^{s}_{T_{r}} - \int_{0}^{\pi^{s}_{T_{r}}} F(y)dy - w^{R_{s}}_{T} q^{R_{s}}_{T} = 0, \pi^{R_{r}}_{T_{r}} = \pi^{s}_{T_{r}}, \) and \( \pi^{R_{r}}_{T_{r}} = \pi^{s}_{T_{r}}. \)

(ii) when \( 0 < \delta_{s} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \) and \( \pi^{s}_{T_{r}} - \delta_{r} \leq \delta_{s} < 1 \), then \( w^{R_{s}}_{T} \) satisfies \( \Pi - \pi^{s}_{T_{r}} - \int_{0}^{\pi^{s}_{T_{r}}} F(y)dy - w^{R_{s}}_{T} q^{R_{s}}_{T} = 0, \pi^{R_{r}}_{T_{r}} = \pi^{s}_{T_{r}}, \) and \( \pi^{R_{r}}_{T_{r}} = \delta_{r}(1-\delta_{s})\Pi > \pi^{s}_{T_{r}}, \) and \( \pi^{R_{r}}_{T_{r}} = \pi^{s}_{T_{r}}. \)

(iii) when \( \pi^{s}_{T_{r}} < \delta_{s} < 1 \) and \( \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} < \delta_{r} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \), then \( w^{R_{s}}_{T} \) satisfies \( \pi^{s}_{T_{r}} - \int_{0}^{\pi^{s}_{T_{r}}} F(y)dy - w^{R_{s}}_{T} q^{R_{s}}_{T} = 0, \pi^{R_{r}}_{T_{r}} = \delta_{s}(1-\delta_{s})\Pi > \pi^{s}_{T_{r}}, \) and \( \pi^{R_{r}}_{T_{r}} = \pi^{s}_{T_{r}}. \)

(iv) when \( \pi^{s}_{T_{r}} < \delta_{s} < 1 \) and \( \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} < \delta_{r} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \), then \( w^{R_{s}}_{T} \) satisfies \( \frac{\delta_{s}(1-\delta_{s})}{1-\delta_{s}, \delta_{s}}\Pi > \pi^{s}_{T_{r}}, \) and \( \pi^{R_{r}}_{T_{r}} = \pi^{s}_{T_{r}}. \)

Propositions 5 and 6 indicate that with BCF, at least one player’s profit is greater than in the Stackelberg game. Hence, the RB game realizes the Pareto improvement. Player j’s expected profit is decreasing with player i’s discount factor. Fig. 2 shows that the player’s expected profit is divided into four regions by discount factor. The player’s decision depends upon the discount factor. In addition, we note that in the player j-initiated negotiation, player j earns more profit than in the player i-initiated negotiation.

Proposition 7. In TCF,

(i) the supplier prefers to initially offer a wholesale price contract;

(ii) there exists a unique subgame perfect equilibrium of \((w^{R_{s}}_{T}, q^{R_{s}}_{T})\) that is immediately accepted by the retailer, where \( q^{R_{s}}_{T} = F^{-1}(c) = q^{R_{s}}_{T} \) and \( w^{R_{s}}_{T} \) satisfies \( M - \int_{\pi^{s}_{T_{r}}}^{\pi^{s}_{T_{r}}} F(y)dy = 0 \) where \( M = \max\{\pi^{s}_{T_{r}}, \delta_{s}(\Pi - \pi^{s}_{T_{r}})\}, \)

\( \pi^{R_{r}}_{T_{r}} = \Pi - M, \) and \( \pi^{R_{r}}_{T_{r}} = M. \) There exist the following subcases:

Subcase (1): if \( 0 < \delta_{s} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \) and \( 0 < \delta_{r} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \), then \( w^{R_{s}}_{T} \) satisfies \( \pi^{s}_{T_{r}} - \int_{\pi^{s}_{T_{r}}}^{\pi^{s}_{T_{r}}} F(y)dy = 0, \pi^{R_{r}}_{T_{r}} = \Pi - \pi^{s}_{T_{r}} > \pi^{s}_{T_{r}_{s}}, \) and \( \pi^{R_{r}}_{T_{r}} = \pi^{s}_{T_{r}}. \)

Subcase (2): if \( 0 < \delta_{s} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \) and \( \pi^{s}_{T_{r}} < \delta_{r} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \), then \( w^{R_{s}}_{T} \) satisfies \( \delta_{r}(\Pi - \pi^{s}_{T_{r}}) - \int_{\pi^{s}_{T_{r}}}^{\pi^{s}_{T_{r}}} F(y)dy = 0, \pi^{R_{r}}_{T_{r}} = \Pi - \delta_{r}(\Pi - \pi^{s}_{T_{r}}) > \pi^{s}_{T_{r}_{s}}, \) and \( \pi^{R_{r}}_{T_{r}} = \delta_{r}(\Pi - \pi^{s}_{T_{r}}) > \pi^{s}_{T_{r}}. \)

