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Component Procurement Strategy in TRIAD Competitive Supply Chains

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ABSTRACT
In complex supply chains today, intermediary organizations such as contract manufacturers and group purchasing organizations (GPO) are prevalent, and firms like Original Equipment Manufacturers (OEMs) confer their purchasing and procurement processes to such organizations. Because of their potential impact on the efficiency of supply chain, it is important to investigate the role of intermediaries in competitive supply chains. A prominent issue regarding intermediaries is whether an OEM can control components procurement or confer this task to intermediary organizations. This article studies the equilibrium point between two competing OEMs for procurement strategies for substitutable products. Each one of the OEMs may either procure directly its needs from the component supplier or devolve procurement to a contract manufacturer. We analyze OEMs' procurement Stackelberg game under two contracting power cases in such a supply chain: the game of supplier, where the component supplier is the game leader, and the game of OEM, where the OEMs are the players that play the first move. We show that small OEM always prefers to control its procurement functions. This is because it would receive a lower price if the component supplier were able to determine the price that discriminate the OEMs. By contrast, the bigger OEM's preference depends on the power of contracting. Under the supplier game, the bigger OEM never prefers procure directly, while under the OEM game it may have incentives to use direct procurement under some conditions. This implies that if the market power shifts from the supplier to the OEMs, more OEMs turn from delegation towards direct control.

1. Introduction

Because of economic evolutions in recent years, we can see the emergence of complex international supply chains with worldwide manufacturers, mostly called original equipment manufacturers (OEMs). Besides the important role of OEMs in this complex worldwide supply chains, we affirm the strong role of intermediaries in supply chains because of their positive influence on supply chain efficiency, too. The notion of intermediary has emerged in the

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literature of economics, referring to those economic agents that coordinate and arbitrate transactions between a group of supply chain firms' [1]. This importance has led to the proposition of the *intermediation theory of the firm* by Spulber in 1996 [2]. He believes that an intermediary acts as the fundamental building block of economic activities.

Fierce competition in the global marketplace has driven many original equipment manufacturers (OEMs) to outsource their production processes to external suppliers. By doing so, the OEMs can reduce production costs while focusing on core competencies such as product design and marketing [3]. It has been widely believed that the trend of outsourcing will continue in the near future.

A prevailing practice in production outsourcing is called contract manufacturing, i.e., instead of making the products themselves, OEMs depend on contract manufacturers to produce their products. In order to fulfill the production function, the contract manufacturer may need to procure certain parts and components on behalf of the OEM. This gives rise to a fundamental question: should the OEM control the procurement of components or delegate this task to the contract manufacturer?

This question has received an increasing deal of attention in the business media in recent years. Industry evidence shows that both the “delegation” and the “control” strategies have been adopted by OEMs. Often firms competing in the same market select different procurement strategies. For instance, Sun Microsystems imposes a tight control on component procurement, whereas Cisco prefers to delegate the responsibility to its contract manufacturers [4]. Even the same firm may customize the strategies for different parts and components. Dell delegates the procurement of some components for its notebooks, including cases and circuit boards, to its contract manufacturers, but controls the procurement of CPUs, hard disk drives, and memory chips [5]. Similarly, Hewlett-Packard (HP) delegates commodity-like components to suppliers, but controls the procurement of strategic components [6]. A more recent industry trend indicates that more and more OEMs are switching from the “delegation” strategy to the “control” strategy. Boeing has launched a procurement program to negotiate contracts directly with fastener suppliers instead of decentralized procurement via its first-tier manufacturing partners [7]. Such a trend has also been observed in the service industries. For example, rather than asking Boeing and Airbus to manage engine parts procurement, airline carriers have increasingly used direct contracts with aircraft engine manufacturers [4].

An OEM’s decision to delegate or control its component procurement is critical when it intends to use outsourcing as a competitive weapon in the marketplace. Interestingly, it is quite common that competing OEMs share common contract manufacturers and depend on the same supplier for critical components or parts. For example, Dell and HP compete in the laptop computer market. They use a common contract manufacturer, Wistron, to produce their products [8]. In addition, both Dell and HP use the same components, such as Intel’s processors. Similarly, a number of OEMs (e.g., Apple, Motorola Mobility, and Nokia) depend on Foxconn for the manufacturing of their smartphones, and they all use the chips supplied by Qualcomm, a dominant chip maker for smartphones and other electronics products [9]. Clearly, competition plays an important role in firms’ procurement strategy decisions. In particular, when selecting its own procurement structure (i.e., delegation or control), a firm must take its competitors’ strategies into consideration.

Our paper attempts to gain a better understanding of who should control component procurement in a supply chain with competition. We provide insights into this question through a stylized model of game theory. Two competing OEMs that outsource their production to a common contract manufacturer are considered; both of the OEMs’ products require a key component provided by a third-party supplier. The OEMs may either procure the component directly from the supplier or delegate the procurement function to the contract manufacturer.

Two bargaining power schemes are studied. In the first power scheme, the supplier acts as the Stackelberg leader by setting its price first; in the second, the OEMs are the Stackelberg leaders setting their margins first. By comparing these two power schemes, we examine how market power distribution affects the OEMs’ procurement decisions.

With the above model setup, we characterize the equilibrium outcome of the procurement game and study the driving forces underlying the firms’ component sourcing strategy. There are several major findings from this paper. First, product substitutability itself is not a significant factor in the OEMs’ choice between delegation and control. Instead, a critical factor is the potential market size. Contrary to our intuition, it is the smaller OEM that always prefers to control its component procurement regardless of the relative market power between OEMs and suppliers. This is because direct contracting allows the component supplier to price discriminate the two OEMs, and the smaller OEM will receive a lower component price due to its weaker market position.

Second, we find that the bargaining power distribution among the supply chain members may affect the OEMs' preferences over different component procurement strategies. When the component supplier has dominant market power, the larger OEM is always worse off if its competitor deviates from "delegation" to "control".

When the component supplier can price discriminate between the OEMs, which happens as long as one of them uses direct contracting, it will lower the price for the smaller OEM, while raising the price for the larger OEM. Thus, in this case, the larger OEM will not choose direct contracting. However, when the OEMs act as Stackelberg leaders (i.e., the OEMs have dominant market power), even the larger OEM may then prefer to directly contract with the component supplier under reasonable conditions. In this case, the OEMs set their own margins first, allowing them to extract higher surplus from the supplier via direct contracting.

This finding suggests that the shift of market power from the upstream to the downstream supply chain members may lead to more OEMs deviating from "delegation" to "control" in component procurement. This result is corroborated with the most recent procurement trends in industry.

Third, to our surprise, it has been found that the market outcomes under the above two power distribution schemes are exactly the same. Specifically, both the product prices and the production quantities in equilibrium are identical under the two power schemes. This implies that customer welfare does not depend on the market power distribution within the supply chain. The total supply chain profit will remain constant, while the distribution of profits among the supply chain members may change as the power distribution scheme changes.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 sets up the model and describes the procurement structures for the OEMs. Sections 4 and 5 present the game analysis for the supplier Stackelberg and the OEM Stackelberg schemes, respectively. Section 6 compares the outcomes from the two Stackelberg schemes. Extensions and discussions of the basic model are provided in Section 7, and the paper concludes with Section 8. All proofs are given in the Appendix.

2. Literature Review

This paper studies firms' procurement strategies in a supply chain setting. There is extensive literature on how firms should design procurement contracts to ensure an efficient and responsive supply (see [10] and [11]). Most studies in this literature consider the contracting relationship between a buyer and a supplier (or multiple potential suppliers). In particular, the buyer is interested in inducing the desirable operational performance (e.g., cost efficiency, fill rate, and lead time) from the supplier.

