The Role of Contract Negotiation and Industry Structure in Production Outsourcing

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Despite the spread of cost-driven outsourcing practices, academic research cautions that suppliers' cost advantage may weaken manufacturers' bargaining positions in negotiating outsourcing agreements, thereby hurting their profitability. In this study, we attempt to further understand the strategic impact of low-cost outsourcing on manufacturers' profitability by investigating the contractual form of outsourcing agreements and the industry structure of the upstream supply market. We consider a two-tier supply chain system, consisting of two competing manufacturers, who have the option to produce in-house or to outsource to an upstream supplier with lower cost. To reach an outsourcing agreement, each manufacturer engages in bilateral negotiation with her supplier, who may be an exclusive supplier or a common supplier serving both manufacturers. Our analysis shows that wholesale-price contracts always mitigate the competition between manufacturers regardless of whether they compete with price or quantity. In contrast, two-part tariffs intensify the competition when the manufacturers compete with quantity, but soften it when they compete with price. As a result, when outsourcing with two-part tariffs, the manufacturers may earn lower profits than they would from in-house production, although the suppliers are more cost efficient. This suggests that managers have to be wary about the downside of using coordinating contracts such as two-part tariffs when pursuing low-cost outsourcing strategies. Our analysis also sheds some light on the profitability of using an exclusive supplier for outsourcing. When outsourcing with wholesale-price contracts, the competing manufacturers are better off outsourcing to an exclusive supplier. However, when outsourcing with two-part tariffs, the manufacturers may earn higher profits by outsourcing to a common supplier than to an exclusive one when the manufacturers’ bargaining power is sufficiently strong (weak) under quantity (price) competition.

Key words: outsourcing; wholesale-price contract; common vs. exclusive supplier; two-part tariff; multiunit bilateral bargaining

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1. Introduction

In the last few decades, many manufacturing firms have outsourced production processes to external suppliers to allow them to focus their resources on core competencies such as product development, marketing, and distribution. It is widely believed that well-executed outsourcing strategies have the potential to achieve significant cost reduction for manufacturers. In the computer industry, OEMs such as Hewlett-Packard, Dell, and Acer have long pursued outsourcing strategies—a majority part of their production processes have been outsourced to contract manufacturers located in low-wage countries to improve cost efficiency (see, e.g., Dedrick and Kraemer 2006, iSuppli 2009, Ladendorf 2009).

Although the cost-reduction benefit of outsourcing is well understood, its effect on manufacturers’ bottom-line performance is not so transparent. On the one hand, suppliers’ cost efficiency may bring savings to manufacturers. On the other hand, the manufacturers have to share part of their profits with the suppliers, and profit allocation naturally depends on the negotiated outsourcing agreements. Recently, Feng and Lu (2012) demonstrated the strategic perils of low-cost outsourcing by showing that suppliers’ cost advantage may weaken competing manufacturers’ bargaining positions in negotiating outsourcing agreements, thereby hurting their profitability. Building upon the modeling framework of Feng and Lu (2012), we attempt to further understand the impact of low-cost outsourcing on manufacturers’ profitability by investigating two related managerial factors: (i) the contractual form of outsourcing agreements and (ii) the industry structure of the upstream supply market.

In a stylized two-tier supply chain system, we study two competing manufacturers, who have the option to produce in-house or to outsource to an upstream supplier with lower cost. To reach an
outsourcing agreement, each manufacturer engages in bilateral negotiation with her supplier. The manufacturers subsequently compete in the product market by setting either prices or quantities. We study the implications of two contractual forms in outsourcing negotiations: wholesale-price contract and two-part tariff.

Anecdotal evidence suggests that in the computer and electronics industries outsourcing agreements often take the form of wholesale-price contracts (e.g., A. Montalbano, Personal communication). Wholesale-price contract is also the predominant choice in research studies on manufacturing outsourcing (see e.g., Cachon and Harker 2002, Gilbert et al. 2006b, Ulku et al. 2007). Despite its wide use in practice, wholesale-price contract has long been criticized by academic researchers as a major cause of supply chain inefficiency due to its well-known double marginalization effect. It is found that in many situations two-part tariffs as well as other sophisticated contracts are able to correct channel inefficiencies caused by wholesale-price contracts (Cachon 2003). Two-part tariffs and similar two-part pricing schemes have also been constructed to achieve centralized system performance in various service outsourcing settings (e.g., Akan et al. 2011, Hasija et al. 2008, Ren and Zhou 2008).

Given their importance in outsourcing practices and academic research, we systematically compare the outsourcing agreements and firm profitability under wholesale-price contracts and two-part tariffs. To facilitate the comparison, we consider an integrated benchmark in which each manufacturer acquires her supplier’s production process and thus attains his cost efficiency. We find that regardless of whether the manufacturers compete with price or quantity, wholesale-price contracts always mitigate the competition compared to the integrated benchmark. In contrast, two-part tariffs intensify the competition when the manufacturers compete with quantity, but soften it when they compete with price. As a result, when outsourcing with two-part tariffs, the manufacturers with relatively low bargaining power may earn lower profits than they would from in-house production, although the suppliers are more cost efficient. Surprisingly, despite the intensified competition, outsourcing is generally the manufacturers’ dominant strategy in equilibrium.

These different manufacturer profitabilities can be attributed to the impact of contractual form on outsourcing negotiation. Under wholesale-price contracts, the negotiated unit prices are always above the suppliers’ marginal cost. While the margin earned by the suppliers may lead to supply chain inefficiency (due to double marginalization), it prevents the manufacturers from competing too aggressively against each other. By contrast, under two-part tariffs, the negotiated unit prices are always below the suppliers’ marginal cost when the manufacturers subsequently compete with quantity in the product market. Although a two-part tariff achieves bilateral coordination between each pair of manufacturer and supplier, the other edge of the sword is that it may intensify downstream competition due to the lowered marginal cost of the manufacturers. This suggests that managers have to be wary about the downside of using coordinating contracts such as two-part tariffs when pursuing low-cost outsourcing strategies.

The industry structure of the upstream supply market is another factor we explore. Over the last decade, merger and acquisitions among contract manufacturers have been active in various industries ranging from electronics and semiconductor to personal care products, which creates gigantic manufacturing powerhouses focusing on providing production services to downstream OEMs (e.g., Pitman 2007, Ruffolo 2007, Takahashi 2010). These upstream consolidations increase the possibility that competing manufacturers end up sourcing from the same supplier. For example, when Flextronics acquired Solectron in 2007, competitors like Hewlett-Packard and IBM, who used to source from the two firms separately, started to work with the same firm. To investigate the effect of such industry structure changes on outsourcing profitability, we compare the equilibrium outcomes of two simple yet representative industry structures of the supply market: (i) an exclusive-supplier structure in which each manufacturer outsources to a dedicated supplier and (ii) a common-supplier structure in which both manufacturers outsource to the same supplier.

Under wholesale-price contracts, we find that outsourcing to a common supplier always lowers a manufacturer’s profit compared with outsourcing to an exclusive supplier. Two key differences exist between the two industry structures: first, the common-supplier structure coordinates downstream competition to a certain extent compared with the exclusive-supplier structure, Second, the common supplier has an enhanced bargaining position because he earns a positive disagreement payoff thanks to the option to serve both manufacturers. For the manufacturers, the enhancement of the supplier’s bargaining position is always the dominant effect, and thus their profits get hurt.

Under two-part tariffs, the comparison across the two industry structures is subtle and depends on the mode of competition. When the manufacturers’ bargaining power is sufficiently strong (weak), they can earn higher profits under quantity (price) competition by outsourcing to a common supplier than to an exclusive one. This surprising outcome stems from
the fact that the common supplier charges a lower (higher) unit price than the exclusive suppliers under quantity (price) competition. The higher negotiated unit price under price competition also induces an interesting side effect—the manufacturers’ bargaining position is enhanced. This happens because a higher unit price charged by the supplier makes insourcing more profitable to the manufacturers. As a result, the common supplier may earn a lower profit than the total of the two exclusive suppliers—an interesting outcome that would not arise in the principal-agent model where suppliers act as Stackelberg leaders.

The rest of the article is organized as follows. We review the related literature in section 2 and introduce the model in section 3. We derive the equilibrium of manufacturer competition and the bargaining solutions in section 4. Section 5 focuses on characterizing the implications of contractual form on negotiation outcomes and market competition, while section 6 is devoted to the comparison between the two industry structures. We conclude in section 7. All proofs are relegated to the Appendix.

2. Related Literature

Our study contributes to the production outsourcing literature. Studies in this literature can be roughly grouped into two streams: non-competitive and competitive. Our study belongs to the latter. In the absence of competition, a number of papers study managerial issues that arise in the process of production outsourcing, such as capacity pooling, incomplete contracting, and allocation of demand risks between supply chain partners (see e.g., Plambeck and Taylor 2005, Ulkii et al. 2007, Van Miegghem 1999). In competitive settings, research has been focused on the strategic implications of production outsourcing. In several different contexts, it is shown that production outsourcing may soften competition between manufacturers (e.g., Cachon and Harker 2002, Gilbert et al. 2006b). A commonality of these studies is that the outsourcing agreements take the form of wholesale-price contracts. Our study also investigates the strategic effect of outsourcing, and we find that the competition-softening effect reported in the previous literature hinges on the specific contractual form being used, namely, wholesale-price contract. Surprisingly, we show that competition may become intensified when the negotiated outsourcing agreements are two-part tariffs.

Our study also contributes to the extensive literature on supply chain coordination. This stream of work studies the efficiency of various contracts in models of bilateral monopoly (e.g., Taylor 2002, Cachon and Lariviere 2005, Tsay 1999) or models of a monopolist manufacturer selling through multiple retailers (e.g., Bernstein and Federgruen 2005, Cachon and Lariviere 2005, Gilbert et al. 2006a, Taylor 2002), as well as models of competing manufacturers selling to single or multiple retailers (e.g., Cachon and Kök 2010, Ha and Tong 2008). Cachon (2003) provides a comprehensive review for this literature. A consensus of this literature is that wholesale-price contracts lead to inefficiencies in channel decisions due to double marginalization whereas more complex contracts, such as two-part tariffs, achieve system optimality. Unlike this literature that largely adopts the Stackelberg approach to derive contracting outcomes, we investigate contracting behaviors in a setting with both competition and contract negotiations. We demonstrate that wholesale-price contracts may outperform two-part tariffs in terms of both manufacturer profitability and supply chain efficiency, a sharp contrast to previous findings in this literature. Our finding attests to the importance of assessing contract performance in the presence of competition and contract negotiations.

Our study is closely related to Feng and Lu (2012), who find that suppliers’ cost efficiency may reduce competing manufacturers’ outsourcing profits by weakening their bargaining positions in negotiations. Our study differs from Feng and Lu (2012) along three important dimensions. First, they assume that firms negotiate over profit allocation, which is a common assumption in theoretical bargaining models. In reality, firms often negotiate over specific contractual terms such as unit wholesale prices (see section 1 for cited anecdotal evidence). In light of this, we analyze negotiation over two representative contracts, namely, wholesale-price contract and two-part tariff. This modeling change leads to divergent negotiation outcomes depending on the contractual form. Specifically, the negotiated two-part tariffs may feature a unit price lower than the suppliers’ marginal cost. In contrast, the negotiated wholesale-price contracts always have a unit price higher than the suppliers’ marginal cost. Therefore, compared with the case of negotiating over profit allocation, that is, the model of Feng and Lu (2012), the manufacturer competition in our model may be intensified under two-part tariffs while softened under wholesale-price contracts. Second, incorporating different contractual forms leads to contrasting equilibrium outcomes under price and quantity competition. Outsourcing with two-part tariffs intensifies the competition between the manufacturers when they compete with quantity but softens the competition when they compete with price. In contrast, the mode of competition does not have any qualitative impact on the equilibrium outcome in Feng and Lu (2012). Third, we focus on characterizing the difference between the equilibrium outcomes of the
exclusive-supplier structure and the common-supplier structure, which is not explored in Feng and Lu (2012). Although Feng and Lu (2012) study both supply structures, they focus on characterizing the bargaining effect, but do not compare the firms’ profitability across the two structures.