Subcase (3) if \( \pi^{s}_{T_{r}} < \delta_{s} < 1 \) and \( 0 < \delta_{r} \leq \frac{\pi^{s}_{T_{r}}}{\pi^{s}_{T_{r}}} \), then \( w^{R_{s}}_{T} \) satisfies \( \pi^{s}_{T_{r}} - \int_{w^{R_{s}}_{T}}^{\pi^{s}_{T_{r}}} F(y)dy = 0, \pi^{R_{r}}_{T_{r}} = \Pi - \pi^{s}_{T_{r}} > \pi^{s}_{T_{r}_{s}}, \) and \( \pi^{R_{r}}_{T_{r}} = \pi^{s}_{T_{r}}. \)
Subcase (4): if \( \frac{\pi^*_{Bj}}{\pi - \delta_j} \) < \( \delta_s \) < 1 and \( \frac{\pi^*_{Bj}}{\pi - \delta_j} \) < \( \delta_r \) < 1, then \( w^*_{T} \) satisfies \( \frac{\delta_j(1-\delta_s) \Pi - \int_{w^*_{T}}^{\bar{y}} F(y)dy = 0, \pi^*_{T} = \frac{1-\delta_s}{1-\delta_s-\delta_r} \Pi > \pi^*_{T} \), and \( \pi^*_{T} = \frac{\delta_j(1-\delta_s) \Pi}{1-\delta_s-\delta_r} \).

In TCF, the player that initially offers a contract can earn more. Hence, the dominant supplier with full capital prefers to initially offer a contract. The RB game always orders the optimal supply chain order quantity. At least one player earns more expected profit than in the Stackelberg game. Hence, the RB game realizes the Pareto improvement. As with BCF, there also exists a unique optimal wholesale price contract with TCF. This price can be agreed immediately in the first round.

4. Numerical simulations. We present numerical samples to clarify the above theoretical results. We use the exponential distribution \( F(x) = exp(-0.01x) \) to depict random demand \( D \) (see [9]). Figure 3 illustrates the influence of bargaining power on the wholesale price under the NB game given \( c = 0.2 \). In TCF, \( w^*_{T} \) is strictly decreasing with \( \beta \) (Proposition 1). At the same time, Figure 3 also discloses that \( w^*_{T} < w^*_{B} \) with BCF and \( w^*_{T} < w^*_{T} \) with TCF when both players play the NB game (Proposition 2).

Figures 4 and 5 illustrate the relationship of the player’s expected profit with bargaining power under the NB and Stackelberg games. Assume \( c = 0.2 \) for Figure 4(a) and Figure 5(a), and \( c = 0.65 \) for Figure 4(b) and Figure 5 (b). The results in Figures 4 and 5 reveal that the NB game brings the supplier and retailer more expected profit than does the Stackelberg game (Proposition 1(i) and (ii)). The relationship of the player’s expected profit with \( \beta \) indicates that the player with stronger bargaining power gains the greater part of the total surplus. When \( c < c_1 = 0.5 \) or when \( c_1 \leq c < 1 \) and \( 0 < \beta < \beta_1 = 0.307 \), the supplier’s expected profit with TCF is greater than with BCF. The supplier prefers to offer TCF under the NB game (Proposition 3).
Tables 2 and 3 illustrate the effect of the discount factor on the supplier’s expected profit under the RB game. The numerical results show the following findings: (1) the supplier’s expected profit is increasing in her own discount factor and decreasing in the retailer’s discount factor with TCF and BCF (Propositions 5 and 6); (2) when the production cost is low (e.g., $c = 0.2$), the supplier always obtains...
greater expected profit with TCF than with BCF. The influences of the discount factors are negligible (Propositions 5 and 6); (3) when the production cost is high (e.g., \( c = 0.65 \)), the supplier’s expected profit depends upon the discount factors. The stronger the bargaining power, the greater part of the total surplus the player obtains (Propositions 4 and 7); (4) a low production cost always leads to greater supplier expected profit than a high production cost, either with BCF or with TCF. Therefore, the supplier should give more attention to controlling the production cost and offering TCF. Both actions will create greater expected profit for the supplier.