In the recent literature, there has been increasing interest in studying firms' component procurement strategies when outsourcing to contract manufacturers (See [12] and [13]). Our paper is most related to this growing body of literature.

This research differs from the proposed literature in two aspects. First, we study a downstream firm's decision on whether to control or delegate its component procurement, a key question not addressed in the above supply contracting studies. Second, our problem setting involves a competing three-tier, rather than a two-tier supply chain.

Most of research studies considering competition in a supply chain management investigate pricing decisions using a game theory approach (See [14], [15], [16] and [17]). However, few researches investigate delegation vs. control problem when outsourcing in more than two-tier supply chains. Guo et al. (2010) considered a three-tier supply chain where an OEM might choose from three outsourcing structures [18]. These structures may involve either controlling or delegating the component procurement function. It has been assumed that both the contract manufacturer's and the component supplier's production costs are private information.

They characterized each firm's optimal decision and compared their profits in different outsourcing structures. Kayı¸s et al. (2013) studied a contracting problem where an OEM chooses between delegating component procurement to the contract manufacturer and contracting directly with the component supplier [4]. They examined how asymmetric cost information and contract complexity can influence the optimal component procurement decision. They showed that if complex contracts could be used, then the OEM would be indifferent between delegation and control of component procurement; however, under price-only contracts, either of these procurement schemes could be optimal. Similarly, Wang et al. (2013) examined the interaction between the OEM's delegation decision and the contract format [19].

They found that the contract formats have different impacts on the OEM's delegation decision. They also characterized the conditions under which the OEM might prefer a specific contract format. Deshpande et al. (2011) studied the component procurement problem from a distinct perspective [20]. In particular, they aimed to develop secure price-masking mechanisms that possess some useful properties, such as preserving the private component prices of all parties in the supply chain.

When studying the component procurement problem, most studies consider a monopolist OEM in the market. Chen et al. (2012) is an exception in which two competing OEMs outsource to a common contract manufacturer [21]. It has been assumed that only the large OEM can choose its component procurement structure, and the small OEM must delegate its procurement function to the contract manufacturer. This is different from our paper where both OEMs can choose their component procurement structures. In addition, Chen et al. (2012) considered only the OEM Stackelberg game, whereas two bargaining power schemes were considered (either supplier or OEM as the Stackelberg leader).

There are papers in the literature of economics that study similar problems where firms transact in a multi-tier network; see, e.g., [22], [23], [24], and [25]. These studies adopt the principal-agent framework to investigate the firms' optimal transaction strategies in a network. This paper focuses on studying the impact of market competition and power distribution on the OEMs' component procurement strategies. Therefore, both the model setting and the insights are different from the above-mentioned papers in the economics literature.

3. Model Setting

A three-tier supply chain consisting of a component supplier, a contract manufacturer, and two original equipment manufacturers is considered. The downstream original equipment manufacturers (OEMs), denoted by M1 and M2, produce and sell partially differentiated products in the same market. Both OEMs use the contract manufacturer to perform significant manufacturing tasks. For instance, they depend on the contract manufacturer for the assembly of a portion, sometimes the whole of the product. Next, C is used to stand for the contract manufacturer. Like the OEMs, the contract manufacturer does not manufacture its product from scratch; instead, it needs a key component (e.g., a computer chip) from the upstream supplier. Let S denote the component supplier. Such a supply chain structure is quite common in industry.

We are interested in the OEMs' procurement strategies in such a model setting. Specifically, an important question for the OEMs to ask is: should they control or delegate their component procurement to their contract manufacturer and when? To address this question, a two-stage game among the above four players is studied: the OEMs (M1 and M2), the contract manufacturer (C), and the component supplier (S). In the first stage of the game, the OEMs choose their procurement strategy simultaneously. In particular, an OEM may choose to either control procurement of the key component or delegate it to the contract manufacturer.

The former case is referred to as "direct contracting", or D for short, since the OEM directly contracts with the component supplier, while the latter case is called "indirect contracting", or I for short, since the OEM outsources procurement to the contract manufacturer. Clearly, depending on the OEMs' decisions in the first stage, there are four possible procurement structures: {II, DD, DI, ID}, where the letters stand for the procurement strategies of the two OEMs, respectively.

For illustration, figure 1 corresponds to the II structure (indirect contracting for both M1 and M2), where both OEMs delegate component procurement to C, which means that C is responsible for procurement of the key component from S. Figure 2 represents the DD structure (direct contracting for both M1 and M2), where both OEMs contract directly with S to supply the key component to C. For brevity, we omit the pictures for procurement structures DI and ID as self-evident by-products of our discussion so far.