3. The Model

We follow the basic setup of the two-tier supply chain model constructed in Feng and Lu (2012). Consider two competing manufacturers who have the option to produce in house or to outsource production to an upstream supplier. The manufacturers are indexed by \( i, i = 1,2 \) and so are the suppliers. The industry structure of the supply market takes one of the two forms: (i) two exclusive suppliers who each serve only one downstream manufacturer and (ii) a common supplier who serves both manufacturers. These structures are commonly studied in the outsourcing and channel management literatures (e.g., Cachon and Harker 2002, Ha and Tong 2008, McGuire and Staelin 1983) and also find their resemblance in reality (see section 1). If a manufacturer produces in house, she incurs a constant marginal cost, denoted by \( c \). If production is outsourced, the upstream supplier incurs a constant marginal cost, denoted by \( c_S \). Consistent with the reality that outsourcing is generally associated with cost savings, we assume that \( 0 < c_S \leq c \).

3.1. Demand and Product Competition

Each manufacturer sells a differentiated product. The inverse demand function for manufacturer \( i \)'s product is given by

\[
 p_i = a - bq_i - gybq_j, \quad i = 1,2, j \neq i,
\]

where \( a > c, b > 0, \) and \( y \in (0,1) \) measures the degree of substitutability. When \( y \) approaches 0, the two products become independent; when \( y \) approaches 1, they become perfect substitutes.

The manufacturers compete for customers by setting either price or quantity. These two modes of competition are both possible depending on industry characteristics. Because price competition requires timely adjustment of production quantities, industries that have long lead time in production are more likely to engage in quantity competition (see e.g., Singh and Vives 1984).\(^3\) As we shall show later, the mode of competition plays a pivotal role in shaping equilibrium outcomes.

3.2. Bargaining and Contracts

Each manufacturer negotiates bilaterally with her supplier over an outsourcing agreement that may take one of the following two forms: (i) a wholesale-price contract \( w_i \), where \( w_i \) denotes the unit wholesale price charged to manufacturer \( i \), and (ii) a two-part tariff contract \( (v_i, F_i) \), where \( v_i \) is the unit price and \( F_i \) is the fixed fee, both of which are paid by manufacturer \( i \) to supplier \( i \). For the sake of analytical simplicity and tractability, we focus on these two common contract types. We discuss alternative contractual forms in section 7.

We follow the multiunit bilateral bargaining framework described in Feng and Lu (2012) to determine the negotiated contractual terms. Let \( \theta \in [0,1] \) denote a manufacturer’s bargaining power vis-à-vis her supplier.

3.3. Sequence of Events

The firms play the following two-stage game:

1. (Negotiation Stage) A contract is negotiated bilaterally between a manufacturer and a supplier. All negotiations occur in parallel. Upon reaching an agreement, the manufacturer outsources production to the supplier; otherwise, the manufacturer produces in house.
2. (Competition Stage) The manufacturers compete in the product market.

4. Preliminaries: Manufacturer Competition and Bargaining

In this section, we present the preliminary analyses that are essential steps involved in solving the sourcing game. We first characterize the competitive equilibrium between the manufacturers as a function of their marginal costs. We then present the solution approach for deriving the negotiated outsourcing contracts.

4.1. Manufacturer Competition

For convenience, let \( \bar{c}_i \) denote manufacturer \( i \)'s marginal cost of acquiring product \( i \). It follows that \( \bar{c}_i = c \) when the manufacturer insources, and \( \bar{c}_i = w_i \) or \( v_i \), depending on the contractual form of her outsourcing agreement. Under quantity competition, manufacturer \( i \) chooses \( q_i \) to maximize her gross profit \( (p_i - \bar{c}_i)q_i \). Under price competition, manufacturer \( i \) chooses \( p_i \) instead. The next lemma characterizes the equilibrium of manufacturer competition. The expressions are identical for the exclusive-supplier and the common-supplier structures.

**Lemma 1:** **Manufacturer Competition.** Given their marginal costs \((\bar{c}_i, \bar{c}_j)\), the competitive equilibrium between the manufacturers is given by the following: For \( i = 1,2, j \neq i \),
(i) under quantity competition, if \( \frac{a_i-c_i}{a_i-c_j} \leq \frac{2}{7} \), \( p_i^* = \frac{a_i-c_i}{2} \) and \( q_i^* = 0 \); if \( \frac{2}{7} < \frac{a_i-c_i}{a_i-c_j} < \frac{2}{7} \), \( p_i^* = c_i \),
\[ + \frac{2(a_i-c_i)-2(a_i-c_j)}{4-\gamma} \) and \( q_i^* = \frac{2(a_i-c_i)-2(a_i-c_j)}{b(4-\gamma)} \); if \( \frac{a_i-c_i}{a_i-c_j} \geq \frac{2}{7} \), \( p_i^* = \frac{a_i-c_i}{2} \) and \( q_i^* = \frac{a_i-c_i}{2b} \).

(ii) under price competition, if \( \frac{a_i-c_i}{a_i-c_j} \leq \frac{2-\gamma}{2\gamma} \), \( p_i^* = a - \frac{2-\gamma}{2\gamma} a_i \) and \( q_i^* = 0 \); if \( \frac{2}{\gamma} - \frac{2}{\gamma} \), \( p_i^* = c_i \),
\[ + \frac{2(2-\gamma)(a_i-c_i)-2(a_i-c_j)}{4-\gamma} \) and \( q_i^* = \frac{2(2-\gamma)(a_i-c_i)-2(a_i-c_j)}{b(4-\gamma)} \); if \( \frac{a_i-c_i}{a_i-c_j} \geq \frac{2-\gamma}{2\gamma} \), \( p_i^* = c_i + \frac{1-(2-\gamma)(a_i-c_i)}{2\gamma} \) and \( q_i^* = \frac{a_i-c_i}{2\gamma} \).

The equilibrium prices and quantities given by Lemma 1 are standard results of a differentiated duopoly with linear demands. With these equilibrium variables, we express manufacturer \( i \)'s gross profit as \( G_i(c_i, c_j) \equiv q_i^* (p_i^* - c_i) \) and her supplier \( i \)'s gross profit from product \( i \) as \( G_i(c_i, c_j) \equiv q_i^* (c_i - c_j) \) when production is outsourced.

### 4.2. Bargaining

Now we describe the bargaining solution approach for the two industry structures separately. In essence, we adopt the multiunit bilateral bargaining framework as described in Feng and Lu (2012) to model the bargaining processes in this two-tier competing supply chain system. For theoretical details and references of this framework, refer to Feng and Lu (2012).

#### 4.2.1. Exclusive Supplier

Consider the negotiation between manufacturer \( i \) and supplier \( i \), \( i = 1,2 \) under the exclusive-supplier structure. There are two possible negotiation outcomes: (i) the negotiation breaks down and the manufacturer produces in-house and (ii) an agreement is reached and the supplier provides outsourcing service to the manufacturer. For convenience, we use \( C_i \) to denote the manufacturer’s fixed cost. Recall that \( c_i \) denotes the manufacturer’s marginal cost. It follows that under insourcing, \( c_i = c \) and \( C_i = 0 \). Under outsourcing, \( c_i = w_i \) and \( C_i = 0 \) with a wholesale-price contract, while \( c_i = v_i \) and \( C_i = F_i \) with a two-part tariff.

Let \( \Pi_i \) and \( \pi_i \) denote the profits of manufacturer \( i \) and supplier \( i \), respectively. These profits are what the manufacturer and the supplier potentially earn from the outsourcing deal if the negotiation goes through. Thus, they depend on the subsequent market competition and the transfer payments between the two parties. Hence, the profits are given by \( \Pi_i = G_i(c_i, c_j) - C_i \) and \( \pi_i = G_i(c_i, c_j) + C_i \). To define the bargaining problem, we also need to specify the players’ disagreement points, that is, their profits when the negotiation breaks down. In this case, manufacturer \( i \) insources and incurs marginal cost \( c \) while supplier \( i \) makes no profit. Let \( D_i \) and \( d_i \) denote the disagreement points of manufacturer \( i \) and supplier \( i \), respectively, and their expressions are given by \( D_i = G_i(c, c_j) \) and \( d_i = 0 \).

Taking the negotiation outcome between manufacturer \( j \) and supplier \( j \) as given, in other words, taking \( c_j \) as given, the set of feasible solutions for the bargaining problem between manufacturer \( i \) and supplier \( i \) can be defined as
\[
B_i = \{(\Pi_i, \pi_i) : \Pi_i \geq D_i, \pi_i \geq d_i | c_i\}.
\]

For the bargaining problem to be well defined, one needs to verify the existence of a bargaining solution in the feasible set \( B_i \). A sufficient condition for that is \( B_i \) being convex. This is trivially true in the classical Nash bargaining problem (Nash 1950, Osborne and Rubinstein 1990), in which \( \Pi_i + \pi_i \) is a constant. In our model, however, the channel profit \( \Pi_i + \pi_i \) depends on the bargaining outcome because the manufacturers’ subsequent competitive decisions depend on the negotiated contractual terms. While \( B_i \) is convex under a two-part tariff, it is not so under a wholesale-price contract. Nevertheless, following Horn and Wolinsky (1988), we can show that \( B_i \) is the upper boundary of a convex set and there exists a bargaining solution in \( B_i \) (see Remark 1 in the Appendix). Thus, if a deal is settled, the bargaining solution \( (\bar{c}_i, \bar{C}_i) \) maximizes the following Nash product:
\[
\Omega_i = (\Pi_i - D_i)^{\alpha} (\pi_i - d_i)^{1-\alpha}.
\]

The negotiated contracts of the two competing supply chains form a Nash equilibrium, that is, the so-called Nash–Nash solution.

#### 4.2.2. Common Supplier

Now we consider the common-supplier structure. We assume that the common supplier negotiates bilaterally with the manufacturers (see similar setups in Davidson 1988, Dukes et al. 2006, Horn and Wolinsky 1988). In other words, there are still two bargaining units in parallel. Bilateral bargaining, as opposed to multilateral bargaining, is appropriate in our context because the manufacturers are competitors, who generally could not engage in coalitional bargaining. Furthermore, this approach reflects the wide occurrence of bilateral negotiations in channel relationships (see Draganska et al. 2010, Iyer and Villas-Boas 2003, Kadiyali et al. 2000).

Given the negotiation outcome between the supplier and manufacturer \( j \) that is, \( (c_j, \bar{C}_j) \), the supplier and manufacturer \( i \) settle on \( (\bar{c}_i, \bar{C}_i) \) that maximizes the Nash product specified by Equation (2) with the profits and disagreement points modified as follows:
\[
\Pi_i = G_i(c_i, c_j) - C_i,
\]
\[
\pi_i = G_i(c_i, c_j) + G_j(c_i, c_j) + \bar{C}_i + \bar{C}_j,
\]
\[
D_i = G_i(c, c_j),
\]
\[
d_i = G_j(c, c_j) + \bar{C}_j.
\]
The feasible set of profit allocation is given by $B_i = \{(\Pi_i, \pi_i) : \Pi_i \geq D_i, \pi_i \geq d_i | (\tilde{c}_i, \tilde{C}_i)\}$.

Similar to the exclusive-supplier case, $B_i$ is the upper boundary of a convex set under a wholesale-price contract (see Horn and Wolinsky 1988) and $B_j$ is convex under a two-part tariff. Thus, for given $(\tilde{c}_i, \tilde{C}_i)$, there is a bargaining solution in $B_i$ that maximizes the Nash product specified by Equation (2). We shall note that $\pi_i$ is the profit of the common supplier, and thus $\pi_i = \pi_j$ by definition.