**Table 2.** \( \pi_{B}^{RF} \) and \( \delta_{j} \) given \( c = 0.2 \)

| \( \delta_{s} \) \( \delta_{r} \) | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|
| B | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 |
| T | 47.35 | 47.35 | 47.35 | 47.35 | 47.35 | 47.35 | 47.35 | 47.35 | 47.35 |
| B | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 |
| T | 46.89 | 46.89 | 46.89 | 46.89 | 46.89 | 46.89 | 46.89 | 46.89 | 46.89 |
| B | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 |
| T | 46.43 | 46.43 | 46.43 | 46.43 | 46.43 | 46.43 | 46.43 | 46.43 | 46.43 |
| B | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 | 34.76 |
| T | 45.97 | 45.97 | 45.97 | 45.97 | 45.97 | 45.97 | 45.97 | 45.97 | 45.97 |
| B | 34.38 | 34.38 | 34.38 | 34.38 | 34.38 | 34.38 | 34.38 | 34.38 | 34.38 |
| T | 45.51 | 45.51 | 45.51 | 45.51 | 45.51 | 45.51 | 45.51 | 45.51 | 45.51 |
| B | 31.70 | 31.70 | 31.70 | 31.70 | 31.70 | 31.70 | 31.70 | 31.70 | 31.70 |
| T | 45.05 | 45.05 | 45.05 | 45.05 | 45.05 | 45.05 | 45.05 | 45.05 | 45.05 |
| B | 29.01 | 29.01 | 29.01 | 29.01 | 29.01 | 29.01 | 29.01 | 29.01 | 29.01 |
| T | 44.59 | 44.59 | 44.59 | 44.59 | 44.59 | 44.59 | 44.59 | 44.59 | 44.59 |
| B | 26.33 | 26.33 | 26.33 | 26.33 | 26.33 | 26.33 | 26.33 | 26.33 | 26.33 |
| T | 44.13 | 44.13 | 44.13 | 44.13 | 44.13 | 44.13 | 44.13 | 44.13 | 44.13 |
| B | 23.64 | 23.64 | 23.64 | 23.64 | 23.64 | 23.64 | 23.64 | 23.64 | 23.64 |
| T | 43.67 | 43.67 | 43.67 | 43.67 | 43.67 | 43.67 | 43.67 | 43.67 | 43.67 |

Note: The symbols “B” and “T” denote “BCF” and “TCF”, respectively.

**Table 3.** \( \pi_{B}^{RF} \) and \( \delta_{j} \) given \( c = 0.65 \)

| \( \delta_{s} \) \( \delta_{r} \) | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|
| B | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 |
| T | 6.36 | 6.43 | 6.49 | 6.56 | 6.63 | 6.70 | 6.77 | 6.85 | 6.92 |
| B | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 |
| T | 5.71 | 5.83 | 5.96 | 6.09 | 6.22 | 6.36 | 6.51 | 6.67 | 6.83 |
| B | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 |
| T | 5.05 | 5.21 | 5.38 | 5.57 | 5.76 | 5.97 | 6.20 | 6.45 | 6.71 |
| B | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 |
| T | 4.37 | 4.56 | 4.77 | 5.00 | 5.25 | 5.53 | 5.83 | 6.18 | 6.56 |
| B | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 | 5.19 |
| T | 3.68 | 3.89 | 4.12 | 4.37 | 4.67 | 5.00 | 5.38 | 5.83 | 6.36 |
| B | 4.82 | 4.82 | 4.82 | 4.82 | 4.82 | 4.82 | 4.83 | 5.19 | 5.19 |
| T | 2.98 | 3.18 | 3.41 | 3.68 | 4.00 | 4.37 | 4.83 | 5.38 | 6.09 |
| B | 4.46 | 4.46 | 4.46 | 4.46 | 4.46 | 4.46 | 4.46 | 4.46 | 4.77 |
| T | 2.26 | 2.44 | 2.66 | 2.92 | 3.23 | 3.62 | 4.12 | 4.77 | 5.67 |
| B | 4.10 | 4.10 | 4.10 | 4.10 | 4.10 | 4.10 | 4.10 | 4.10 | 5.00 |
| T | -0.03 | -0.03 | -0.03 | -0.03 | -0.03 | -0.03 | -0.03 | -0.03 | -0.03 |
| B | 3.74 | 3.74 | 3.74 | 3.74 | 3.74 | 3.74 | 3.74 | 3.74 | 3.74 |
| T | -0.91 | -0.91 | -0.91 | -0.91 | -0.91 | -0.91 | -0.91 | -0.91 | -0.91 |
5. Conclusion and management insights. We analyze the bargaining equilibrium in a two-echelon supply chain consisting of an upstream supplier and a downstream capital-constrained retailer. The newsvendor-like retailer can borrow from a bank or use the supplier’s trade credit to fund his orders. With a wholesale price contract, both players negotiate the wholesale price and order quantity to maximize individual expected profit. We first find that in both the BCF and TCF schemes, the NB and RB bargaining games both reach the supply chain optimal order quantity. With two financing schemes, the NB game overcomes the double marginalization effect under the Stackelberg game to achieve supply chain coordination. The RB game realizes the Pareto improvement of the supply chain. Second, under the NB game, whether the supplier prefers to offer TCF depends upon the production cost and bargaining power. The player with stronger bargaining power obtains a greater expected profit in two financing schemes. Under the RB game, the supplier always offers a contract to obtain greater expected profit with TCF. The player’s expected profit is decreasing in its opponent’s discount factor. There always exists a unique optimal wholesale price contract to be agreed immediately in the first-round negotiation under the RB game.

Our work points to two important management insights. First, with a wholesale price contract, the NB and RB games can realize the supply chain optimal quantity. Therefore, the supplier and retailer should consider a negotiation to improve the supply chain performance. Second, the supplier and retailer try their best to increase bargaining power and obtain greater profit. In addition, the supplier takes efficient actions to control the production cost. By offering TCF at a low production cost, the supplier will obtain greater profit.