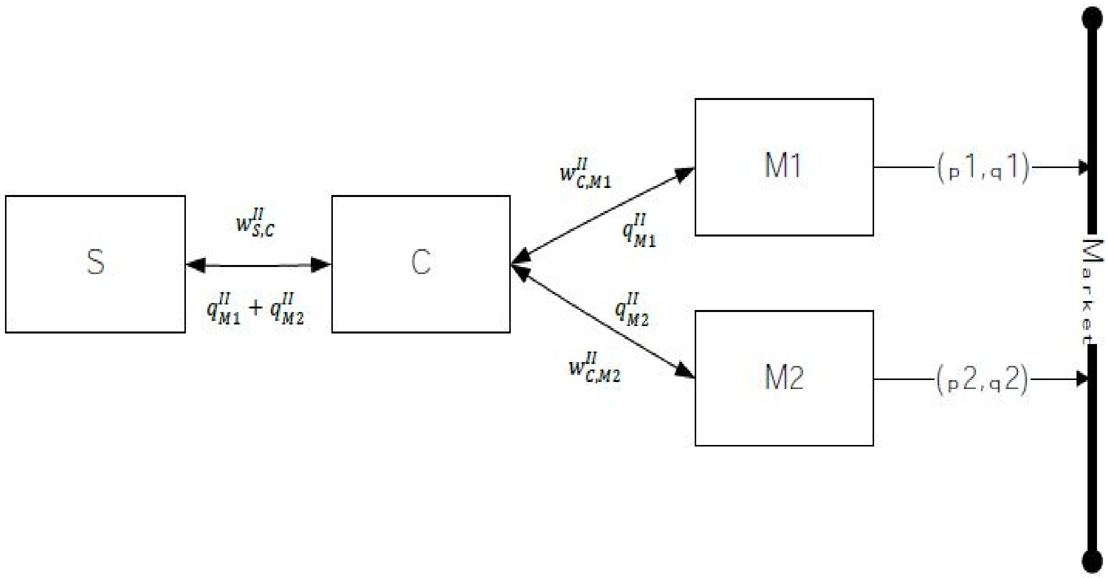

Fig. 1. II procurement structure

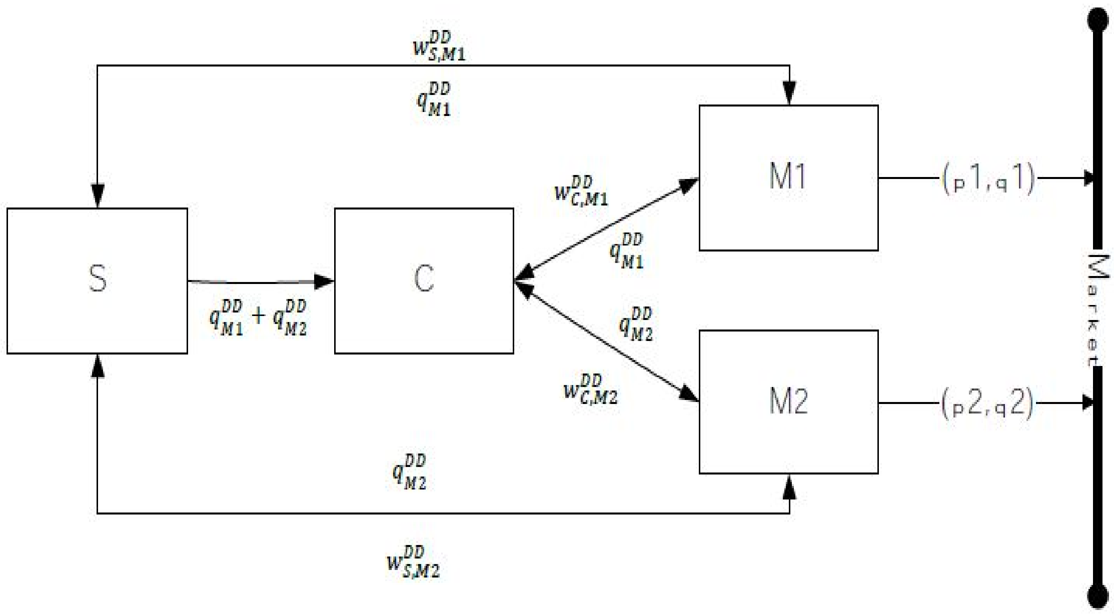

Fig. 2. DD procurement structure

After the procurement structure has been determined in the first stage, players set their prices and place their orders in the second stage of the game. The sequence of the players' decisions in the second stage depends on the bargaining power distribution. We consider two power schemes in this paper. In the first scheme, the supplier acts as the Stackelberg leader, whereas, in the second scheme, the OEMs serve as the Stackelberg leader. Although these are two extremes on the power distribution spectrum, we may derive useful insights by analyzing and comparing these extreme cases. Details of these power schemes will be introduced in the next two sections. However, first, some notations should be introduced.

Tab. 1. Notations used in this research

Notation	Denotes
$i \in \{M_1, M_2\}$	the OEMs
$j \in \{II, DD, DI, ID\}$	the procurement structures
p_i^j	the price for OEM i in the market under procurement structure j.
q_i^j	the demand for OEM i in the market under procurement structure j.
q_C^j	the order quantity from CM to Supplier under procurement structure j.
$w_{l,k}^j$	a wholesale price offered by l to k under procurement structure j: $l \in \{S, C\}$ and $k \in \{C, M_1, M_2\}$
$m_i{}^j$	The margin announced by OEM i under procurement structure j.
α	M2's market depth while M1's market depth is normalized to 1.
γ	the substitution effect of the products satisfying $0 \le \gamma \le 1$.

A linear duopoly demand function is considered as follows:

$$q_{M_1}^j = 1 - p_{M_1}^j + \gamma p_{M_2}^j \tag{1}$$

$$q_{M_1}^j = \alpha - p_{M_2}^j + \gamma p_{M_1}^j \tag{2}$$

This model has been widely used to model price competition in the market (see, e.g., [26], and [27]).

Market demand for many electronics products, such as cell phones, computers, and game consoles, can be modeled as above where each OEM's market depth is a proxy of its market power, brand image, and leadership position in the market. Thus, $\alpha > 1$ implies that M2 has a stronger position than M1 in the market, i.e., M2 enjoys a higher demand if the firms charge the same market price. All firms' production costs are normalized to zero to simplify the analysis and exposition without affecting the qualitative results. Each firm's objective is to maximize its own profit.

Throughout the paper, we focus on wholesale price arrangement between any two parties. Wholesale price contracts are commonly observed in practice because of their simplicity in format and ease of implementation. Although non-linear price contracts may reduce double marginalization and are appealing in theory, they are more complicated and less commonly used in industry (see [27], and [28], for more discussions).

As mentioned earlier, we focus on two power schemes among the players: supplier or OEMs as the Stackelberg leader. The next two sections are devoted to the equilibrium analysis for these two schemes.

4. Supplier Stackelberg

First, the supplier is the Stackelberg leader in the pricing stage of the game. For any chosen procurement structure j ∈ {II,DD,DI,ID} in the first stage, the sequence of events in the pricing stage is as follows. First, the component supplier sets a unit price for the key component; second, the contract manufacturer determines its prices for the OEMs' inputs; finally, the OEMs set their market prices and place orders at the contract manufacturer or supplier accordingly.

If an OEM chooses indirect contracting, then C gets a price quote for the key component from S and, then, offers a wholesale price to the OEM. Otherwise, the OEM directly contracts with S to source the key component, and the supplier will deliver the component directly to the contract manufacturer. In this case, the contract manufacturer charges the OEM a processing fee per unit of product.

The two-stage procurement game can be solved by backwards induction. First, we analyze the second stage of the game where the firms set their wholesale prices and order quantities.

To make sure that OEMs will survive in the market under the II structure, the following conditions are required:

$$p_{M1}^{II} \geq w_{C,M_1}{}^{II}, p_{M2}^{II} \geq w_{C,M_2}{}^{II} \;, \quad w_{C,M1}^{II} \geq w_{S,C}{}^{II}, w_{C,M2}^{II} \geq w_{S,C}{}^{II}, \quad q_{M1}^{II} \geq 0, q_{M2}^{II} \geq 0,\; w_{C,M1}^{II} \geq 0 \,. \qquad (3)$$

Using the results in Table 2, we can show that the conditions in Eq. (3) are equivalent to Assumption 1:

Assumption 1 (A1): $\boldsymbol{\alpha} \leq \frac{\gamma-6}{3\gamma-2}$ for $\boldsymbol{\gamma} \leq \frac{2}{3}$. (4)

This assumption guarantees that both firms stay in the market in equilibrium; otherwise, M2 will price M1 out of the market under the II procurement structure.

Since we are interested in the impact of competition on the firms' component procurement strategy, we use A1 to exclude the scenario where only one OEM survives under competition. Similar assumptions can be found in the literature that involves market competition in different settings (see, e.g., [25]).

Each OEM chooses its market price $\boldsymbol{p_i^j}$ and associated order quantity $\boldsymbol{q_i^j}$ to maximize its own profit. OEM i's profit under procurement structure j can be written as follows:

$$\boldsymbol{\pi_i}^{\boldsymbol{j}} = (\boldsymbol{p_i}^{\boldsymbol{j}} - \boldsymbol{w_{S,i}}^{\boldsymbol{j}} - \boldsymbol{w_{C,i}}^{\boldsymbol{j}})\boldsymbol{q_i}^{\boldsymbol{j}}; \qquad (5)$$

where $q_i{}^j$, i ∈ {M1,M2}, are given by Eq. (1) and Eq. (2). Notice that some of the wholesale prices do not exist under certain procurement structures. For instance, $w_{S,M_1}{}^j$ and $w_{S,M_2}{}^j$ do not exist under the II structure; this is because the OEMs do not contract with the component supplier directly. To simplify our notation, the non-existing prices are set to zero, i.e.,

$$\mathrm{w_{S,M_1}}^{\mathrm{II}} = \mathrm{w_{S,M_2}}^{\mathrm{II}} = \mathrm{w_{S,M_1}}^{\mathrm{ID}} = \mathrm{w_{S,M_2}}^{\mathrm{DI}} = \mathrm{w_{S,C}}^{\mathrm{DD}} = 0; \qquad (6)$$

The contract manufacturer aims to maximize its profit by quoting input prices for the OEMs. The contract manufacturer's profit under procurement structure j can be written as follows:

$$\pi_C{}^j = w_{C,M_1}{}^j q_{M_1}{}^j + w_{C,M_2}{}^j q_{M_2}{}^j - w_{S,C}{}^j q_C{}^j; \quad (7)$$

Similarly, the component supplier chooses the unit prices for the key component to maximize its profit:

$$\pi_S{}^j = w_{S,M_1}{}^j q_{M_1}{}^j + w_{S,M_2}{}^j q_{M_2}{}^j + w_{S,C}{}^j q_C{}^j; \quad (8)$$

It is worth noting that in DD, ID, and DI procurement structures, both the component supplier and the contract manufacturer can set different prices for the two OEMs. As a result, these three structures are equivalent in terms of game analysis and equilibrium outcome. This observation greatly simplifies our analysis because we need to focus on only two procurement structures: II and DD.