5. The Impact of Contractual Form on Outsourcing Negotiation and Market Competition

We explore the impact of contractual form on outsourcing negotiation and market equilibrium in this section. To do this, we derive the negotiated contractual terms using both wholesale-price contracts and two-part tariffs. In our subsequent analysis, it becomes apparent that the cost differential between the manufacturers and the suppliers is a key driver of the equilibrium outcome. To measure the cost differential, we use the index of outsourcing cost advantage, as introduced in Feng and Lu (2012):

$$\Delta \equiv \frac{a - c_s}{a - c}.$$ 

As this index increases, the suppliers’ cost advantage over the manufacturers increases. Using this index instead of a cost ratio allows us to express the firms’ relative cost positions in the perspective of their potential margins, captured by $a - c$ and $a - c_s$, respectively, for the manufacturers and the suppliers.

We will next derive the bargaining outcome and the resulting market equilibrium. For convenience, we use OO, II, OI, IO to denote the four possible equilibrium sourcing outcomes that may arise: (Outsource, Outsource), (Insource, Insource), (Outsource, Insource), and (Insource, Outsource). In addition, we need to use ÕO to denote the outsourcing equilibrium in the common-supplier structure while the other three outcomes are identical to those in the exclusive-supplier structure.

5.1. Equilibrium Sourcing Decisions

We first present the equilibrium sourcing decisions of the manufacturers.

**Proposition 1**: Wholesale-Price Contract. When the firms negotiate over wholesale-price contracts, OO always arises as an equilibrium regardless of the industry structure and the competition mode. Moreover, it is unique when $\theta \in [0,1)$ and $\Delta > 1.7$.

According to Proposition 1, OO is always an equilibrium when wholesale-price contracts are employed. And it is unique as long as the manufacturers do not have all the bargaining power or when the suppliers have a strict cost advantage.

**Proposition 2**: Two-Part Tariff. When the firms negotiate over two-part tariffs, the manufacturers’ equilibrium sourcing decisions are given by:

(i) (Exclusive Supplier) Under quantity competition, OO arises as a unique equilibrium. Under price competition, there exists a unimodal function $\bar{y}_p(\Delta)$ such that when $\theta > \bar{y}_p(\Delta)$, OO arises as a unique equilibrium; otherwise, both OI and IO arise in equilibrium.

(ii) (Common Supplier) Under quantity competition, there exist a decreasing function $\bar{y}_q(\Delta)$ and a unimodal function $\bar{y}_Q(\Delta)$ such that $OO$ arises in equilibrium when $\bar{y}_q(\Delta) \leq \theta \leq \bar{y}_Q(\Delta)$; otherwise, both OI and IO arise in equilibrium. Under price competition, there exists an increasing function $\bar{y}_p(\Delta)$ such that $OO$ arises in equilibrium when $\theta \leq \bar{y}_p(\Delta)$; otherwise, both OI and IO arise in equilibrium.

Proposition 2 part (i) shows that when two-part tariffs are employed, outsourcing is not always the equilibrium outcome in the exclusive-supplier structure. Under quantity competition, OO is always the equilibrium because outsourcing to a low-cost supplier gives the manufacturers a cost advantage when competing in the market. Under price competition, a manufacturer’s best response to an insourcing opponent is always to outsource. Facing an outsourcing opponent, however, a manufacturer may prefer insourcing when her bargaining power is extremely low.$^8$

Proposition 2 part (ii) indicates that OI and IO may also arise in equilibrium, but for a different reason—the common supplier may not be willing to offer outsourcing service to both manufacturers when they have strong bargaining power (see the proof for details). Because an outsourced product can enjoy a significant competitive advantage over an insourced product due to upstream cost advantage, the common supplier may increase his profit significantly by offering outsourcing service to only one of the manufacturers when his bargaining power is low (i.e., $\theta > \bar{y}_Q$). Moreover, under quantity competition, a manufacturer with low bargaining power (i.e., $\theta < \bar{y}_Q$) may choose to insource when her opponent outsources.

After characterizing the manufacturers’ equilibrium sourcing decisions, we will next focus on the properties of the outsourcing equilibrium. It is worth noting that our numerical analysis indicates that in the case of two-part tariffs, the equilibrium region of OI and IO are extremely small compared with that of
In this subsection, we investigate the impact of contractual form on manufacturers’ outsourcing profitability. To facilitate analysis, we consider the following two benchmarks. The centralized benchmark is one in which the decisions of all the firms are centralized, thereby eliminating the difference between setting price or quantity. The optimal quantity and price are

\[ q^C = \frac{a - c_S}{2b(1 + \gamma)} \quad \text{and} \quad p^C = c_S + \frac{a - c_S}{2}. \]

The integrated benchmark is one in which each manufacturer produces at her supplier’s cost \( c_S \) and competes against each other. The equilibrium quantity and price under quantity competition are

\[ q^I = \frac{a - c_S}{b(2 + \gamma)} \quad \text{and} \quad p^I = c_S + \frac{a - c_S}{2 + \gamma}. \]

and those under price competition are

\[ q^I = \frac{a - c_S}{b(1 + \gamma)(2 - \gamma)} \quad \text{and} \quad p^I = c_S + \frac{(1 - \gamma)(a - c_S)}{2 - \gamma}. \]

The quantities and prices in the integrated benchmark are identical to those derived from the model analyzed in Feng and Lu (2012), in which the two parties in a supply chain negotiate directly over profit allocation without specifying a unit transfer price. Thus, by comparing the bargaining solutions under wholesale-price contracts and two-part tariffs to the integrated benchmark, we can isolate the effect of contractual form on outsourcing profitability. Further, the integrated benchmark and the centralized benchmark coincide only in the bilateral monopoly setting (i.e., \( \gamma = 0 \)). In other words, they are generally distinct in our model with competition (i.e., \( 0 < \gamma < 1 \)).

We start by comparing the negotiated wholesale prices with the firms’ marginal costs. This comparison helps to explain the competition intensity result that we will present later.

Proposition 3: Wholesale-Price Contract. When the firms negotiate over wholesale-price contracts, the following relations hold for \( X \in \{OO, OO\} \) regardless of the competition mode:

(i) \( c_S \leq w_X \leq c \).

(ii) \( p^X \geq p^I \), where the equality holds when \( c = c_S \).

(iii) There exist a decreasing function \( \Delta_X(\gamma) \geq 1 \) and a constant \( \theta^X \in [0, 1] \) such that \( p^X > p^C \) if \( \Delta < \Delta_X(\gamma) \) and \( \theta < \theta^X \); otherwise, \( p^X \leq p^C \).

The intuition of Proposition 3 part (i) is straightforward: the negotiated wholesale prices have to be in between the cost of the upstream and the downstream to allow both parties to be better off from the trade. Part (ii) of the proposition suggests that when \( c > c_S \), outsourcing under wholesale-price contracts softens competition compared with the integrated benchmark, as reflected in a higher market price, that is, \( p^X > p^I \). But, when \( c = c_S \), the competition-softening effect disappears. It is worth commenting on this result with respect to the earlier studies (see e.g., Cachon and Harker 2002, Gilbert et al. 2006b, Liu and Tyagi 2011), which find that outsourcing softens competition in the absence of upstream cost advantage, that is, \( c = c_S \). These studies assume that the manufacturer’s cost structure is nonlinear as opposed to linear in our model. Similarly, studies on channel decentralization (see, e.g., Coughlan and Wernerfelt 1989, McGuire and Staelin 1983) find that manufacturers can alleviate the competition between them by delegating distribution to downstream retailers when \( c = c_S \). These studies, unlike ours, do not allow the downstream firms to leverage their insourcing option when contracting with the upstream firms. In contrast, the downstream firms in our model (i.e., the manufacturers) have an insourcing option which forces the wholesale prices to be equal to their marginal cost as opposed to being above. Taken together, our results suggest that the competition-softening effect of outsourcing (or decentralization) under wholesale-price contracts hinges on the fact that the downstream firms’ cost structure is nonlinear or the fact that the downstream firms lack an insourcing option.

Part (iii) of Proposition 3 indicates that when the upstream–downstream cost differential is sufficiently small and when the manufacturers have sufficiently weak bargaining power, outsourcing with wholesale-price contracts attains a market price higher than the centralized benchmark. This suggests that the margins charged by the upstream can be so significant that they lead to a lower output level than the centralized benchmark, an outcome similar to the double marginalization problem in the bilateral monopoly setting.

We now characterize the negotiation outcome and competition intensity under two-part tariffs. It is straightforward to show that under both industry structures,

\[ \Pi_i = \theta(\Pi_i - D_i + \pi_i - d_i) + D_i = \theta(\Pi_i + \pi_i) + (1 - \theta)D_i, \quad i \in \{1, 2\}. \]

This relationship indicates that taking the competing supply chain’s bargaining outcome as given, each negotiated two-part tariff achieves bilateral coordination for the corresponding manufacturer–supplier.
pair—notice that the manufacturer’s net gain from the trade, that is, \( \Pi_i - D_i \), is proportional to the total trade surplus, that is, \( \Pi_i - D_i + \pi_i - d_i \). Furthermore, a manufacturer’s profit can be decomposed into two parts: \( \theta \) portion of the channel profit and \( 1 - \theta \) portion of her disagreement point. Proposition 4 characterizes the unit prices of equilibrium two-part tariffs and compares equilibrium market prices against the integrated benchmark.

**Proposition 4: Two-Part Tariff.** When the firms negotiate over two-part tariffs, the following relations hold for \( X \in \{\text{OO}, \text{OO}\} \):

(i) Under quantity competition, \( v^X \leq c_S \leq c \) and \( p^X \leq p^C \).

(ii) Under price competition, \( c_S \leq c \leq v^X \) when \( \Delta < \Delta^X \), \( c_S \leq v^X \) when \( \Delta > \Delta^X \), and \( c_S \leq v^X \leq c \) when \( \Delta = \Delta^X \), where \( \Delta^{OO} = \frac{4 - 2x_2 - \gamma}{(2 - \gamma)(2 - \gamma)} \) and \( \Delta^{OO} = \frac{4}{\gamma - 1} \).

Moreover, \( p^X \leq p^C \).

Taking the competing supply chain’s bargaining outcome as given, the unit price \( \nu \) is chosen to maximize the trade surplus, \( \Pi_i - D_i + \pi_i - d_i \), and the fixed fee \( F \) is set to allocate the trade surplus proportionally to each party’s bargaining power. Thanks to the fixed fee, the unit price of the negotiated two-part tariffs can be set below the supplier’s cost \( c_S \) or above the manufacturer’s cost \( c \) depending on the mode of competition, as indicated in Proposition 4.

Under quantity competition, the unit prices are below the suppliers’ cost, indicating that the upstream is over-subsidizing downstream output. Under price competition, in contrast, the unit prices are always higher than the suppliers’ cost and may even exceed the manufacturers’ cost. The different rankings of the unit prices under quantity and price competition stem from the fact that quantities (prices) are strategic substitutes (complements). Under quantity competition, the supplier–manufacturer pair of a supply chain has little incentive to set a high unit price because doing so would decrease its own quantity but increase the quantity of the competing supply chain. In contrast, under price competition, each supply chain has a strong incentive to increase the unit price because doing so not only raises the price of its own product in the downstream market but also lifts that of the competing supply chain, leading to increased profits in both supply chains.

Proposition 4 also indicates that compared with the integrated benchmark, competition between the manufacturers is intensified when they compete with quantity, but is softened when they compete with price. This is caused by the fact that the suppliers charge a unit price below (above) their marginal cost under quantity (price) competition (as shown in Proposition 4). This result suggests that the conventional wisdom that outsourcing mitigates competition between manufacturers (e.g., Cachon and Harker 2002, Gilbert et al. 2006b) is at best incomplete—the impact of outsourcing on downstream competition critically depends on the contractual form and the mode of competition.

### 5.3. System Profit

We have shown that two-part tariffs’ ability to coordinate supply chains bilaterally may intensify downstream competition. While avoiding this problem, a wholesale-price contract causes double marginalization, leading to an inefficient level of supply chain output. This trade-off makes it interesting to compare the performance of the two contracts in terms of the supply chain’s system profit. Figure 1 illustrates the ranking under both quantity and price competition.