The paper can be extended in the following two possible directions. First, in our model, the supplier is endowed with full capital. The capital-constrained retailer can borrow from a bank or use the supplier’s trade credit to fund his business. In practice, however, the supplier also faces capital shortage. The supplier often must resort to financial institutions. Therefore, considering the supply chain with both capital-constrained players will yield more-interesting results. Second, our current model focuses on the bargaining equilibrium in both the BCF and TCF schemes. In addition to such financing schemes, the retailer with limited capital can utilize equity financing to mitigate his capital pressure. Incorporating equity financing into our current model would be a different and interesting topic in bargaining analysis.

Appendixes

Appendix A (Proof of proposition 1)

(i) In BCF, solving the first-order conditions of Equation (1) yields

\[ \frac{\partial G_B}{\partial w_B} = -q_B^N(w_B^N q_B^N - c q_B^N - d_2) + q_B^N \left( \int_0^{q_B^N} F(y) dy - w_B^N q_B^N - d_1 \right) = 0 \]

and

\[ \frac{\partial G_B}{\partial q_B} = (\bar{F}(q_B^N) - w_B^N)(w_B^N q_B^N - c q_B^N - d_2) + (w_B^N - c)(\int_0^{q_B^N} F(y) dy - w_B^N q_B^N - d_1) = 0. \]

When \( q_B^N \neq 0 \), then \( q_B^N = \bar{F}^{-1}(c) \) and \( w_B^N = \frac{c q_B^N + \int_0^{q_B^N} F(y) dy + d_2 - d_1}{2 q_B^N} \). Therefore, we have

\[ \pi_B^N = (w_B^N - c) q_B^N = d_2 + \frac{1}{2}(\int_0^{q_B^N} F(y) dy - c q_B^N - d_1 - d_2) > d_2 \]

and

\[ \pi_B^N = \int_0^{q_B^N} F(y) dy - w_B^N q_B^N = d_1 + \frac{1}{2}(\int_0^{q_B^N} F(y) dy - c q_B^N - d_1 - d_2) > d_1. \]

Because

\[ \frac{\partial^2 G_B}{\partial w_B^2} (\bar{q}_B^N, q_B^N) = -2(q_B^N)^2 < 0, \quad \frac{\partial^2 G_B}{\partial q_B^2} (\bar{w}_B^N, q_B^N) = -4q_B^N + 3c q_B^N + \int_0^{q_B^N} F(y) dy + d_2 - d_1 = c q_B^N - \int_0^{q_B^N} F(y) dy + d_1 - d_2, \]

and

\[ \frac{\partial^2 G_B}{\partial q_B^2} (\bar{w}_B^N, q_B^N) = -4q_B^N + 3c q_B^N + \int_0^{q_B^N} F(y) dy + d_2 - d_1 = c q_B^N - \int_0^{q_B^N} F(y) dy + d_1 - d_2. \]
-4w_B^N q_B^N + 3cq_B^N + \int_0^{q_B^N} \bar{F}(y)dy + d_2 - d_1 = cq_B^N - \int_0^{q_B^N} \bar{F}(y)dy + d_1 - d_2 and 
\frac{\partial^2 G_1}{\partial q_B^N \partial q_B^N} |_{(w_B^N, q_B^N)} = \frac{2(q_B^N)^2}{2(q_B^N)^2} \text{, we have } \frac{\partial^2 G_1}{\partial q_B^N \partial q_B^N} = \frac{\partial^2 G_1}{\partial q_B^N \partial q_B^N} |_{(w_B^N, q_B^N)} = \frac{(q_B^N)^2 f(q_B^N)}{2(q_B^N)^2} \left(\int_0^{q_B^N} \bar{F}(y)dy - cq_B^N - d_2 \right) . \text{ Because }
\int_0^{q_B^N} \bar{F}(y)dy - cq_B^N - d_2 > 0, \frac{\partial^2 G_1}{\partial q_B^N \partial q_B^N} < 0. 

Hence, there exists a unique Nash bargaining equilibrium \((w_B^N, q_B^N)\).