The second stage of the game is also solved backwards. First, we solve the optimal market prices $p_i{}^j$ for the OEMs, given the wholesale prices $\boldsymbol{w_{l,k}^j}$ charged by the upstream firms; second, we solve the contract manufacturer's optimal prices $\boldsymbol{w_{C,i}^j}$; lastly, we solve the component supplier's optimal prices $\boldsymbol{w_{S,i}^j}$. The equilibrium outcome for the second-stage game, including all firms' prices, order quantities, and profits, is given in Table 2.

Tab. 2. Equilibrium outcomes of the second-stage game (supplier Stackelberg).

Variable	$j = II$	$j = DD$
$p_{M_1}{}^j$	$\frac{26+(3-11\gamma)\gamma+\alpha(2+\gamma(23+\gamma-8\gamma^2))}{8(4-5\gamma^2+\gamma^4)}$	$\frac{14-5\gamma^2+\alpha\gamma(13-4\gamma^2)}{4(4-5\gamma^2+\gamma^4)}$

Variable	$j = II$	$j = DD$
${p_{M_2}}^j$	$\frac{2+\alpha(26+(3-11\gamma)\gamma)+\gamma(23+\gamma-8\gamma^2)}{8(4-5\gamma^2+\gamma^4)}$	$\frac{13\gamma-4\gamma^3+\alpha(14-5\gamma^2)}{4(4-5\gamma^2+\gamma^4)}$
${q_{M_1}}^j$	$\frac{6-\alpha(2-3\gamma)-\gamma}{8(4-\gamma^2)}$	$\frac{2+\alpha\gamma}{4(4-\gamma^2)}$
${q_{M_2}}^j$	$\frac{3\gamma-2-\alpha(-6+\gamma)}{8(4-\gamma^2)}$	$\frac{2\alpha+\gamma}{4(4-\gamma^2)}$
${w_{S,M_1}}^j$	0	$\frac{1+\alpha\gamma}{2(1-\gamma^2)}$
${w_{S,M_2}}^j$	0	$\frac{\alpha+\gamma}{2(1-\gamma^2)}$
${w_{C,M_1}}^j$	$\frac{5+\alpha+\gamma+5\alpha\gamma}{8-8\gamma^2}$	$\frac{1+\alpha\gamma}{4(1-\gamma^2)}$
${w_{C,M_2}}^j$	$\frac{1+5\gamma+\alpha(5+\gamma)}{8-8\gamma^2}$	$\frac{\alpha+\gamma}{4(1-\gamma^2)}$
${w_{S,C}}^j$	$\frac{1+\alpha}{4-4\gamma}$	0
${\pi_{M_1}}^j$	$\frac{(-6+\alpha(2-3\gamma)+\gamma)^2}{64(4-\gamma^2)^2}$	$\frac{(2+\alpha\gamma)^2}{16(4-\gamma^2)^2}$
${\pi_{M_2}}^j$	$\frac{(2+\alpha(-6+\gamma)-3\gamma)^2}{64(4-\gamma^2)^2}$	$\frac{(2\alpha+\gamma)^2}{16(4-\gamma^2)^2}$
${\pi_C}^j$	$\frac{10+\gamma(-9+5\gamma)-6\alpha(2+(-5+\gamma)\gamma)+\alpha^2(10+\gamma(-9+5\gamma))}{32(4-5\gamma^2+\gamma^4)}$	$\frac{2+6\alpha\gamma+\gamma^2+\alpha^2(\gamma^2+2)}{16(4-5\gamma^2+\gamma^4)}$
${\pi_S}^j$	$\frac{(1+\alpha)^2}{16(2-\gamma)(1-\gamma)}$	$\frac{2+6\alpha\gamma+\gamma^2+\alpha^2(\gamma^2+2)}{8(4-5\gamma^2+\gamma^4)}$

Based on Table 2, we may conduct comparative statistical analysis of the firms' equilibrium decisions. For instance, under the II procurement structure, M2's order quantity ${q_{M_2}}^{II}$ increases in α, meaning that a deeper market would allow M2 to sell more in the market. However, M1's order quantity may behave differently: $\boldsymbol{{q_{M_1}}^{II}}$ can either increase or decrease in α. As α increases, the component supplier will increase its wholesale price ${w_{S,C}}^{II}$, resulting in a higher procurement cost for both OEMs. Despite the higher procurement cost, it is still optimal for M2 to increase its market price and order more due to the deeper market (larger α). From M1's perspective, any increase in α will lead to a higher procurement cost and a higher market price set by its competitor, simultaneously.

Clearly, the former change would reduce the M1's order quantity, while the latter change would increase M1's demand. It appears that for sufficiently differentiated products ($\gamma < \frac{2}{3}$), the effect of higher procurement cost dominates the effect of higher demand, which results in a lower order quantity for M1. On the other hand, for highly substitutable products ($\gamma > \frac{2}{3}$), the effect of higher demand dominates the effect of higher procurement cost; thus, M1's order quantity increases in α. In contrast, under the DD procurement structure, both OEMs increase their order quantities as α increases. This is because under the DD structure, the supplier is able to customize its prices for the OEMs, whereas it finds it optimal to set its prices such that both M1 and M2 increase their orders.

Table 2 also enables us to compare the firms' performances across different procurement structures, helping to characterize the equilibrium in the two-stage procurement game. The following proposition summarizes the main findings from this comparison.

Propostion 1. The following relationships hold under the supplier Stackelberg scheme:

i. ${p_{M_1}}^{II} \geq {p_{M_1}}^{DD}$ *and* ${p_{M_2}}^{II} \leq {p_{M_2}}^{DD}$*; M1 charges a higher market price in II, while M2 charges a higher market price in DD.*

ii. ${q_{M_1}}^{DD} + {q_{M_2}}^{DD} = {q_{M_1}}^{II} + {q_{M_2}}^{II}$ *; the total production quantity is independent of the procurement structure chosen by the OEMs.*

iii. ${\pi_{M_1}}^{DD} \geq {\pi_{M_1}}^{II}$ *and* ${\pi_{M_2}}^{DD} \leq {\pi_{M_2}}^{II}$*; M1 earns a higher profit in DD, while M2 earns a higher profit in II.*

iv. ${\pi_C}^{DD} \leq {\pi_C}^{II}$*; the contract manufacturer makes a higher profit in II.*

v. ${\pi_S}^{DD} \geq {\pi_S}^{II}$ *; the component supplier makes a higher profit in DD.*

vi. ${\pi_C}^{DD} + {\pi_S}^{DD} \leq {\pi_C}^{II} + {\pi_S}^{II}$*; the Supply chain profit is higher in II.*