Under quantity competition, a higher supply chain profit is obtained under two-part tariffs than under wholesale-price contracts when the upstream cost
advantage is sufficiently large or when the manufacturers’ bargaining power is sufficiently small. This implies that the need for bilateral coordination increases when the cost differential is high or when the suppliers have strong bargaining power. In these situations, a substantial margin would be charged by the upstream suppliers under wholesale-price contracts, making the supply chains severely inefficient. Under price competition, the overall trend is similar to that under quantity competition except that when the upstream cost advantage is close to zero or when the manufacturers’ bargaining power is close to one. In these situations, both two-part tariffs and wholesale-price contracts soften competition, but the former is able to soften competition more than the latter when the cost differential is small or when the suppliers have weak bargaining power. This is because the suppliers have a small leeway in increasing their margin under wholesale-price contracts, while they have the flexibility to command a higher margin under two-part tariffs and reallocate profit through a fixed fee. These results suggest that we need to refine our understanding about two-part tariffs—something ability to improve supply chain performance critically depends on several strategic factors such as the upstream—downstream cost differential, bargaining power, and the mode of competition.

Finally, it is interesting to note that as $\gamma$ decreases, that is, when the products become more differentiated, the region for two-part tariffs to achieve higher system profit enlarges. Represented graphically, in the left panel of Figure 1, the boundary curve shifts to the northwestern direction, while in the right panel, the distance between the two curves reduces.

6. Outsourcing Profitability: Exclusive vs. Common Supplier

In this section, we seek to answer our second research question: how does the industry structure of the upstream supply market affect the manufacturers’ outsourcing profitability?

6.1. Wholesale-Price Contract

When the outsourcing contracts take the form of wholesale-price contracts, the comparison between the two industry structures yields a simple relation—the manufacturers are always better off while the suppliers are always worse off in the exclusive-supplier structure than in the common-supplier structure, as shown in the next proposition.

**Proposition 5: Wholesale-Price Contract.** When the firms negotiate over wholesale-price contracts, the following relations hold regardless of the competition mode:

(i) $w^{OO} \leq w^{OO}$,
(ii) $\Pi^{OO} \leq \Pi^{OO}$, $\pi^{OO} \geq 2w^{OO}$.

Part (i) of Proposition 5 shows that the equilibrium wholesale prices are higher in the common-supplier structure. This is caused by the fact that the single supplier in the upstream market has an incentive to mitigate downstream competition by charging higher unit prices to the manufacturers. In other words, the common supplier coordinates the competition to certain extent compared with the exclusive suppliers. As a result of this, the exclusive suppliers’ total profit is less than that of the common supplier. Meanwhile, the manufacturers are always worse off in the common-supplier structure. This is because the common supplier has an enhanced bargaining position compared with the exclusive suppliers due to the fact that when the negotiation breaks down between the common supplier and a manufacturer, he still earns a positive profit by supplying to the other manufacturer only.

To further understand the results in Proposition 5, we plot the firms’ and the supply chain’s profits as a function of the manufacturers’ bargaining power in Figure 2. Several observations can be made from the figure. First, unlike the case of no
competition (i.e., \( c = 0 \) or, equivalently, the bilateral monopoly setting), the centralized performance is achieved when the competing manufacturers have intermediate bargaining power. Second, the supply chain’s profit is in general unimodal in the manufacturers’ bargaining power. This can be explained by two opposing effects of wholesale-price contracts. On the one hand, adding a margin on top of the supplier’s cost leads to supply chain inefficiency, commonly known as the double marginalization effect. On the other hand, the added margin forces the manufacturers to charge a higher price to the customers, thereby softening the market competition. The former effect is decreasing in the manufacturers’ bargaining power while the latter is increasing in the manufacturers’ bargaining power. As a result, the centralized performance is achieved when both supply chain parties have some bargaining power. This finding contrasts sharply with the outcome in the bilateral monopoly setting, where the centralized performance is achieved when the manufacturers have all the bargaining power (i.e., when double marginalization can be completely eliminated). This difference suggests that the effect of contract negotiation on supply chain performance under competition may not be as simple as that in the bilateral monopoly setting. Our subsequent analysis using two-part tariffs will echo this message.

6.2. Two-Part Tariff

When the firms negotiate over two-part tariffs, the comparison between the two industry structures is more complex than in the case of wholesale-price contracts, as shown in the next proposition.

**Proposition 6:** Two-part Tariff. When the firms negotiate over two-part tariffs, the following relations hold:

(i) **Under quantity competition,** \( v^{oo} \leq v^{oo} \) and \( \pi^{oo} \leq 2\pi^{oo} \). Furthermore, there exists a decreasing function \( \vartheta^{oo} (\Delta) \) such that \( \Pi^{oo} \leq \Pi^{oo} \) for \( \theta \leq \vartheta^{oo} (\Delta) \) and \( \Pi^{oo} \leq \Pi^{oo} \) otherwise.

(ii) **Under price competition,** \( q^{oo} \geq q^{oo} \). Furthermore, there exists a decreasing function \( \vartheta^{oo} (\Delta) \) and a unimodal function \( \vartheta^{oo} (\Delta) \) such that \( \Pi^{oo} \leq (\theta) \Pi^{oo} \) for \( \theta \geq (\theta) \vartheta^{oo} (\Delta) \) and \( \theta \geq \vartheta^{oo} (\Delta) \) for \( \theta \leq (\theta) \vartheta^{oo} (\Delta) \).

Proposition 6 indicates that under two-part tariffs, the negotiated unit prices of the common-supplier case are lower (higher) than those of the exclusive-supplier case under quantity (price) competition. Compared with the exclusive suppliers, the common supplier partially internalizes the competition between the two supply chains because he engages in two simultaneous negotiations with the manufacturers. Under price competition, this leads to higher unit transfer prices and higher supplier profit, just like in the case of wholesale-price contracts. However, under quantity competition, the flexibility of two-part tariffs in supporting any unit transfer prices leads to a surprising negotiation outcome—the common supplier ends up charging a lower unit price than the exclusive suppliers.

Due to the changes in the negotiated unit prices, the supply chain’s profit is lower (higher) than that in the exclusive-supplier case under quantity (price) competition, as illustrated in Figure 3. For both structures, the figure shows that two-part tariffs cannot achieve the centralized performance. This is in stark contrast to the outcome in bilateral monopoly settings, where two-part tariffs are well acknowledged to eliminate supply chain inefficiency. Furthermore, Figure 3 shows that the manufacturers’ outsourcing profit can be strictly lower than their insourcing profit, which indicates that the manufacturers’ may get caught up in a prisoner’s dilemma to outsource production in equilibrium.

**Figure 3** Equilibrium Profits under Two-part Tariffs. Solid Lines: Exclusive Suppliers; Dashed Lines: Common Supplier

**Notes:** \( a = 100, c = 60, c_0 = 20, b = 2, \gamma = 0.7. \)
Although the comparison of the supply chain's profit is clear-cut between the two industry structures, the comparison of the firms' profits bears some interesting subtleties, as indicated by Proposition 6. The result is demonstrated in Figure 4, where we plot the firms' profit ranking as a function of the manufacturers' bargaining power and the index of outsourcing cost advantage. Notice that when the manufacturer's bargaining power is sufficiently large, the manufacturers' profit is higher (lower) in the common-supplier structure than in the exclusive-supplier structure under quantity (price) competition. The combined effects of the trade surplus and the manufacturer's disagreement point lead to the mixed outcome that the manufacturers' profit may be higher or lower in the common-supplier structure than in the exclusive-supplier structure.

Finally, compared with the exclusive suppliers, the common supplier earns a lower profit under quantity competition due to a lowered unit price charged to the manufacturers. Under price competition, surprisingly, the common supplier may earn a smaller profit when the index of outsourcing cost advantage is sufficiently small. This is precisely caused by the increase in the manufacturer's disagreement point due to the higher unit price. This result invalidates a general notion that a monopolist supplier is better off than competing suppliers. Our result suggests that there exists an additional effect that may hurt the monopolist supplier's profit—the manufacturers may obtain a stronger bargaining position in the common-supplier structure due to the higher unit price than that in the exclusive-supplier structure.

7. Discussion and Conclusion

In this section, we discuss several limitations of our model and summarize the managerial insights derived from the analysis.

7.1. Model Limitations

Our model assumes an established trading relationship between a supplier and a manufacturer. But it is...
silent about how the exogenous trading relationship has been formed. Incorporating it into the bargaining process would require expanding the sets of potential suppliers and manufacturers and adopting an appropriate solution approach. For example, one may extend the framework developed by Lovejoy (2010) to allow for multiple potential trading pairs to negotiate in equilibrium. In addition, one may consider allowing firms to trade with multiple firms, giving rise to a many-to-many, or non-exclusive, supply chain structure.

Our analysis compares the negotiation outcomes of two different contract types: wholesale-price contracts and two-part tariffs. The choice of contract type is exogenous to our model. Given that in the presence of competition two-part tariffs may hurt outsourcing manufacturers, a natural question arises: if the contract type is subject to negotiation, would the manufacturers be able to avoid the use of two-part tariffs when necessary? Unfortunately, it is not the case—one can show that the equilibrium choice of contract type is always two-part tariff when wholesale-price contract is the alternative. This is similar in spirit to the result of Feng and Lu (2013).

Some other assumptions of our model can also be relaxed. For example, we can relax the assumption of deterministic demand by incorporating uncertainty in the customer’s willingness to pay through the intercept of the inverse demand function at the stage of contract negotiation. One can show that the equilibrium contract parameters are identical to the base model with the demand intercept replaced by its expected value. If, however, demand uncertainty is not resolved by the stage of downstream competition, one would need to consider the possibility of stockout or overstock as well as the associated impact on consumers’ purchasing decisions. In other words, the ex post product substitutability may depend on the manufacturers’ competitive decisions.

Finally, we do not consider scale economies in production. It is not ex ante clear whether manufacturers with scale economies will become more likely to outsource, that is, a similar result obtained by Cachon and Harker (2002). Given that they study the outsourcing problem using wholesale-price contracts, it is possible that the effect of scale economies on outsourcing identified in their study can be reversed under a two-part tariff, in light of the findings of this study.

7.2. Managerial Insights
In this study, we investigate competing manufacturers’ outsourcing profitability in the presence of contract negotiations. Building on the model introduced in Feng and Lu (2012), we explore two managerial factors: (i) the contractual form of outsourcing agreements and (ii) the industry structure of the upstream supply market. Some interesting findings emerge in our model that provide a theoretical support for the use of wholesale-price contracts in practice. We find that when the outsourcing agreements take the form of wholesale-price contracts, manufacturer competition is softened compared with the integrated benchmark. In contrast, if two-part tariffs are employed, manufacturer competition can be intensified due to this contract form’s flexibility to allow a unit transfer price below the suppliers’ marginal cost. Although a two-part tariff is touted for its ability to coordinate channel decisions in bilateral monopoly settings, our results suggest that competition may turn this benefit into a disadvantage. This finding contributes to the growing literature on supply chain contracting under competition by demonstrating that coordinating contracts’ benefits in bilateral-monopoly settings do not necessarily carry over to competitive settings.

Two-part tariffs also induce several unexpected outcomes in the comparison between the exclusive-supplier structure and the common-supplier structure. Intuitively one may think that manufacturers can improve profits by outsourcing to an exclusive supplier instead of a common supplier. That is indeed true if wholesale-price contracts are used. However, with two-part tariffs manufacturers can benefit from outsourcing to a common supplier. This is because negotiating over two-part tariffs may hurt a common supplier by forcing him to a lower unit transfer price than that charged by exclusive suppliers.