(ii) Let \(G = \ln G_2 = \beta \ln \left(\int_{w_B^N}^{q_B^N} \bar{F}(y)dy - d_3 \right) + (1 - \beta) \ln \left(\int_{w_B^N}^{q_B^N} \bar{F}(y)dy - cq_B^N - d_4 \right) . \text{ From } \frac{\partial G}{\partial w_B^N} = \beta \frac{\bar{F}(q_B^N) - w_B^N \bar{F}(w_B^N)}{\int_{w_B^N}^{q_B^N} \bar{F}(w_B^{N'})} + (1 - \beta) \frac{\int_{w_B^N}^{q_B^N} \bar{F}(w_B^{N'})} {\int_{w_B^N}^{q_B^N} \bar{F}(w_B^{N'})} = 0 \text{ and } \frac{\partial G}{\partial q_B^N} = -\beta \frac{\bar{F}(q_B^N) - w_B^N \bar{F}(w_B^N)}{\int_{w_B^N}^{q_B^N} \bar{F}(w_B^{N'})} + (1 - \beta) \frac{\int_{w_B^N}^{q_B^N} \bar{F}(w_B^{N'})} {\int_{w_B^N}^{q_B^N} \bar{F}(w_B^{N'})} = 0, \text{ we have when } q_B^N \neq 0, \text{ then } q_B^N = \bar{F}^{-1}(c) \text{ and } w_B^N \text{ is given by } \int_{w_B^N}^{q_B^N} \bar{F}(y)dy - cq_B^N = d_4 + (1 - \beta) \left(\int_0^{q_B^N} \bar{F}(y)dy - cq_B^N - d_3 - d_4 \right) > d_4 \text{ and } \pi_{q_B^N} = \int_{w_B^N}^{q_B^N} \bar{F}(y)dy = d_3 + \beta \left(\int_0^{q_B^N} \bar{F}(y)dy - cq_B^N - d_3 - d_4 \right) > d_3 . \text{ Because } \frac{\partial^2 G}{\partial w_B^N \partial q_B^N} |_{(w_B^N, q_B^N)} = \frac{-\beta f(q_B^N) \left(\int_{w_B^N}^{q_B^N} \bar{F}(y)dy - d_3 \right) - \beta q_B^N \bar{F}(w_B^N) - c^3 \left(\int_{w_B^N}^{q_B^N} \bar{F}(w_B^{N'}) \bar{F}(w_B^{N'}) \right)^2}{\left(1 - \beta \right) \left(\int_{w_B^N}^{q_B^N} \bar{F}(w_B^{N'}) \bar{F}(w_B^{N'}) \right)^2} \text{ and } \frac{\partial^2 G}{\partial w_B^N \partial q_B^N} |_{(w_B^N, q_B^N)} = \frac{-\beta q_B^N \bar{F}(w_B^N) \left(\int_{w_B^N}^{q_B^N} \bar{F}(y)dy - d_3 \right) - \beta q_B^N \bar{F}(w_B^N) - c^3 \left(\int_{w_B^N}^{q_B^N} \bar{F}(w_B^{N'}) \bar{F}(w_B^{N'}) \right)^2}{\left(1 - \beta \right) \left(\int_{w_B^N}^{q_B^N} \bar{F}(w_B^{N'}) \bar{F}(w_B^{N'}) \right)^2} , \text{ we have } \frac{\partial^2 G}{\partial w_B^N \partial q_B^N} - \frac{\partial^2 G}{\partial w_B^N \partial q_B^N} = \frac{\partial^2 G}{\partial w_B^N \partial q_B^N} \left(\int_{w_B^N}^{q_B^N} \bar{F}(y)dy - d_3 \right) > 0 , \text{ we have } \frac{\partial^2 G}{\partial w_B^N \partial q_B^N} = \frac{\beta^2 \left(\int_{w_B^N}^{q_B^N} \bar{F}(w_B^N) \bar{F}(w_B^N) \right)^2 \left(\int_{w_B^N}^{q_B^N} \bar{F}(y)dy - d_3 \right)}{1 - \beta \left(\int_{w_B^N}^{q_B^N} \bar{F}(w_B^N) \bar{F}(w_B^N) \right)^2} \text{ and } \frac{\partial^2 G}{\partial w_B^N \partial q_B^N} = \frac{\beta \left(\int_{w_B^N}^{q_B^N} \bar{F}(w_B^N) \bar{F}(w_B^N) \right)^2 \left(\int_{w_B^N}^{q_B^N} \bar{F}(y)dy - d_3 \right)} {1 - \beta \left(\int_{w_B^N}^{q_B^N} \bar{F}(w_B^N) \bar{F}(w_B^N) \right)^2} . \text{ Because } \int_{w_B^N}^{q_B^N} \bar{F}(y)dy - d_3 > 0 , \text{ we have } \frac{\partial^2 G}{\partial w_B^N \partial q_B^N} = \frac{\beta \left(\int_{w_B^N}^{q_B^N} \bar{F}(w_B^N) \bar{F}(w_B^N) \right)^2 \left(\int_{w_B^N}^{q_B^N} \bar{F}(y)dy - d_3 \right)} {1 - \beta \left(\int_{w_B^N}^{q_B^N} \bar{F}(w_B^N) \bar{F}(w_B^N) \right)^2} > 0 . \text{ Hence, there exists a unique Nash bargaining equilibrium } (w_B^N, q_B^N) .

(iii) In TCF, \(w_B^N \) is given by \( \int_{w_B^N}^{q_B^N} \bar{F}(y)dy - q_B^N \int_{0}^{q_B^N} \bar{F}(y)dy + \beta \int_{0}^{q_B^N} \bar{F}(y)dy + \beta q_B^N + (\beta - 1)d_3 + \beta d_4 = 0 . \text{ We have } \frac{\partial w_B^N}{\partial q_B^N} = c q_B^N - c \frac{\int_{w_B^N}^{q_B^N} \bar{F}(y)dy}{\int_{w_B^N}^{q_B^N} \bar{F}(y)dy} \leq \frac{\bar{F}(y)dy}{q_B^N \int_{w_B^N}^{q_B^N} \bar{F}(y)dy} = 0 .