vii. *If α = 1, then all firms' profits would be the same in DD and II.*

Proposition 1 offers useful insights into the firms' preferences over different procurement structures. From Proposition 1(iii), we know that the smaller OEM (M1) prefers direct procurement (DD), whereas the larger OEM (M2) prefers indirect procurement (II). One must also recall that procurement structures DD and DI yield the same equilibrium outcomes. Therefore, the smaller OEM (M1) would deviate from the II structure to contract with the component supplier, while the larger one would not unilaterally move away from the II structure. To better understand what drives M1 to contract directly with S, one needs to notice that the total procurement costs for M1 and M2 would decrease and increase, respectively, if at least one of the OEMs directly contracts with the supplier:

$$ {w_{S,M_1}}^{j} + {w_{C,M_1}}^{j} < {w_{C,M_1}}^{\mathrm{II}} \quad \& \quad {w_{S,M_2}}^{j} + {w_{C,M_2}}^{j} > {w_{C,M_2}}^{\mathrm{II}} \; j \in \{DD, DI, ID\} \qquad (9) $$

If M1 contracts directly with S, the supplier would have the opportunity to customize its price for each of the OEMs. In particular, the component supplier decreases its component price for M1, while it increases its price for M2; this is because M2 has a deeper market. This benefits M1 by reducing its procurement cost, while it increases M2's procurement cost at the same time. A higher procurement cost drives up M2's market price, which in turn also increases M1's market demand.

Moreover, notice that the component supplier's profit is higher under the DD procurement structure since it has the opportunity to price discriminate its final customers (the OEMs) based on their demand characteristics. Unlike S, the contract manufacturer's profit would decrease if any of the OEMs deviates from the II procurement structure. In fact, the II structure is more profitable than any of the other procurement structures for the contract manufacturer. This is because, under the II structure, it is the contract manufacturer, rather than the component supplier, which is able to better customize its prices for the OEMs.

Now, we are in a position to present the equilibrium outcome of the procurement game between the two OEMs.

Propostion 2. Under the supplier Stackelberg scheme, if α > 1, then M1 always prefers direct contracting and given M1's choice, M2 would be indifferent between direct and indirect contracting, i.e., both DD and DI are equilibria of the procurement game. If α = 1, then both OEMs are indifferent among the procurement structures, i.e., any procurement structure is an equilibrium of the procurement game.

In a symmetric case with α = 1, both of the OEMs are indifferent among all procurement structures. In other words, no OEM would strictly prefer to deviate from any procurement structure. In contrast, in an asymmetric case with α > 1, the smaller OEM (M1) prefers to directly contract with S to procure its component. Such a preference is in line with the component supplier's incentive to separate its component prices for the OEMs. In particular, given its dominant market power, the supplier would charge a lower price to the smaller OEM, but a higher price to the larger one. This increase in component price for the larger OEM can be implemented through higher prices for components sold to C or higher direct procurement prices for the larger OEM.

The above finding indicates that an OEM may prefer to directly contract with the component supplier if it has a relatively small market share. This seems to corroborate with some practical examples. As mentioned earlier, Motorola changed its procurement strategy from delegation to direct procuring, which occurred at a time when Motorola's market share started to shrink ([30] and [31]). Not surprisingly, we find that the contract manufacturer's profit will be squeezed as more OEMs wish to gain the control of their component procurement. Pick (2004) mentioned that the Electronics Manufacturing Services (EMS) providers, which are equivalent to the contract manufacturer in our model, can generate significant profits by capturing the purchase-price variance resulting from the acquisition and sale of components; however, a number of large OEMs are institutionalizing component procurement control to minimize or eliminate the purchase-price variance [32]. As a result, the EMS providers have lost a significant portion of their value-added from procurement.

It is noteworthy that substitution parameter γ, which measures the level of product competition, does not have any effect on the OEM's optimal choice of procurement structure. Instead, it is the difference in the market depth (i.e., α > 1) that motivates the OEMs to choose different procurement strategies. This observation indicates that product substitutability is not the driving force behind the new practice of procurement control. The key driving force is that the component suppliers may offer discounts to the OEMs with shrinking market size to better customize their prices for prospering OEMs.

As Proposition 2 asserts, the smaller OEM prefers to contract directly with S in an asymmetric market depth scenario. However, direct contracting might impose additional costs, such as negotiation, administration, and monitoring, on the OEMs. Thus, there is a trade-off between the costs and benefits of direct contracting. Instead of explicitly modeling these costs, we try to shed some light on the value of procurement control in our model. $\frac{\pi_{M_1}{}^{\mathrm{DD}}-\pi_{M_1}{}^{\mathrm{II}}}{\pi_{M_1}{}^{\mathrm{II}}}$ is defined as the value of procurement control for M1. The following proposition characterizes the effect of the degree of product substitutability (γ) and competitor's market depth (α) on the value of procurement control for M1.

Propostion 3. Under the supplier Stackelberg scheme, the value of procurement control for M1 increases in α, but decreases in γ.

Under the II procurement structure, the supplier cannot charge the OEMs differentiated prices; therefore, as α increases, the increase in component price will have similar impacts on both OEMs. However, under the DD structure, as α increases, the supplier would charge more differentiated prices to the OEMs because M2 will be capable of taking higher component prices. As a result, the smaller OEM will find it more attractive to deviate from II to DD. On the contrary, as γ increases, both OEMs will enjoy higher potential market demands (all else being equal, more substitutability implies higher demand for each OEM). Thus, the supplier has less incentive to offer a large discount to the deviating OEM. This decreases the value of enforceability for M1.

5. OEM Stackelberg

We now proceed to study the second power scheme, where the OEMs take the leadership position in the second stage of the procurement game. Such a contracting scheme occurs when the OEMs have relatively stronger bargaining power than the rest of the supply chain. For instance, as the smartphone market expands rapidly, leading OEMs, such as Apple and Nokia, have obtained significant bargaining power against their contract manufacturers and component suppliers. See, for example, [23] and [14] in which similar contracting schemes are studied. Recall that, in the first stage of the game, each OEM determines its procurement strategy (i.e., whether to directly contract with S or delegate component procurement to C); thus, again, there are four possible procurement structures: {DD, II,DI, ID}. Figure 1 and Figure 2 display two of these procurement structures, II and DD, that are the focus of our analysis. In the second stage, firms decide on their prices and order quantities under the chosen procurement structure in the first stage. The sequence of events under the OEM Stackelberg is as follows: first, the OEMs announce their margins for their products, ${m_{M_1}}^j$ and ${m_{M_2}}^j$, j ∈ {DD, II, DI, ID}; second, the component supplier posts its unit prices; lastly, the contract manufacturer sets its prices for the OEMs' products. Unlike the supplier Stackelberg scheme, now it is the contract manufacturer who determines the order quantities for both products because it is the last firm that sets its prices.