We shall point out that our analysis for two-part tariffs carries over to other coordinating contracts. In particular, one can establish one-to-one correspondence between two-part tariffs and revenue-sharing contracts (consisting of a unit price and a percentage of manufacturer revenue shared by the supplier) or between two-part tariffs and profit-sharing contracts (consisting of a unit price and a percentage of manufacturer profit shared by the supplier). By one-to-one correspondence, we mean that for every two-part tariff, there exists a revenue-sharing or profit-sharing contract that leads to the same profit for each firm. The negotiated two-part tariffs give rise to the same profit allocation and downstream market equilibrium as the negotiated revenue-sharing or profit-sharing contracts. Moreover, the two-part tariff is a special case of the quantity discount contract, which can be treated as the mix of a set of two-part tariffs.
Appendix A. Proofs and Remarks

Remark 1: Feasible Set of the Bargaining Problem. Under a wholesale price contract, that is, \( \tilde{c}_i = w_i \) and \( \tilde{C}_i = 0 \), \( B_i \) is the upper boundary of a convex set (see Horn and Wolinsky 1988). We demonstrate \( B_i \) via an example in Figure A1. The set \( B_i \) corresponds to the solid line of profit pairs \((\Pi_i, \pi_i)\), which are obtained by varying the wholesale price \( \tilde{c}_i = w_i \) over \([c_5, c]\). In particular, manufacturer \( i \)'s profit should be at least \( D_i \) (corresponding to \( w_i = c \)), and supplier \( i \)'s profit should be at least \( d_i = 0 \) (corresponding to \( w_i = c_5 \)). We can expand the contract space by including a randomized contract to make the feasible region convex. This region contains any profit pair below the solid line \( B_i \) and above the dashed line connecting the two ends of \( B_i \). Clearly, randomization leads to a convex feasible region, which ensures that the bargaining problem is well defined. We further note that for any point \((\Pi^i, \pi^i)\) below the curve \( B_i \), there exists a point \((\Pi^t, \pi^t) \in B_i \) such that \( \Pi^t_i \leq \Pi^i_i \) and \( \pi^t_i \leq \pi^i_i \). Hence, we only need to look for a bargaining solution within \( B_i \).

Under a two-part tariff, that is, \( \tilde{c}_i = v_i \) and \( \tilde{C}_i = F_i \), we first compute the players’ profits for each \( v_i \) with \( F_i = 0 \), which gives the nonlinear concave curve in the right panel of Figure A1. A feasible \( v_i \) must ensure that the total supply chain profit is above \( D_i + d_i \), that is, \( v_i \leq c \). We further note that for each feasible \( v_i \), the resulting trade surplus \( \Pi_i + \pi_i - D_i - d_i \) can be allocated between \( \Pi_i \) and \( \pi_i \) in any way by varying the fixed payment \( F_i \). Thus, the feasible set \( B_i \) corresponds to the area above the horizontal axis and in between the two solid lines, which is clearly convex. We shall remark that for a large enough \( \tilde{c}_i \) (i.e., \( c < a - \frac{\theta}{2}(a - \tilde{c}_i) \)), \( B_i \) becomes empty. In this case, manufacturer \( i \) becomes a monopolist in the downstream market and always chooses to produce in house.

Proof of Proposition 1. The proof uses the result of Proposition 3, which is proven without assuming Proposition 1. Because \( c_5 \leq w^X \leq c \) for \( X \in \{OI, OO, OO\} \), we obtain

\[
\Pi_i^O = G_1(c, c) \leq G_1(w^O, c) = \Pi_i^O^O,
\]

\[
\Pi_i^{OI} = G_1(c, w^O) \leq G_1(c, c) \leq G_1(w^{OO}, w^{OO}) = \Pi_i^{OO},
\]

\[
\Pi_i^{OII} = G_1(c, w^{OI}) \leq G_1(c, c) \leq G_1(w^{OO}, w^{OO}) = \Pi_i^{OO}.
\]

The above relations hold because, as one can easily check based on Lemma 1, \( G_1(\tilde{c}_1, \tilde{c}_2) \) is decreasing in \( \tilde{c}_1 \) and increasing in \( \tilde{c}_2 \), and \( G_i(\tilde{c}, \tilde{c}) \) is decreasing in \( \tilde{c} \). Therefore, \( \text{Outsourcing, Outsourcing} \) always arises as an equilibrium.

Proof of Proposition 2. The proof uses the result of Proposition 4, which is proven without assuming Proposition 2. We present the proof for quantity competition and that for price competition can be found in the Online Appendix.

To show part (i), we first note that the exclusive suppliers always prefer outsourcing to insourcing. Therefore, we focus on the manufacturers’ sourcing decisions. We have

Figure A1 The Feasible Set of \((\Pi_i, \pi_i)\) for the Bargaining Game under Quantity Competition

Notes: \( c_5 = 50, c = 80, a = 100, b = 1, \gamma = 0.95, \) and \( \theta = 0.5 \). Given \( \tilde{c}_i = 75, D_i \approx 35.43 \).
\[ \Pi_{\text{DI}} - \Pi_{\text{II}} = \theta[G_1(v^{\text{OI}}, c) + g_1(v^{\text{OI}}, c) - G_1(c, c)] = \theta \frac{(a-c)^2}{8b(2-\gamma^2)(2+\gamma^2)} \phi(\Delta), \]

where

\[ \phi(\Delta) = 4(2+\gamma)^2 \Delta^2 - 4\gamma(2+\gamma)^2 \Delta - 16 + \gamma^2 (12 + 4\gamma + 2\gamma^2). \]  

(A1)

Note that \( \phi'(\Delta) = 4(2 + \gamma^2)(2\Delta - \gamma) \geq 0 \) and \( \phi(1) = \gamma^4 \geq 0 \). It follows that \( \phi(\Delta) \geq 0 \) for any \( \Delta \geq 1 \). Hence we deduce that \( \Pi_{\text{DI}} \geq \Pi_{\text{II}} \).

Also, we note from the proof of Proposition 4 that when \( \Delta > \Delta_{\text{UB}} \), \( \Pi_{\text{IO}} \leq \Pi_{\text{OO}} \). When \( \Delta > \Delta_{\text{UB}} \), we have

\[ \Pi_{\text{OO}} - \Pi_{\text{II}} = \theta[G_1(v^{\text{OO}}, v^{\text{OO}}) + g_1(v^{\text{OO}}, v^{\text{OO}}) - G_1(c, v^{\text{OO}})] + (1-\theta)[G_1(c, v^{\text{OO}}) - G_1(c, v^{\text{OI}})] \]

\[ = \theta \frac{(a-c)^2 \phi_M(\Delta)}{16b(4+2\gamma-\gamma^2)(2-\gamma^2)^2} + \frac{(1-\theta)(a-c)^2 \phi_N(\Delta)}{16b(2-\gamma)^2(2+\gamma)^2(4+2\gamma-\gamma^2)^2(2-\gamma^2)^2}, \]

where

\[ \phi_M(\Delta) = 32(2-\gamma^2)^3 \Delta^2 - (4+2\gamma-\gamma^2)^2 (4-\gamma^2 - 2\gamma \Delta)^2 \]  

(A2)

\[ \phi_N(\Delta) = -(4-\gamma^2)^2(4+2\gamma-\gamma^2)^2 (4-\gamma^2 - 2\gamma \Delta)^2 + 64(2-\gamma^2)^2(4+\gamma(2-\gamma) - \gamma(2+\gamma) \Delta)^2. \]  

(A3)

It is easy to verify that \( \phi_M(1) = \gamma^4(16-8\gamma^2-\gamma^4) \geq 0 \) and \( \phi_N(1) = \gamma^6(128 - 128\gamma^2 + 32\gamma^4 - \gamma^6) \geq 0 \). Furthermore,

\[ \phi_M'(1) = 4(128 + 64\gamma - 160\gamma^2 - 64\gamma^3 + 72\gamma^4 + 16\gamma^5 - 14\gamma^6 - \gamma^7) > 0, \]

\[ \phi_M'(\Delta_{\text{UB}}) = \frac{32(4-\gamma^2)^2(2-\gamma^2)^3}{\gamma} > 0. \]

Since \( \phi_M \) is either convex or concave in \( \Delta \), we must have \( \phi_M'(\Delta) > 0 \) and thus \( \phi_M(\Delta) \geq 0 \). Also,

\[ \phi_N'(\Delta_{\text{UB}}) = 16\gamma^6(2-\gamma^2)^2 \geq 0. \]

We deduce that \( \phi_N(\Delta) \) is concave and thus \( \phi_N(\Delta) \geq 0 \). It follows that \( \Pi_{\text{OO}} \geq \Pi_{\text{II}} \). Therefore, we obtain part (i). Next we prove part (ii). We first examine the manufacturers’ sourcing decisions. We have

\[ \Pi_{\text{OO}} - \Pi_{\text{IO}} = \theta[G_1(v^{\text{OO}}, v^{\text{OO}}) + g_1(v^{\text{OO}}, v^{\text{OO}}) + g_2(v^{\text{OO}}, v^{\text{OO}}) - g_2(c, v^{\text{OO}}) - G_1(c, v^{\text{OI}})] \]

\[ + (1-\theta)[G_1(c, v^{\text{OO}}) - G_1(c, v^{\text{OI}})] \]

\[ = \theta \frac{(a-c)^2 \phi_A(\Delta)}{16b(2-\gamma^2)^2(4-\gamma^2)^2} + \frac{(1-\theta)(a-c)^2 \phi_B(\Delta)}{16b(2-\gamma^2)^2(4-\gamma^2)^2}, \]

where

\[ \phi_A(\Delta) = \begin{cases} 
-(4-\gamma^2)^2 + 4\gamma(16-12\gamma^2 + 3\gamma^4)\Delta + 8(1-\gamma)(4-\gamma^2)(2-\gamma^2)\Delta^2 & \text{if } \Delta \leq \Delta_1 \\
(4-\gamma^2)[-(4-\gamma^2)^2 + 4\gamma(4-\gamma^2)^2 + 2(8-8\gamma - 4\gamma^2 + 4\gamma^2 - \gamma^4)\Delta^2] & \text{if } \Delta > \Delta_1,
\end{cases} \]

\[ \phi_B(\Delta) = \begin{cases} 
\gamma^4[-32 + 16\gamma^2 - \gamma^4 + 4\gamma(4-\gamma^2)\Delta] & \text{if } \Delta \leq \Delta_1, \\
-(4-\gamma^2)^2[(4-\gamma^2)^2 - 2\gamma^2] & \text{if } \Delta > \Delta_1.
\end{cases} \]
In deriving the above, we note that \(q_1(c, v^{\text{O}O}) \geq (\cdot) 0\) for \(\Delta \leq (\cdot) \Delta_1 = \frac{4(2-\gamma)}{7(4-\gamma)} \leq \Delta^{UB} = \frac{4-\gamma}{2\gamma}\). We obtain
\[
\phi_A(1) = \gamma(4-4\gamma + \gamma^2) \leq (\cdot) 0\) for \(\gamma \leq (\cdot) 2\sqrt{2} - 1\). Also, \(\phi_B(1) = \gamma(32 + 16\gamma + 16\gamma^2 - 4\gamma^3 - \gamma^4) \leq 0\).

Define
\[
\chi_1(\Delta) = (4 - \gamma^2) \phi_A(\Delta) - \phi_B(\Delta) = \begin{cases} 
8[-8(2 - \gamma^2) + \gamma(4 - \gamma^2)\Delta + (1 - \gamma)(4 - \gamma^2)^2\Delta^2](2 - \gamma^2) & \text{if } \Delta \leq \Delta_1, \\
2(2 - \gamma)^3(2 + \gamma^2)^2(2 - \gamma^2)\Delta^2 & \text{if } \Delta > \Delta_1.
\end{cases}
\]

It is clear that \(\chi_1(\Delta)\) is positive and increasing in \(\Delta\) for \(\Delta > \Delta_1\). For \(\Delta \leq \Delta_1\), \(\chi_1(\Delta)\) is convex with a minimizer of \(\Delta = -\frac{1}{6(1 - \gamma)}\). Then \(\chi_1(\Delta)\) is positive and increasing for \(\Delta \geq 1\).