Appendix B (Proof of proposition 2)

(i) According to Jing et al. \[20\], \(q_{\bar{B}}^N \) is given by \( \int_{q_{\bar{B}}^N}^{q_{\bar{B}}^N} \bar{F}(y)dy - q_{\bar{B}}^N \int_{0}^{q_{\bar{B}}^N} \bar{F}(y)dy = c \) and \( w_{\bar{B}}^N = \bar{F}(q_{\bar{B}}^N) . \text{ Because } \bar{F}(q_{\bar{B}}^N) = c \text{, then } \bar{F}(q_{\bar{B}}^N) = q_{\bar{B}}^N \int_{q_{\bar{B}}^N}^{q_{\bar{B}}^N} \bar{F}(y)dy + d_3 . \text{ Hence, we have } \bar{q}_{\bar{B}}^N > q_{\bar{B}}^N . \text{ From Proposition 1, } w_{\bar{B}}^N - w_{\bar{B}}^N = c q_{\bar{B}}^N + \int_{0}^{q_{\bar{B}}^N} \bar{F}(y)dy + d_3 - d_2 - w_{\bar{B}}^N = c(q_{\bar{B}}^N - q_{\bar{B}}^N) - 2w_{\bar{B}}^N(q_{\bar{B}}^N - q_{\bar{B}}^N) + \int_{0}^{q_{\bar{B}}^N} \bar{F}(y)dy \leq 2\bar{F}(y)dy - 2w_{\bar{B}}^N(q_{\bar{B}}^N - q_{\bar{B}}^N) = 0 .

(ii) Similarly, according to Jing et al. \[20\], \(q_{\bar{B}}^N \) solves \( \bar{H}(q_{\bar{B}}^N) = 1 . \text{ Therefore, } w_{\bar{B}}^N = 1 . \text{ Because } w_{\bar{B}}^N \leq w_{\bar{B}}^N .
According to Proposition 2 in Jing et al. [20], \( \pi_{BS} < \pi_{N} \). Suppose \( q_{B}^{S} < q_{B}^{T} \). Let \( \triangle(p) \), which is a contradiction. Therefore, we have \( \triangle(1) \geq 0 \), i.e., \( \triangle(1) < 0 \). Because \( \triangle(1) \mid_{c=0} = \frac{1}{2} \left( \int_{0}^{q_{B}^{S}} F(y)dy + \int_{q_{B}^{S}}^{q_{B}^{T}} F(y)dy\right) > 0 \). Therefore, there exists a threshold \( c_{1} \) such that \( \triangle(1) > 0 \) if \( 0 < c < c_{1} \) but \( \triangle(1) \leq 0 \) if \( c_{1} \leq c < 1 \). To summarize, we have the following results: if \( 0 \leq c < c_{1} \), then \( \pi_{BS} > \pi_{N} \), i.e., the supplier prefers TCF; if \( c_{1} \leq c < 1 \) and \( 0 < \beta < \beta_{1} \), then \( \pi_{BS} > \pi_{N} \), i.e., the supplier prefers TCF; if \( c_{1} \leq c < 1 \) and \( \beta_{1} \leq \beta < 1 \), then \( \pi_{BS} \leq \pi_{N} \), i.e., the supplier prefers BCF. 

Appendix D (Proof of Proposition 4) 

(i) In BCF, let \( m_{s} \) and \( m_{r} \) be the least expected profits that the supplier and the retailer accept in the subgame perfect equilibrium.

Case 1: when the supplier offers \((w_{B}^{R}, q_{B}^{R})\), then \((w_{B}^{R}, q_{B}^{R})\) satisfy

\[
\int_{0}^{q_{B}^{R}} F(y)dy - w_{B}^{R}q_{B}^{R} = m_{r}.
\]

From \( L_{1}(w_{B}^{R}, q_{B}^{R}, \lambda_{1}) = w_{B}^{R}q_{B}^{R} - c_{B}^{R} + \lambda_{1} \left( \int_{0}^{q_{B}^{R}} F(y)dy - w_{B}^{R}q_{B}^{R} - m_{r} \right) \), we have \( \lambda_{1} \geq 0 \), \( (w_{B}^{R}, q_{B}^{R}, \lambda_{1}) \) satisfies

\[
\begin{align*}
\frac{\partial L_{1}}{\partial w_{B}^{R}} &= q_{B}^{R} - \lambda_{1}q_{B}^{R} = 0 \\
\frac{\partial L_{1}}{\partial q_{B}^{R}} &= w_{B}^{R} - c + \lambda_{1}(F(q_{B}^{R}) - w_{B}^{R}) = 0 \\
\lambda_{1} \left( \int_{0}^{q_{B}^{R}} F(y)dy - w_{B}^{R}q_{B}^{R} - m_{r} \right) &= 0
\end{align*}
\]

Thus, \( \lambda_{1} = 1 \), \( \bar{F}(q_{B}^{R}) = c \) and \( \int_{0}^{q_{B}^{R}} F(y)dy - w_{B}^{R}q_{B}^{R} = m_{r} \).