The notation remains largely unchanged from the previous section. Under procurement structure j, OEM i chooses optimal margin m_i^j to maximize its profit:

$$\pi_i^j = m_i^j q_i^j; \quad (10)$$

where the order quantity for each product is given by:

$$q_{M_1}{}^j = 1 - (w_{S,M_1}{}^j + w_{C,M_1}{}^j + m_{M_1}{}^j) + \gamma(w_{S,M_2}{}^j + w_{C,M_2}{}^j + m_{M_2}{}^j); \quad (11)$$

$$q_{M_2}{}^j = \alpha - (w_{S,M_2}{}^j + w_{C,M_2}{}^j + m_{M_2}{}^j) + \gamma(w_{S,M_1}{}^j + w_{C,M_1}{}^j + m_{M_1}{}^j); \quad (4)$$

Similar to the previous section, we define:

$$w_{S,M_1}{}^{\text{II}} = w_{S,M_2}{}^{\text{II}} = w_{S,M_1}{}^{\text{ID}} = w_{S,M_2}{}^{\text{DI}} = w_{S,C}{}^{\text{DD}} = 0; \quad (5)$$

since these wholesale prices do not really exist. The contract manufacturer and component supplier aim to maximize their profits given by Eqs. 7 and 8, respectively. Before presenting the game analysis, again, the following assumption under the OEM Stackelberg scheme is introduced.

Assumption 2 (A2): $\alpha \frac{17+3\gamma}{3-7\gamma}$; for $\gamma \leq \frac{3}{7}$ (6)

The reason behind this assumption is similar to that of Assumption A1. It is straightforward to verify that A2 is a weaker condition than A1, i.e., any pair (α, γ) that satisfies A1 would also satisfy A2. This implies that as the OEMs gain more bargaining power in the supply chain, the region where one OEM price discriminates the other one out of the market shrinks.

Analogous to the supplier Stackelberg, we observe that under the OEM Stackelberg scheme, the equilibrium outcomes will be the same under DD, DI, and ID procurement structures. As a result, we focus on the DD and II structures in the subsequent analysis. Closed-form solutions for the firms' prices, order quantities, and profits in equilibrium are derived and presented in Table 3..

Tab. 3. Equilibrium outcomes of the second-stage game (OEM Stackelberg).

Variable	$j = II$	$j = DD$
$m_{M_1}{}^j$	$\frac{17-3(\alpha-\gamma)+7\alpha\gamma}{35+18\gamma-5\gamma^2}$	$\frac{2+\alpha\gamma}{4-\gamma^2}$
$m_{M_2}{}^j$	$\frac{17\alpha-3(1-\alpha\gamma)+7\gamma}{35+18\gamma-5\gamma^2}$	$\frac{2\alpha+\gamma}{4-\gamma^2}$
$q_{M_1}{}^j$	$\frac{(3+\gamma)(17+3\gamma+\alpha(7\gamma-3))}{8(5-\gamma)(7+5\gamma)}$	$\frac{2+\alpha\gamma}{4(4-\gamma^2)}$
$q_{M_2}{}^j$	$\frac{(3+\gamma)(7\gamma-3+\alpha(17+3\gamma))}{8(5-\gamma)(7+5\gamma)}$	$\frac{2\alpha+\gamma}{4(4-\gamma^2)}$
$w_{S,M_1}{}^j$	0	$\frac{2+3\alpha\gamma+\gamma^2}{2(4-5\gamma^2+\gamma^4)}$
$w_{S,M_2}{}^j$	0	$\frac{2\alpha+3\gamma+\alpha\gamma^2}{2(4-5\gamma^2+\gamma^4)}$
$w_{C,M_1}{}^j$	$\frac{1}{8}(\frac{6(1+\alpha)}{\gamma-5}-\frac{3(1+\alpha)}{\gamma-1}+\frac{2(1-\alpha)}{\gamma+1}-\frac{8(1-\alpha)}{5\gamma+7})$	$\frac{2+3\alpha\gamma+\gamma^2}{4(4-5\gamma^2+\gamma^4)}$
$w_{C,M_2}{}^j$	$\frac{1}{8}(\frac{6(1+\alpha)}{\gamma-5}-\frac{3(1+\alpha)}{\gamma-1}-\frac{2(1-\alpha)}{\gamma+1}+\frac{8(1-\alpha)}{5\gamma+7})$	$\frac{2\alpha+3\gamma+\alpha\gamma^2}{4(4-5\gamma^2+\gamma^4)}$

Variable	$j = II$	$j = DD$
${w_{S,C}}^j$	$\frac{1}{4}(\frac{1+\alpha}{1-\gamma}+\frac{2(1+\alpha)}{\gamma-5})$	0
${\pi_{M_1}}^j$	$\frac{(3+\gamma)(17+3\gamma+\alpha(7\gamma-3))^2}{8(5-\gamma)^2(7+5\gamma)^2}$	$\frac{(2+\alpha\gamma)^2}{4(4-\gamma^2)^2}$
${\pi_{M_2}}^j$	$\frac{(3+\gamma)(7\gamma-3+\alpha(17+3\gamma))^2}{8(5-\gamma)^2(7+5\gamma)^2}$	$\frac{(2\alpha+\gamma)^2}{4(4-\gamma^2)^2}$
${\pi_C}^j$	$\frac{(3+\gamma)^2}{32(5-\gamma)^2(7+5\gamma)^2(1-\gamma^2)}(149-102\alpha + 149\alpha^2 - 7\gamma(3+\alpha(3\alpha-74)) + \gamma^2(139+\alpha(102+139\alpha)) + \gamma^3(7+3\alpha)(3+7\alpha))$	$\frac{4+5\gamma^2+2\alpha\gamma(8+\gamma^2)+\alpha^2(4+5\gamma^2)}{16(4-\gamma)^2(1-\gamma^2)}$
${\pi_S}^j$	$\frac{(1+\alpha)^2(3+\gamma)^2}{16(5-\gamma)^2(1-\gamma)}$	$\frac{4+5\gamma^2+2\alpha\gamma(8+\gamma^2)+\alpha^2(4+5\gamma^2)}{8(4-\gamma)^2(1-\gamma^2)}$

Based on this table, comparative statistical analysis of the firms' equilibrium decisions may be conducted. It is not difficult to check that M2's order quantity increases in α under both II and DD procurement structures. However, M1's order quantity may either increase or decrease in α under the II procurement structure. In particular, M1's order quantity decreases in α when γ is low enough ($\gamma < \frac{3}{7}$). This result is similar to the one observed under the supplier Stackelberg. Nevertheless, it is interesting to notice that the two thresholds on γ for which the M1's order quantity is decreasing in α are different: $\gamma < \frac{2}{3}$ under the supplier Stackelberg vs. $\gamma < \frac{3}{7}$ under the OEM Stackelberg. Therefore, if M1's order quantity increases in α under the supplier Stackelberg, it would also increase in α under the OEM Stackelberg, yet not vice versa.

The next proposition summarizes the main findings from the comparison between the two procurement structures, namely II and DD. Define

$$\boldsymbol{\Delta = 2(\gamma-5)^2(7+5\gamma)^2(2\alpha+\gamma)^2 - (3+\gamma)(\gamma^2-4)^2(7\gamma-3+\alpha(17+3\gamma))^2}; \quad (7)$$

Propostion 4. The following relationships hold under the OEM Stackelberg scheme:

${m_i}^{DD} \geq {m_i}^{II}$; *i.e., the OEMs set higher margins in DD than in II.*

i. ${q_{M_1}}^{DD} + {q_{M_2}}^{DD} \leq {q_{M_1}}^{II} + {q_{M_2}}^{II}$; *i.e., the total production quantity is higher in II than in DD..*

ii. ${\pi_{M_1}}^{DD} \geq {\pi_{M_1}}^{II}$; *i.e., M1 prefers DD to II.*

iii. ${\pi_{M_2}}^{DD} > {\pi_{M_2}}^{II}$; *i.e., M2 prefers DD if and only if Δ>0.*

iv. ${\pi_C}^{DD} \leq {\pi_C}^{II}$; *i.e., the contract manufacturer prefers II to DD.*

v. ${\pi_S}^{DD} \leq {\pi_S}^{II}$; *i.e., the component supplier prefers II to DD.*

vi. ${\pi_C}^{DD} + {\pi_S}^{DD} \leq {\pi_C}^{II} + {\pi_S}^{II}$; *i.e., the Supply chain profit is higher in II.*