We further note that \(\phi_A(\Delta)\) is increasing in \(\Delta\) for \(\Delta \leq \Delta_1\). For \(\Delta > \Delta_1\), \(\phi_A(\Delta)\) is convex and
\[
\phi_A(\Delta) = \frac{\gamma}{4}(16(1 - \gamma)(4 - 3\gamma^2) + 16\gamma^3(1 - \gamma^2) + 5\gamma^5) \geq 0.
\]

Then \(-\phi_A(\Delta)\) is decreasing in \(\Delta\). Since \(\chi_1(\Delta)\) is increasing in \(\Delta\), we deduce that \(\bar{\theta}_Q = \max\{-\phi_A(\Delta_1), 1\}\) is decreasing in \(\Delta\). Also,
\[
\phi_A(\Delta) = \frac{1}{\gamma^2(4 - \gamma^2)}[64(2 - \gamma)(1 - \gamma)(8 + 4\gamma - 8\gamma^2 - 2\gamma^3 + 4\gamma^4 + \gamma^5) + \gamma^2(64 - 32\gamma - \gamma^3)] \geq 0.
\]

Hence, for \(\gamma \leq 2\sqrt{2} - 1\), there exists a \(\Delta_2 \in [1, \Delta_1]\) such that \(\phi_A(\Delta) \leq (\cdot) 0\) for \(\Delta \leq (\cdot) \Delta_2\). Therefore, \(\bar{\theta}_Q(\Delta) = 0\) for \(\gamma \leq 2\sqrt{2} - 1\) and \(\Delta > \Delta_2\). Hence, both manufacturers would outsource if \(\theta > \bar{\theta}_Q(\Delta)\).

Now consider the common supplier’s incentive of offering outsourcing service. Note that \(\pi^{\text{O}I} \geq 0\), and
\[
\pi^{\text{O}I} - \pi^{\text{O}I} = \theta[g_1(v^{\text{O}I}, c) + g_2(c, v^{\text{O}I}) - g_1(v^{\text{O}I}, v^{\text{O}I}) - g_2(v^{\text{O}I}, v^{\text{O}I})] + (1 - \theta)[g_1(v^{\text{O}I}, v^{\text{O}I}) + g_2(v^{\text{O}I}, v^{\text{O}I})] + g_1(v^{\text{O}I}, v^{\text{O}I}) + g_2(v^{\text{O}I}, v^{\text{O}I}) - g_1(v^{\text{O}I}, v^{\text{O}I}) - g_2(v^{\text{O}I}, v^{\text{O}I}) - g_1(v^{\text{O}I}, c) - g_1(v^{\text{O}I}, c) + g_1(c, c)]
\]
\[
= \frac{\theta(a - c)^2\gamma^3\Phi_A(\Delta)}{4b(2 - \gamma^2)^2(2 - \gamma^2)(2 + \gamma)^2} + \frac{(1 - \theta)(a - c)^2\Phi_B(\Delta)}{8b(2 - \gamma^2)^2(2 - \gamma^2)(2 + \gamma)^2},
\]
where
\[
\Phi_A(\Delta) = \begin{cases} 
2[4 - 2\gamma^2 - \Delta(4 - \gamma^2)]\Delta & \text{if } \Delta \leq \Delta_1, \\
-(2 - \gamma)^2(2 + \gamma)^2 & \text{if } \Delta > \Delta_1,
\end{cases}
\]
\[
\Phi_B(\Delta) = \begin{cases} 
+4\gamma[8(8 - 8\gamma^2 + 16\gamma^4 - \gamma^6)\Delta + 4(4 - \gamma^2)^2(2 - 4\gamma - \gamma^2 + \gamma^3)\Delta^2] & \text{if } \Delta \leq \Delta_1, \\
(2 - \gamma)^2[32 - \gamma^2(2 + \gamma)(20 - 6\gamma - 2\gamma^2 - \gamma^3) + (2 + \gamma)^2\Delta(4\gamma(2 - \gamma^2) + 4(2 - 4\gamma + \gamma^3)) - \Delta] & \text{if } \Delta > \Delta_1.
\end{cases}
\]

It is easy to see that \(\Phi_A(\Delta) < 0\) and \(\Phi_B(\Delta) < 0\). Also note that \(\Phi_B(1) = \gamma^4[8(8 + 6\gamma - \gamma^3)] > 0\) for \(\gamma < (\cdot) \gamma_1 = 0.679961\). Now define
\[
\chi_2(\Delta) = \frac{\Phi_B(\Delta) - 2\gamma^3(2 - \gamma)(2 + \gamma)^2\Phi_B(\Delta)}{2 - \gamma^2} = \begin{cases} 
-64(1 + \gamma) + \gamma^2(32 + 32\gamma - \gamma^4) + 12\gamma(4 - \gamma^2)^2\Delta + 4(1 - 2\gamma)(4 - \gamma^2)^2\Delta^2 & \text{if } \Delta \leq \Delta_1, \\
(2 - \gamma)^2[16 - \gamma^2(12 + 4\gamma + \gamma^2) + 4\gamma(2 + \gamma)^2\Delta + 2(2 + \gamma)^2(2 - 4\gamma + \gamma^2)\Delta^2] & \text{if } \Delta > \Delta_1.
\end{cases}
\]

For \(\Delta \leq \Delta_1\), \(\chi_2(\Delta)\) is convex (concave) for \(\gamma \leq (\cdot) \frac{1}{2}\). Also,
\[
\chi_2(1) = \gamma^4(4 + 4\gamma - \gamma^2) \geq 0, \\
\chi_2'(1) = 4(2 - \gamma)^3(2 + \gamma)^2 \geq 0, \\
\chi_2(\Delta) = \frac{1}{\gamma^2}[256 - 512\gamma + 64\gamma^2 + 344\gamma^3 - 192\gamma^4 - 96\gamma^5 + 48\gamma^6 - \gamma^8] \geq 0.
\]

It follows that \(\chi_2(\Delta) \geq 0\). For \(\Delta > \Delta_1\), \(\chi_2(\Delta)\) is convex (concave) if \(\gamma \leq (\cdot) \frac{1}{2} 2 - \sqrt{2} \approx 0.586\). Also,
When the side of Equation (A6) is nonnegative and the second term is nonpositive, we have $N_2(\Delta) > 0$ for $\gamma \leq 2 - \sqrt{2}$.

Then, $N_2(\Delta) \geq 0$ in this case. Therefore, we conclude that $\pi^{O_O} - \pi^{I_{i}} \geq (\leq 0)$ for $\theta \leq (\geq \theta) \overline{\theta}_Q = 1 - \max \left\{ \frac{\gamma}{\gamma} (2 - \gamma)(2 + 2\gamma) \frac{\Delta}{\Delta_1} \right\}$. Hence, the supplier would offer outsourcing service to both manufacturers only when $\theta \leq \overline{\theta}_Q$. We obtain part (ii).

**Proof of Proposition 3.** For ease of exposition, define $\Delta_1 = \frac{a - c}{c_1}$ and $\Delta_2 = \frac{a - c}{c_2}$. We also omit the case when one manufacturer becomes a monopoly because this consideration does not alter the results. There are four scenarios to analyze, depending on the industry structures and the mode of competition. We present detailed analysis for one scenario and provide the equilibrium conditions for the other three as they follow in the similar way and the derivation is mainly algebraic.

(a) **Exclusive Suppliers and Quantity Competition.** Recall that $c_i = c$ under insourcing and $c_i = w_i$ under outsourcing. We can derive from Lemma 1 the players’ gross profits as

$$\tilde{G}_i(\Delta_1, \Delta_2) = \frac{(a - c)}{b} \frac{(2\Delta_1 - \gamma \Delta_2)^2}{\gamma - 4\gamma^2}$$

$$\tilde{G}_i(\Delta_1, \Delta_2) = \frac{(a - c)}{b} \frac{(2\Delta_2 - \gamma \Delta_1)^2}{\gamma - 4\gamma^2}.$$  

Substituting the above into the Nash product in Equation (2) and differentiating with respect to $\Delta_1$, we obtain the first-order condition of $\Delta_1$

$$\frac{\partial \Omega^{OO}}{\partial \Delta_1} = \frac{4(a - c)}{b(4 - \gamma^2)^{\gamma+1}} \frac{(4\Delta_1 - 1)(\Delta_1 - \gamma \Delta_2)}{\gamma - 4\gamma^2} \frac{(2\Delta_1 - \gamma \Delta_2)^2}{\gamma} - \frac{(\Delta_1 - \gamma \Delta_2)(2\Delta_1 - \gamma \Delta_2)}{\gamma} = 0,$$

where

$$\Xi^{OO}_1(\Delta_1, \Delta_2) = \theta(\Delta - \Delta_1)(2\Delta_2 - \gamma \Delta_2)^2 + (1 - \theta)(\Delta - \Delta_1)(1 + \Delta_1 - \gamma \Delta_2)(2\Delta_1 - 4\Delta_1 + \gamma \Delta_2).$$

Because any feasible $\Delta_1$ must ensure nonnegative $\tilde{G}_i$ and $\tilde{G}_i$, we have $\Delta_1 \geq \gamma \Delta_2/2$, $\Delta_1 \geq \gamma \Delta_2 - 1$, $\Delta_1 \geq 1$ and $\Delta_1 \leq \Delta$. Also, $\Xi^{OO}_1$ is a cubic function in $\Delta_1$ with the coefficient of $\Delta_1^3$ being $-24$. Since the first term on the right-hand side of Equation (A6) is nonnegative and the second term is nonpositive, we have $\Xi^{OO}_1(\Delta, \Delta_2) \leq 0$. Therefore, there exists at least one root in $[1, \Delta]$ that is a local maximizer of $\Omega^{OO}_1$. This root must also satisfy $2\Delta - 4\Delta_1 + \gamma \Delta_2 \leq 0$. Moreover,

$$\frac{\partial \Xi^{OO}_1}{\partial \Delta_1} = -4(1 - \theta)(\gamma \Delta_2 - 1) - \gamma^2 \Delta_2^2 - 4\Delta - 4\Delta_1 + \gamma \Delta_2)(2 - \theta) < 0,$$

$$\Xi^{OO}_1(\gamma \Delta_2/2, \Delta_2) = -(2\Delta - \gamma \Delta_2)(2 - \gamma \Delta_2)(1 - \theta)/4 \leq 0,$$

$$\Xi^{OO}_1(\Delta/2 + \gamma \Delta_2/4, \Delta_2) = (2\Delta - \gamma \Delta_2)^3 \theta/16 \geq 0.$$

The first expression suggests that a feasible wholesale price exists because $\Delta_1 = 1$ or $\Delta_1 = \Delta$ leads to a zero Nash product. Together with the last two expressions, it is clear that the largest root of $\Xi^{OO}_1(\Delta_1, \Delta_2) = 0$ maximizes the Nash product within the range $[1, \Delta]$. Let $\hat{\Delta}(\Delta_2)$ denote this root. Under $OI$, we must have $\Delta^{OI}_1 = \Delta(1) \in [1, \Delta]$, which gives rise to $w^{OI} = a - \Delta^{OI}(a - c) \in [c_i, c]$. 
We further note that
\[
\frac{\partial \Xi_{1}^{OO}}{\partial \Delta_2} - (2\Delta - 4\Delta_1 + \gamma \Delta_2)(\Delta_1 + 1 - \gamma \Delta_2) + \Xi_{1}^{OO}(\Delta_1, \Delta_2)(2\Delta + \gamma \Delta_2 - 1 - 5\Delta_1)
\]
\[
= \theta(\Delta - \Delta_1)(2\Delta_1 - \gamma \Delta_2)(\Delta_1)(2\Delta - \gamma \Delta_2) \geq 0.
\]

Since the second term on the left-hand side is zero at \( \Delta_1 = \Delta(\Delta_2) \), we deduce that \( \Delta(\Delta_2) \) is increasing in \( \Delta_2 \). Also,
\[
\frac{\partial \Xi_{1}^{OO}}{\partial \Delta_1} + \frac{\partial \Xi_{1}^{OO}}{\partial \Delta_2} \leq \frac{\partial \Xi_{1}^{OO}}{\partial \Delta_1} + \frac{1}{\gamma} \frac{\partial \Xi_{1}^{OO}}{\partial \Delta_2}
\]
\[
= -(1 + \Delta_1 - \gamma \Delta_2)[3(\Delta_1 - 1) - 2\Delta + 4\Delta_1 - 2\gamma \Delta_2] + \theta(\Delta_1 - 1)(3 + 2\Delta - \Delta_1 - 2\gamma \Delta_2).
\]

The inequality follows because \( \frac{\partial \Xi_{1}^{OO}}{\partial \Delta_1} \leq 0 \) and \( \frac{\partial \Xi_{1}^{OO}}{\partial \Delta_2} \geq 0 \). If the second term on the right-hand side is negative, the above is nonpositive, which implies the slope of \( \Delta(\Delta_2) \) being less than one. In other words, there exists a unique \( \Delta^{OO} \) satisfying \( \Delta^{OO} = \Delta(\Delta^{OO}) \). It follows that \( w^{OO} = a - \Delta^{OO} (a - c) \in [c, c] \) constitutes the equilibrium under OO. Moreover, since \( \Delta(\cdot) \) is increasing, we have \( \Delta^{OO} = \Delta(\Delta^{OO}) \geq \Delta(1) = \Delta^{O1} \) and thus \( w^{OO} \leq w^{O1} \). This gives part (i).