Case 2: when the retailer offers \((w_{B}^{R}, q_{B}^{R})\), then \((w_{B}^{R}, q_{B}^{R})\) satisfy

\[
\int_{0}^{q_{B}^{R}} F(y)dy - w_{B}^{R}q_{B}^{R} \geq m_{s}.
\]

From \( L_{2}(w_{B}^{R}, q_{B}^{R}, \lambda_{2}) = \int_{0}^{q_{B}^{R}} F(y)dy - w_{B}^{R}q_{B}^{R} + \lambda_{2}(w_{B}^{R}q_{B}^{R} - c_{B}^{R} - m_{s}) \), we have \( \lambda_{2} \geq 0 \), \( (w_{B}^{R}, q_{B}^{R}, \lambda_{2}) \) satisfies

\[
\begin{align*}
\frac{\partial L_{2}}{\partial w_{B}^{R}} &= -q_{B}^{R} - \lambda_{2}q_{B}^{R} = 0 \\
\frac{\partial L_{2}}{\partial q_{B}^{R}} &= F(q_{B}^{R}) - w_{B}^{R} + \lambda_{2}(w_{B}^{R} - c) = 0 \\
\lambda_{2} \left( w_{B}^{R}q_{B}^{R} - c_{B}^{R} - m_{s} \right) &= 0
\end{align*}
\]

Thus, \( \lambda_{2} = 1 \), \( \bar{F}(q_{B}^{R}) = c \) and \( w_{B}^{R}q_{B}^{R} - c_{B}^{R} = m_{s} \). From Case 1 and Case 2, we have \( q_{B}^{R} = \bar{F}^{-1}(c) = \bar{q}^{R} \).
In the one-round bargaining, the supplier prefers to initially provide a contract to ensure the retailer and supplier obtain $\pi_{Br}^S$ and $\Pi - \pi_{Br}^S$, respectively.

In the two-round bargaining, the retailer at the second round prefers to provide a contract to ensure the supplier and retailer obtain $\pi_{Bs}^S$ and $\Pi - \pi_{Bs}^S$, respectively. There exists the discount factor. The retailer’s and the supplier’s actual expected profits at the second round are $(\delta_r(\Pi - \pi_{Br}^S), \delta_s(\Pi - \pi_{Bs}^S))$, which is not the Pareto solution. The bargaining process cannot enter the second round. The retailers expected profit at the first round is no less than $\max\{\pi_{Br}^S, \delta_r(\Pi - \pi_{Br}^S)\}$. Hence, at the first round, the retailer obtains $\max\{\pi_{Br}^S, \delta_r(\Pi - \pi_{Br}^S)\}$, and the supplier obtains $\Pi - \max\{\pi_{Br}^S, \delta_s(\Pi - \pi_{Bs}^S)\}$.

Similarly, in the three-round bargaining, the retailer’s and supplier’s expected profit at the first round are $(\max\{\pi_{Br}^S, \delta_r(\Pi - \max\{\pi_{Bs}^S, \delta_s(\Pi - \pi_{Bs}^S)\})\}, \Pi - \max\{\pi_{Br}^S, \delta_r(\Pi - \max\{\pi_{Bs}^S, \delta_s(\Pi - \pi_{Bs}^S)\})\})$. According to Sutton [45] and Muthoo [34], we have $m = \max\{\pi_{Br}^S, \delta_r(\Pi - \pi_{Bs}^S)\} = \max\{\pi_{Br}^S, \delta_s(\Pi - m)\}$. Hence, the supplier initially provides a contract $(w_{0B}^R, q_{0B}^R)$ at the first round, where $w_{0B}^R$ is given by $m - \int_0^{\pi_{Br}^S} \bar{F}(y)dy - \pi_{0B}^R = 0$ and $q_{0B}^R = q^0$. Furthermore, the retailer obtains $m$ and the supplier obtains $\Pi - m$ at the first round.

(ii) Similar to the proof of (i), we can prove (ii).