We know that the three structures DD, DI, and ID yield the same equilibrium outcome. Thus, Proposition 4 (i) indicates that if one of the OEMs deviates from II, then both OEMs will increase their margins to ${m_i}^{DD}$. Note that the supplier quotes a single price to the contract manufacturer under the II structure; however, under the DD structure, it negotiates with the OEMs separately. As a result, the OEMs can charge higher margins since their market power allows them to squeeze the supplier's margin more than their contract manufacturer is able to. However, from Proposition 4 (iv), asking for higher margins does not necessarily lead to higher profits for the OEMs since it also decreases total production quantity (see

Proposition 4 (ii)). Proposition 4 (iii) shows that the smaller firm, M1, always prefers to directly contract with S; in contrast, Proposition 4 (iv) indicates that even though M2 enjoys a higher margin under the DD structure, the reduction in production quantity can be so significant that (γ, α) must satisfy $\Delta \geq 0$ to make M2 better off in DD. The graph in Figure 3 illustrates three regions: $\Delta \geq 0$, $\Delta \leq 0$, and a non-feasible region under which A2 is violated.

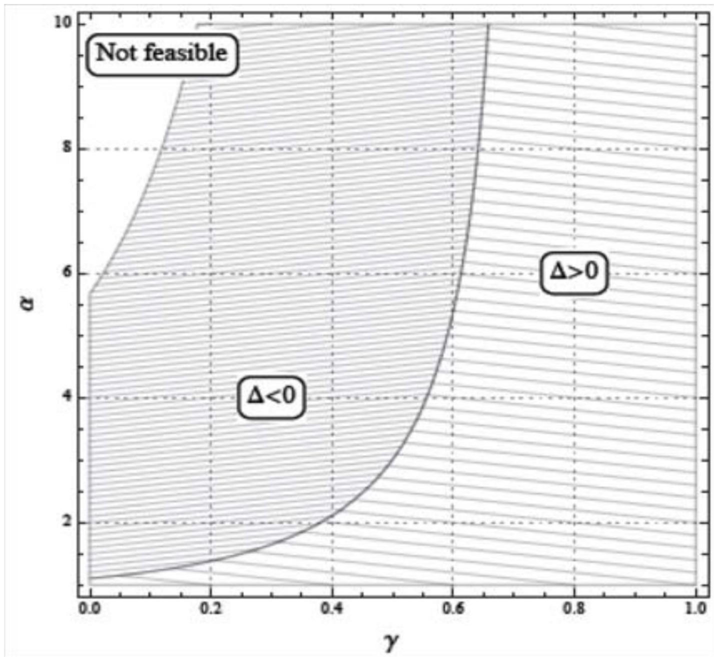

Fig. 3. The sign of Δ on the (γ, α) plane (when $\Delta \geq 0$, both OEMs prefer DD)

To see why direct contracting may benefit M2 under the region $\Delta > 0$, consider a given α. From Table 3, we can see that under the DD structure, both OEMs' margins (m_i^{DD}) are increasing in γ; moreover, the OEMs' profits (π_i^{DD}) are also increasing in γ. This is because, all else being equal, the OEMs will enjoy higher demand when the products are more substitutable. In contrast, under the II structure, $\pi_{M_2}^{II}$ may be decreasing in γ. Therefore, for large enough γ (i.e., the $\Delta > 0$ region), if M2 directly contracts with S, it can increase its margin and profit significantly, which outweighs its loss due to a higher customized component price set by the supplier. Then, a given γ is considered. For a fixed γ that is relatively small, Figure 3 indicates that $\Delta > 0$ only if α is low. This is because for a large α, the supplier can charge more differentiated component prices to the OEMs, which is not in favor of M2. Therefore, M2 can benefit from direct contracting only when α is low enough.

The contract manufacturer prefers to procure the component for both OEMs since any deviation from II by the OEMs decreases its profit. Direct contracting enables the OEMs to increase their margins, which reduces potential margins for the contract manufacturer. Proposition 4 (vi) indicates that, unlike that in the supplier Stackelberg, the component supplier prefers the II structure. There are two forces that work in opposite directions to determine the impact of direct contracting on the supplier. On the one hand, it could increase the supplier's profit since it provides an opportunity for S to customize its prices based on the OEMs' demand functions; on the other hand, OEMs are in an advantageous position to squeeze the supplier's margin when they contract directly with the supplier. Our analysis shows that the adverse effect of direct contracting outweighs the benefit of price differentiation. That is, interestingly, the supplier gets worse off when it has more flexibility in pricing (i.e., it can price differentiate the OEMs).

Next, the sub-game perfect equilibrium is characterized for the procurement game.

Propostion 5. Under the OEM Stackelberg scheme, M1 always prefers direct contracting and M2 prefers direct contracting only when $\Delta > 0$. Given M1's direct contracting choice, M2 is indifferent between direct and indirect contracting. Therefore, both DD and DI are equilibria of the procurement game.

As we mentioned earlier, procurement structures DI and DD are equivalent. Therefore, if M1 chooses to directly contract with the supplier, then M2 would be indifferent between direct and indirect contracting. However, if, for some reason, M1 chooses to delegate the procurement function to C, then M2 may unilaterally use direct contracting when $\Delta > 0$. This implies that when OEMs have strong bargaining power, it is possible that the larger OEM will deviate first from delegation to control its component procurement, which will never happen under the supplier Stackelberg scheme.

As in the supplier Stackelberg scheme, market depth (α) plays a crucial role in motivating the OEMs to control their component procurement, and it is the smaller OEM that always benefits from procurement control. However, unlike before, product substitutability also plays a significant role in the OEMs' preference for their procurement structure. If products are close substitutes (large γ), then both OEMs would benefit from direct contracting. Therefore, as Figure 3 demonstrates, even in a symmetric case where the OEMs' market depths are equal ($\alpha = 1$), both OEMs would prefer direct contracting under the OEMs Stackelberg, whereas under the supplier Stackelberg, all firms are indifferent between direct and indirect contracting.

Lastly, the effect of α and γ on the value of procurement control under the OEM Stackelberg scheme is examined.

Propostion 6. Under the OEM Stackelberg scheme, the value of procurement control for M1 increases in α; however, that is not always true for γ

The intuition behind the result about α is the same as in proposition 3; however, the result about γ is more involved. Proposition 6 demonstrates that the value of procurement control may either increase or decrease in γ. Figure 4 illustrates such a result. Over region $\Delta 1$, where the products are highly substitutable, the value of procurement control increases in γ; over region $\Delta 2$, where the products are more differentiated or market depths are quite different, the value of procurement control decreases in γ. Unlike the supplier Stackelberg, here the value of procurement control can increase in γ. This is because under the OEM Stackelberg, the OEMs take the initiative to set their margins, and for a given α, as γ increases, they can ask for higher margins when they directly contract with S. Recall that, in contrast, under the supplier Stackelberg, the supplier moves first and has less incentive to offer a low discount to the deviating OEM as γ gets larger.