Define \( w^C \) and \( w^I \) to be the corresponding wholesale prices that lead to equilibrium prices \( p^C \) and \( p^I \), respectively. It is easy to see that \( w^I = c_S \leq w^{OO} \leq w^{O1} \) and thus \( p^I \leq p^{OO} \leq p^{O1} \), leading to part (ii). By Lemma 1, we can verify that \( w^C = c_S + \frac{(a-c)}{2(1+\gamma)} \) leads to a downstream price of \( p^C \). Let \( \Delta_C^C = \Delta^{O1} = \frac{a-w^C}{a-c} = \frac{\gamma}{1+\gamma} \).

From Equation (A6), we have
\[
\Xi^{OO}(\Delta_C^C) = \frac{\Delta}{8(1+\gamma)^3} \left[ (1 - \theta)[\gamma \Delta - 2(1+\gamma)] + \gamma(1-\gamma)\Delta[4 + \gamma^2] + \theta^2(2 - \gamma)^2(2 + \gamma)\Delta^2 \right].
\]

It is clear that \( \Xi^{OO}(\Delta_C^C) \geq 0 \) for \( \Delta \geq \frac{2(1+\gamma)}{\gamma} \). For \( \Delta < \frac{2(1+\gamma)}{\gamma} \), the first term inside the square bracket is positive and the second term is negative. Then, a threshold of \( \theta \) can be determined and thus we conclude part (iii).

(b) Exclusive Suppliers and Price Competition. We can derive from Lemma 1 the players’ gross profits as
\[
G_i(\Delta_1, \Delta_2) = \frac{(a - c)^2 (2 - \gamma ^2)\Delta_1 - \gamma \Delta_2}{b(4 - \gamma ^2)^2(1 - \gamma ^2)} \quad (A7)
\]
\[
\tilde{G}_i(\Delta_1, \Delta_2) = \frac{(a - c)^2 (\Delta_1 - \gamma \Delta_2)(2 - \gamma ^2\Delta_1 - \gamma \Delta_2)}{b(4 - \gamma ^2)^2(1 - \gamma ^2)} \quad (A8)
\]

Substituting the above into the Nash product in Equation (2) and differentiating with respect to \( \Delta_1 \), we obtain the first-order condition of \( \Delta_1 \)
\[
\frac{\partial \Omega_{1}^{OO}}{\partial \Delta_1} = \frac{4(a-c)^2 (2 - \gamma ^2)^2}{b(4 - \gamma ^2)^2(1 - \gamma ^2)^{\theta + 1}} \left[ (1 - \theta)(\Delta - 1)(2 - \gamma ^2)(\Delta - \gamma \Delta_2)]^{\theta + 1} \cdot (1 + \Delta_1 - 2\gamma \Delta_2) \right] = 0,
\]
where
\[
\Xi_{1}^{OO}(\Delta_1, \Delta_2) = 2\theta(\Delta - \Delta_1)(2 - \gamma ^2\Delta_1 - \gamma \Delta_2)^2 - (1 - \theta)(\Delta_1 - 1)(2 - \gamma ^2)(\Delta_1 + 1 - 2\gamma \Delta_2) \cdot [(2 - \gamma ^2)(2\Delta_1 - \Delta) - \gamma \Delta_2] ,
\]
and (c) Common Supplier and Quantity Competition. We can derive the first-order condition of \( \Delta_1 \) as in (a) to obtain
\[
\Xi_{1}^{OO}(\Delta_1, \Delta_2) = \theta(2\Delta_1 - \gamma \Delta_2)(\gamma \Delta - (\gamma + \Delta)\Delta_2 + (2 - \gamma )\Delta \Delta_1 + 2\gamma \Delta_1 \Delta_2 - 2\Delta_2^2 + (1 - \theta)(\Delta_1 - 1)(2 - \gamma \Delta )
\]
\[
- 4\Delta_1 + 2\gamma \Delta_2)(1 + \Delta_1 - \gamma \Delta_2) = 0.
\]

\( \Xi_{1}^{OO}(\Delta_1, \Delta_2) \)
(d) Common Supplier and Price Competition. We can derive the first-order condition of $\Delta_1$ as in (b) to obtain

$$
\Xi^{\text{PO}}(\Delta_1, \Delta_2) = 2\theta(\gamma\Delta_2 - (2 - \gamma^2)\Delta_1) [\gamma\Delta_2 + ((2 - \gamma^2)\Delta_1 - 2\gamma\Delta_2)\Delta_1 + [\gamma(\Delta_2 - 1) - (2 - \gamma - \gamma^2)\Delta_1] \Delta_1] \\
+ (1 - \theta)(\Delta_1 - 1)|((2 - \gamma^2)\Delta_1 - 2\gamma\Delta_2 + 2 - \gamma^2)\Delta_1 - (2 - \gamma^2)\Delta_1 + 2\gamma\Delta_2|.
$$

PROOF OF PROPOSITION 5. We prove the result for quantity competition, as that for price competition follows in a similar way.

Case 1: Exclusive Suppliers. By differentiating the Nash product in Equation (2) with respect to $F_1$, we can obtain $F_1 = (1 - \theta) [G_1(v_1, \tilde{c}_2) - G_1(c, \tilde{c}_2)] - \theta g_1(v_1, \tilde{c}_2)$. It is easy to see that the fixed fee $F_1$ allocates the trade surplus $G_1(v_1, \tilde{c}_2) + g_1(v_1, \tilde{c}_2) - G_1(c, \tilde{c}_2)$ proportionally according to the player’s bargaining power. Thus, to maximize the Nash product, the unit price $v_1$ should maximize the total channel profit, $J_1(v_1, \tilde{c}_2) = G_1(v_1, \tilde{c}_2) + g_1(v_1, \tilde{c}_2)$.

Case 1-a: Under quantity competition, it is easy to check that $v_{OI} = \tilde{v}(c)$. Thus

$$
\tilde{v}(\tilde{c}_2) = \begin{cases} 
\frac{c_S - \gamma^2[2(a - c_S) - \gamma(a - \tilde{c}_2)]}{4(2 - \gamma^2)} & \text{if } \frac{a - v_1}{a - \tilde{c}_2} \leq \frac{2 - \gamma^2}{\gamma}, \\
\frac{c_S}{2} & \text{if } \frac{a - v_1}{a - \tilde{c}_2} > \frac{2 - \gamma^2}{\gamma}.
\end{cases}
$$

Thus, $v^{\text{OI}} = \tilde{v}(c)$. By symmetry, $v^{\text{OO}} = c_S - \frac{\gamma^2(a - c_S)}{4 + 2\gamma - \gamma^2}$ is the unique solution of $v^{\text{OO}} = \tilde{v}(v^{\text{OO}})$.

Case 1-b: Under price competition, we can derive in a similar way the following relation

$$
\tilde{v}(\tilde{c}_2) = \begin{cases} 
\frac{c_S + \frac{\gamma^2(2 - \gamma)(a - c_S) - \gamma(a - \tilde{c}_2)}{4(2 - \gamma^2)}}{c_S + \frac{\gamma^2(a - c_S)}{2}} & \text{if } \frac{a - v_1}{a - \tilde{c}_2} \leq \frac{2 - \gamma^2}{\gamma}, \\
\frac{c_S}{2} & \text{if } \frac{a - v_1}{a - \tilde{c}_2} > \frac{2 - \gamma^2}{\gamma}.
\end{cases}
$$

Thus $v^{\text{OI}} = \tilde{v}(c)$. By symmetry, $v^{\text{OO}} = c_S + \frac{\gamma^2(1 - \gamma)(a - c_S)}{4 + 2\gamma - \gamma^2}$ is the unique solution of $v^{\text{OO}} = \tilde{v}(v^{\text{OO}})$. One can easily check that $v^{\text{OO}} = v^{\text{OI}} = c$ when $\Delta = \Delta^{\text{OO}}$.

Case 2: Common Supplier. We omit the details and simply provide the expressions for this case: $v^{\text{OO}} = c_S - \frac{\gamma^2(a - c_S)}{2(2 - \gamma)}$ under quantity competition and $v^{\text{PO}} = c_S + \frac{\gamma^2(a - c_S)}{4}$ under price competition. One can easily check that $v^{\text{OO}} = c$ when $\Delta = \Delta^{\text{OO}}$.

Under quantity competition, a unit price of $w^c = c_S + \frac{\gamma^2(a - c_S)}{2(2 - \gamma)}$ leads to a price of $p^c$, and a unit price of $w^d = c_S$ leads to a price of $p^d$. Thus, $p^X \leq p^I \leq p^C$.

Under price competition, a unit price of $w^c = c_S + \frac{\gamma^2(a - c_S)}{2}$ leads to a price of $p^c$, and a unit price of $w^d = c_S$ leads to a price of $p^d$. Thus, $p^I \leq p^X \leq p^C$.

PROOF PROPOSITION 5. We prove the result for quantity competition, as that for price competition follows in a similar way. For part (i), we compute from Equations (A6) and (A9)

$$
\Xi^{\text{OO}}(\Delta) - \Xi^{\text{PO}}(\Delta) = \gamma(1 - \theta)(\Delta_1 - 1)[1 - (1 - \gamma + \theta)\Delta_1] \geq 0.
$$

This indicates $0 = \Xi^{\text{OO}}(\Delta^{\text{OO}}) \geq \Xi^{\text{PO}}(\Delta^{\text{OO}})$. It follows that $\Delta^{\text{OO}} \geq \Delta^{\text{PO}}$ and thus $w^{\text{OO}} \leq w^{\text{PO}}$. Part (ii) follows immediately from part (i).
Proof of Proposition 6. We present the result for quantity competition, and that for price competition can be found in the Online Appendix. We have, from the proof of Proposition 4,

\[ 
\nu^{\text{OO}} - \nu^{\text{OO}} = -\frac{\gamma^2(2 + \gamma)(a - c_s)}{2(2 - \gamma^2)(4 + 2\gamma - \gamma^2)} \leq 0. 
\]