Appendix E (Proof of proposition 5)

From $m = \max\{\pi_{Br}^S, \delta_r(\Pi - \max\{\pi_{Bs}^S, \delta_s(\Pi - m)\})\}$,

(i) if $\pi_{Bs}^S \geq \delta_s(\Pi - m)$, then $m = \max\{\pi_{Br}^S, \delta_r(\Pi - \pi_{Bs}^S)\}$. Thus, when $\pi_{Br}^S \geq \delta_r(\Pi - \pi_{Bs}^S)$, then $m = \pi_{Br}^S$. When $0 < \delta_s \leq \frac{\pi_{Br}^S}{\Pi - \pi_{Br}^S}$ and $0 < \delta_r \leq \frac{\pi_{Br}^S}{\Pi - \pi_{Br}^S}$, then $w_{0B}^R$ satisfies $\pi_{Br}^S - \int_0^{\pi_{Br}^S} \bar{F}(y)dy - \pi_{0B}^R = 0$, $\delta_r(\Pi - \pi_{Bs}^S)$, and $\pi_{Br}^S = \Pi - \pi_{Br}^S > \pi_{Br}^S + \pi_{Bs}^S - \pi_{Bs}^S = \pi_{Bs}^S$.

(ii) if $\pi_{Bs}^S \geq \delta_s(\Pi - m)$ and $\pi_{Br}^S < \delta_r(\Pi - \pi_{Bs}^S)$, then $m = \delta_r(\Pi - \pi_{Bs}^S)$. When $0 < \delta_s \leq \frac{\pi_{Br}^S}{\Pi - \pi_{Br}^S}$ and $0 < \pi_{Br}^S - \pi_{Bs}^S < \delta_r < 1$, then $w_{0B}^R$ satisfies $\delta_r(\Pi - \pi_{Br}^S) - \int_0^{\pi_{Br}^S} \bar{F}(y)dy - \pi_{0B}^R = 0$, $\delta_r(\Pi - \pi_{Bs}^S)$, and $\pi_{Br}^S = \Pi - \pi_{Br}^S > (1 - \delta_r)(\pi_{Br}^S + \pi_{Bs}^S) + \delta_r \pi_{Bs}^S = (1 - \delta_r)\pi_{Br}^S + \pi_{Bs}^S = \pi_{Bs}^S$.

(iii) if $0 < \delta_s < \delta_r(\Pi - m)$, then $m = \max\{\pi_{Br}^S, \delta_r(\Pi - \pi_{Bs}^S)\}$. Thus, when $\pi_{Bs}^S \geq \delta_s(\Pi - \pi_{Bs}^S)$, then $m = \pi_{Br}^S$. When $\frac{\pi_{Br}^S}{\Pi - \pi_{Br}^S} < \delta_s < 1$ and $0 < \delta_r \leq \frac{\pi_{Br}^S}{\Pi - \pi_{Br}^S}$, then $w_{0B}^R$ satisfies $\pi_{Br}^S - \int_0^{\pi_{Br}^S} \bar{F}(y)dy - \pi_{0B}^R = 0$, $\pi_{Br}^S = \pi_{Br}^S$ and $\pi_{Br}^S = \Pi - \pi_{Br}^S > \pi_{Br}^S + \pi_{Bs}^S - \pi_{Bs}^S = \pi_{Bs}^S$.

(iv) if $\delta_r(\Pi - m)$ and $\pi_{Br}^S < \delta_s(\Pi - \pi_{Bs}^S)$, then $m = \frac{\pi_{Br}^S}{1 - \delta_s(\Pi - \pi_{Br}^S)}$. When $\frac{\pi_{Br}^S}{\Pi - \pi_{Br}^S} < \delta_s < 1$ and $\frac{\pi_{Br}^S}{\Pi - \pi_{Br}^S} < \delta_r < 1$, then $w_{0B}^R$ satisfies $\delta_r(\Pi - \pi_{Bs}^S) - \int_0^{\pi_{Br}^S} \bar{F}(y)dy - \pi_{0B}^R = 0$, $\pi_{Br}^S = \delta_r(\Pi - \pi_{Bs}^S)$, and $\pi_{Br}^S = \Pi - \pi_{Br}^S$.

Appendix F (Proof of proposition 6)

The proof is similar to Proposition 4 and is hence omitted.

Appendix G (Proof of proposition 7)
Similar to the proof of Proposition 3, (i) when the supplier first offers a contract, then $q_T^{R^s} = q^0$ and $w_T^{R^s}$ satisfies $M - \int_0^{q_T^{R^s}} \bar{F}(y)dy - w_T^{R^s}q_T^{R^s} = 0$, where $M = \max\{\pi^S_T, \delta, (\Pi - \max\{\pi^S_T, \delta, (\Pi - M)\})\}$, $\pi^R_T = \Pi - M$ and $\pi^S_T = M$; (ii) if the retailer first offers a contract, then $q_T^{R^s} = q^0$ and $w_T^{R^s}$ satisfies $\Pi - N - \int_0^{q_T^{R^s}} \bar{F}(y)dy - w_T^{R^s}q_T^{R^s} = 0$, where $N = \max\{\pi^S_T, \delta, (\Pi - \max\{\pi^S_T, \delta, (\Pi - N)\})\}$, $\pi^R_T = N$ and $\pi^S_T = \Pi - N$. Similar to the proofs of Propositions 4 and 5, we have $\Pi - M \geq N$. Since the supplier in TCF has stronger bargaining power, she always prefers to first offer a contract. The proofs of the subcases are similar to Proposition 4 and are hence omitted.

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