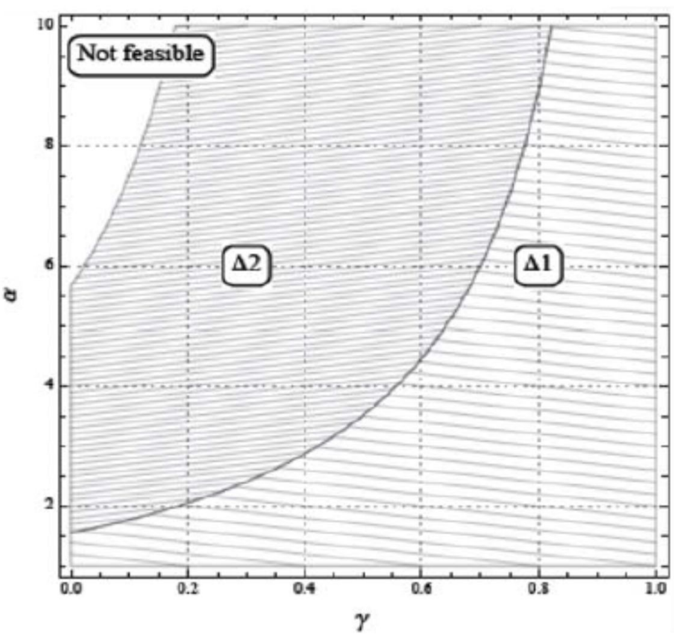

Fig. 4. The value of procurement control increases in γ over $\Delta 1$ but decreases in γ over $\Delta 2$.

6. Comparison of Two Schemes

We have analyzed the procurement game under the supplier and OEM Stackelberg schemes in the previous two sections. Now, our findings are compared. There are several findings that are worth highlighting regarding the firms' preferences over the procurement structures.

First, under both Stackelberg schemes, the smaller OEM prefers direct contracting to indirect contracting. As a result, the II structure, where both OEMs delegate their procurement functions, is generally not a sub-game perfect equilibrium. The only exception is under the supplier Stackelberg scheme with symmetric OEMs (i.e., $\alpha = 1$); in that case, the OEMs are indifferent among the procurement structures so that both II and DD are sub-game perfect equilibria. More interestingly, we have shown that the shift of bargaining power from the supplier to the OEMs will provide more incentives for direct contracting. For the smaller OEM (M1), it strictly prefers direct contracting even when $\alpha = 1$ under the OEM Stackelberg scheme (it is indifferent under the supplier Stackelberg scheme). For the larger OEM (M2), it strictly prefers direct contracting under the condition $\Delta > 0$ in the OEM Stackelberg scheme, while it never prefers direct contracting under the supplier Stackelberg scheme. In addition, the condition $\Delta > 0$ is more likely to hold as γ increases and α decreases. Why would the larger OEM (M2) have more incentive to use direct contracting under the OEM Stackelberg? Note that shifting from indirect contracting to direct contracting has two effects on M2. On the one hand, direct contracting gives the supplier the opportunity to raise the component price for M2, which hurts M2 but helps M1; on the other hand, under the OEM Stackelberg, by direct contracting, M2 can set a higher margin first to extract more surplus from the supply chain, which benefits M2 (such a beneficial effect does not exist under the supplier Stackelberg). It has been shown in the previous section that the latter effect is stronger for larger γ values, while the former effect is stronger for larger α values. Overall, M2 may prefer direct contracting if the second effect dominates, which is more likely to happen as γ increases and α decreases.

The above theoretical results suggest that as the OEMs grow to be more powerful and the products become more substitutable, we would expect to see more firms trying to control their component procurement. In recent years, it has been reported that more and more OEMs and retailers with significant market power (e.g., Boeing, HP, Motorola) have shifted to the practice of procurement control for their first-tier suppliers [4]. These industry anecdotes seem to be in line with our findings.

The component supplier prefers the DD structure under the supplier Stackelberg, whereas it prefers the II structure under the OEM Stackelberg. In the DD structure, the supplier benefits from its ability to customize its prices only if it is the Stackelberg leader. When the OEMs act as the Stackelberg leader, they significantly squeeze the supplier's surplus by setting higher margins. Therefore, the ability of price customization is detrimental to the supplier under the OEM Stackelberg. This indicates that the component supplier may wish to avoid direct contracting when it has relatively weak bargaining power.

The contract manufacturer always prefers the II structure to the DD, regardless of the contracting regime in place. By procuring directly from the supplier, OEMs only need to pay for processing their components (rather than for procurement services). Not surprisingly, any deviation from delegation to direct contracting will hurt the contract manufacturer's profit. In fact, it has been estimated that, in the electronics industry, the EMS providers may suffer from margin losses ranging from 4% to 8% due to the lost value-added from performing procurement services for the OEMs [32]. Driven by such a pressure, many EMS providers have strived to offer more design services on top of manufacturing services to the OEMs.

Based on the equilibrium analysis in the previous sections, we may also investigate the effect of bargaining power shift on the supply chain performance and consumer welfare. The result is given in the next proposition.

Propostion 7. In the sub-game perfect equilibrium, the market prices and supplies of the products are the same under the two Stackelberg schemes.

It is interesting that a shift in the contracting power does not affect each product's market price and supply in equilibrium. Although the OEMs will increase their margins under the OEM Stackelberg, the component supplier and contract manufacturer, who eventually determine each product's market price and supply by setting their prices, find it optimal to keep the supply and price of each product the same as that under the supplier Stackelberg. As a result, the total supply chain profit is independent of the Stackelberg scheme in place; only the profit distribution among the supply chain firms would be affected by the contracting power distribution. This implies that the consumer welfare will not be affected by these changes, either. To better understand this finding, notice that the structure of the sub-game perfect equilibrium of the procurement game is independent of the type of Stackelberg scheme in place; the smaller firm prefers to control its component procurement, whereas the larger firm is indifferent between delegation and control of its component procurement, given that the smaller firm controls its component procurement. The only difference between these two schemes in equilibrium is the order in which firms claim their margins. This proposition shows that this order does not affect order quantities and market prices; therefore, it does not affect consumer welfare.

7. Conclusion

This paper studies the optimal component procurement strategies of two competing OEMs in a three-tier supply chain. Because of insufficient internal resources, the OEMs depend on a contract manufacturer to process an important input, which in turn requires a component from a supplier. The OEMs can choose either to delegate component procurement to the contract manufacturer or to procure directly from the supplier. We analyze the OEMs' equilibrium strategies under two contracting power schemes: supplier Stackelberg where the supplier sets its prices first, and OEM Stackelberg where the OEMs move first to set their margins.

Under the supplier Stackelberg, we find that the OEM with a smaller market size prefers to directly contract with the supplier, whereas the larger OEM prefers to delegate its procurement function (Table 2). Under the OEM Stackelberg, the smaller OEM's preference remains the same; however, the larger OEM may also prefer to control its procurement function. Specifically, the larger OEM prefers direct contracting when the products are sufficiently substitutable (Table 3). These findings reveal two driving forces underlying the recent industry trend of direct contracting. First, by using direct contracting, a smaller OEM may obtain a lower customized price from the supplier. Second, as market power shifts from the upstream to the downstream firms, direct contracting will become a more attractive strategy for the OEMs since it allows them to extract more surpluses from the supply chain.

We also investigate the supply chain performance and social welfare under the above two contracting schemes. Interestingly, it is found that the equilibrium market price and, thus, the supply of the products are exactly the same under both schemes (Tables 2 and 3). In other words, both the supply chain performance and consumer surplus will not be affected by the shift of contracting power between the supplier and the OEMs.

Finally, of note, this investigation and the results are based on a "Bertrand demand function" that models competition between two supply chains. Using a "Cournot demand function" instead may be an interesting future research.

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