For the manufacturers, we have from Proposition 4,

\[
\Pi^{\text{OO}} - \Pi^{\text{OO}} = \theta[G_1(\nu^{\text{OO}}, \nu^{\text{OO}}) + \theta_1(\nu^{\text{OO}}, \nu^{\text{OO}}) + g_2(\nu^{\text{OO}}, \nu^{\text{OO}}) - g_2(c, \nu^{\text{OO}}) \\
- G_1(\nu^{\text{OO}}, \nu^{\text{OO}}) - G_1(\nu^{\text{OO}}, \nu^{\text{OO}})] + (1 - \theta)[G_1(c, \nu^{\text{OO}}) - G_1(c, \nu^{\text{OO}})] \\
= \frac{\gamma^3 \phi_a(\frac{a-c_s}{a-c})}{8b(2 - \gamma^2)(4 - \gamma^2)(4 + 2\gamma - \gamma^2)^2} + (1 - \theta) \frac{(a - c)^2 \phi_b(\frac{a-c_s}{a-c})}{4b(2 - \gamma^2)^2(4 - \gamma^2)^2(4 + 2\gamma - \gamma^2)^2},
\]

where

\[
\phi_a(\Delta) = \begin{cases} 
2[2(4 + 2\gamma - \gamma^2)^2(2 - \gamma^2) + (4 - \gamma^2)(16 + 8\gamma - 8\gamma^2 - \gamma^3 + 2\gamma^4)] & \text{if } \Delta \leq \Delta_t, \\
(4 - \gamma^2)(2 - \gamma^2)(16 - 8\gamma^2 + \gamma^3)\Delta^2 & \text{if } \Delta > \Delta_t.
\end{cases}
\]

\[
\phi_b(\Delta) = \begin{cases} 
\gamma^3(2 + \gamma)\Delta[64 + 32\gamma - 48\gamma^2 + 16\gamma^3 + 8\gamma^4] & \text{if } \Delta \leq \Delta_t, \\
-16(2 - \gamma^2)^2(4 + 2\gamma - \gamma^2 - \gamma(2 + \gamma))\Delta^2 & \text{if } \Delta > \Delta_t.
\end{cases}
\]

In deriving the above, we used the fact that \( q_1(c, \nu^{\text{OO}}) \geq (\leq) 0 \) for \( \Delta \leq (\geq) 0 \), \( \Delta_t = \frac{4(2 - \gamma^2)}{8 + \gamma^2} \leq \Delta^{\text{UB}}_Q = \frac{4\gamma^2}{8 + \gamma^2} \). We note that \( \phi_b(1) = \gamma^4(2 + \gamma)(-64 + 64\gamma^2 + 14\gamma^4 + \gamma^5) \leq 0 \), and \( \phi_b(\Delta) \leq 0 \) for \( \Delta > \Delta_t \). Since \( \phi_b(\Delta) \) is continuous and is convex for \( \Delta \leq \Delta_t \), we deduce \( \phi_b(\Delta) \leq 0 \).

Define

\[
\chi_0(\Delta) = \gamma^3(4 - \gamma^2)\phi_a(\Delta) - 2\phi_b(\Delta) \\
= \begin{cases} 
4\gamma^3(2 + \gamma)(2 - \gamma^2)\Delta[32 + 2\gamma^2(4 - \gamma)^2(2 + \gamma) + (32 - 24\gamma)^2 + 2\gamma^3 + 3\gamma^4 - \gamma^5]\Delta & \text{if } \Delta \leq \Delta_t, \\
(2 - \gamma^2)\gamma^3(4 - \gamma^2)^2(16 - 8\gamma^2 + \gamma^3)\Delta^2 + 32(2 - \gamma^2)(4 + 2\gamma - \gamma^2 - \gamma(2 + \gamma))\Delta^3 & \text{if } \Delta > \Delta_t.
\end{cases}
\]

We obtain \( \chi_0(1) = 4\gamma^3(2 - \gamma)(2 + \gamma)(4 + 3\gamma)(2 - \gamma^2) \geq 0 \). Further note that \( \chi_0(\Delta) \) is continuous in \( \Delta \) and is piecewise convex. Also,

\[
\chi_0'(\Delta) = 4\gamma^3(2 + \gamma)(2 - \gamma^2)[32 - \gamma^2(16 - 4\gamma + \gamma^3)] \geq 0, \\
\chi_0'(\Delta_t^-) = \frac{4\gamma^3(2 + \gamma)(2 - \gamma^2)}{2 - \gamma} \geq 0, \\
\chi_0'(\Delta_t^+) = \frac{8\gamma^3(2 + \gamma)(2 - \gamma^2)^2}{2 - \gamma} \geq 0.
\]

Then, \( \chi_0'(\Delta) \geq 0 \) and thus \( \chi_0(\Delta) \geq 0 \). It follows that \( \Pi^{\text{OO}} - \Pi^{\text{OO}} \leq (\geq) 0 \) if \( \theta \leq (\geq) \vartheta Q = \max\{\frac{2\phi_b(\Delta)}{\chi_0(\Delta)} \cdot 1\} \). Moreover,

\[
\frac{\partial^2 \vartheta Q}{\partial \Delta^2} \cdot \frac{\chi_0(\Delta)}{2} = -\phi_b'(\Delta)\chi_0(\Delta) + \phi_b''(\Delta)\chi_0(\Delta) \\
= \begin{cases} 
-4\gamma^2(2 - \gamma)(2 + \gamma)^3(2 - \gamma^2)(4 + 2\gamma - \gamma^2)\cdot[64(2 - \gamma)(1 - \gamma^2) + \gamma^3(8 + \gamma(16 - \gamma)] & \text{if } \Delta \leq \Delta_t, \\
(2 - \gamma)^2(\Delta^2) & \text{if } \Delta \geq \Delta_t, \\
-32\gamma^3(4 + 2\gamma - \gamma^2)(2 - \gamma^2)\gamma^3(16 - 8\gamma^2 + \gamma^3)\cdot[4 + 2\gamma - \gamma^2 - \gamma(2 + \gamma)] & \text{if } \Delta \geq \Delta_t.
\end{cases}
\]

The inequality follows because \( \Delta \leq \Delta^{\text{UB}}_Q \leq \frac{4 + 2\gamma - \gamma^2}{(4 + 2\gamma - \gamma^2)^2(4 + 2\gamma - \gamma^2)^2} \). We deduce that \( \vartheta Q \) is decreasing in \( \Delta \).
Now we turn to the suppliers’ profits. We have
\[
\pi^{	ext{OO}} - 2\pi^{	ext{OO}} = \theta[\delta_1(v^{	ext{OO}}, c) + \delta_2(c, v^{	ext{OO}}) - \delta_1(v^{	ext{OO}}), v^{	ext{OO}}) - \delta_2(v^{	ext{OO}}, v^{	ext{OO}})] + (1 - \theta)[G_1(v^{	ext{OO}}, v^{	ext{OO}}) + G_2(c, v^{	ext{OO}}) + \delta_1(v^{	ext{OO}}, v^{	ext{OO}}) + \delta_2(v^{	ext{OO}}, v^{	ext{OO}}) - G_1(c, v^{	ext{OO}}) - G_2(v^{	ext{OO}}, c) - 2G_1(v^{	ext{OO}}, v^{	ext{OO}}) - 2\delta_1(v^{	ext{OO}}, v^{	ext{OO}}) + 2G_1(c, v^{	ext{OO}})]
\]
\[
= \frac{\theta(a - c)^2}{4b(2 - \gamma)^2}(2 - \gamma)(2 + \gamma) + \frac{(1 - \theta)(a - c)^2\Phi_2(\Delta)}{2b(2 - \gamma)^2(2 - \gamma)^2(2 + \gamma)^2(4 + 2\gamma - \gamma^2)}
\]
where
\[
\Phi_2(\Delta) = \begin{cases} 
2[4 - 2\gamma^2 - \Delta(4 - \gamma^2)]\Delta & \text{if } \Delta \leq \Delta_1, \\
(2 - \gamma)^2(2 + \gamma)\Delta^2 & \text{if } \Delta > \Delta_1,
\end{cases}
\]
\[
\Phi_1(\Delta) = \begin{cases} 
\gamma^4(2 + \gamma)\Delta[8(4 + 2\gamma - \gamma^2)(2 - \gamma^2) - (2 + \gamma)(32 - 20\gamma^2 + 4\gamma^3 + 2\gamma^4 - \gamma^5)\Delta] & \text{if } \Delta \leq \Delta_1, \\
1024 + \gamma(2 + \gamma)[16(2 - \gamma)(2 - 4\gamma + \gamma^2)(8 + 6\gamma - \gamma^2) - 32(2 + \gamma - \gamma^2)(2 - \gamma^2)^2\Delta] & \\
+ \gamma(2 + \gamma)[8 + (1 - \gamma)(56 + 56\gamma - 40\gamma^2 - 24\gamma^3 + 12\gamma^4 - \gamma^5)]\Delta^2 & \text{if } \Delta > \Delta_1.
\end{cases}
\]

It is easy to see that \(\Phi_1(\Delta) < 0\) and \(\Phi_1(\Delta) < 0\). Also note that \(\Phi_2(1) = \gamma^6(2 + \gamma)(-8 - 4\gamma + \gamma^4) \leq 0\).

Now we check \(\Phi_1(\Delta)\). We first examine the case when \(\Delta \leq \Delta_1\). Since \(32 - 20\gamma^2 + 4\gamma^3 + 2\gamma^4 - \gamma^5 > 0\), \(\Phi_1(\Delta)\) is concave in \(\Delta\) and is positive for \(0 \leq \Delta \leq \Delta_1 = \frac{8(4 + 2\gamma - \gamma^2)(2 - \gamma^2)}{(2 + \gamma)(32 - 20\gamma^2 + 4\gamma^3 + 2\gamma^4 - \gamma^5)} \leq 1\). We deduce that \(\Phi_1(\Delta)\) is negative and decreasing for \(1 \leq \Delta \leq \Delta_1\). We then examine the case when \(\Delta > \Delta_1\). In this case \(\Phi_1(\Delta)\) is convex in \(\Delta\) and
\[
\Phi_1(\Delta_{\text{UB}}) = \frac{\gamma^2}{4}[256(1 - \gamma)(8 + 12\gamma + \gamma^2 - 4\gamma^3) + \gamma^4(448 + 640\gamma - 352\gamma^2 - 160\gamma^3 + 40\gamma^4 + 20\gamma^5 - 3\gamma^6 - \gamma^7)] \leq 0.
\]

Then, \(\Phi_1(\Delta) \leq 0\) in this case. Hence, we conclude that \(\pi^\text{OO} \leq 2\pi^\text{OO}\). We conclude part (i). □

Notes
1. In the Feng and Lu (2012) model, each manufacturer and her supplier negotiate directly over the channel profit. Consequently, the equilibrium decisions (i.e., quantities or prices, depending on the mode of competition) in their model are equal to those under the integrated benchmark.
2. When \(\gamma = 0\), the competitive equilibrium concept is moot because the two manufacturers act as a monopolist in their own market. Since the analysis is straightforward, we skip it for brevity.
3. In reality the line between price and quantity competition can be blurred depending on the time horizon of competition. When given sufficient lead time, capacity constraint can be alleviated through expansion, and thus firms that engage in quantity competition in the short run can be engaged in price competition over the long run.
4. Manufacturer’s fixed cost \(\bar{c}_i\) does not affect the negotiation between manufacturer and supplier because it has no effect on the subsequent manufacturer competition.
5. Bargaining over profit allocation guarantees the convexity of the bargaining set (see, e.g., Feng and Lu 2012) and thus is in general technically less challenging to handle than bargaining over a unit transfer price.
6. For a reference on coalitional bargaining, see Nagarajan and Sošić (2008).
7. When \(\theta = 1\), the suppliers are indifferent between trade and no trade. When \(\Delta = 1\), both the suppliers and the manufacturers are indifferent between insourcing and outsourcing.
8. It can be shown that \(\theta_2(\Delta) = 0\) for \(0 \leq \Delta_1 = \frac{4 + 2\gamma - \gamma^2}{(2 + \gamma)(12 - 2\gamma)}\) or \(\Delta \geq \Delta_2 = \frac{4 - 2\gamma}{(2 + \gamma)}\). Our numerical experiments over the entire parameter ranges for \(\gamma \in (0, 1)\), \(\theta \in [0, 1]\), and \(\Delta \in [\Delta_1, \Delta_2]\) suggest that IO and IO may arise in equilibrium only when the manufacturers’ bargaining power \(\theta\) is below 0.05.
9. This is consistent with the finding of Cai et al. (2012), who suggested that revenue-sharing contracts and two-part tariffs behave similarly in a competing supply chain setting with bilateral negotiations.

References


Supporting Information

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

Appendix: “The Role of Contract Negotiation and Industry Structure in Production Outsourcing”