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Direct Sourcing or Agent Sourcing? Contract Negotiation in Procurement Outsourcing

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Problem definition: In a supply network consisting of a buyer (she), a purchasing agent (he), and a supplier, the buyer can procure the component from the supplier directly and rely on the purchasing agent for complementary services (named direct sourcing ($\mathcal{DS}$)) or authorize the purchasing agent to conduct both procurement and complementary services (named agent sourcing ($\mathcal{AS}$)). When parties bargain pairwisely, how do their bargaining powers influence the equilibrium procurement outsourcing structure?
Academic/Practical Relevance: Both outsourcing structures, $\mathcal{DS}$ and $\mathcal{AS}$, are commonly observed in practice, whereas the literature has rarely answered the questions that we ask.
Methodology: We adopt the generalized Nash bargaining framework to model the negotiations among the parties and derive the corresponding equilibrium outcomes under both outsourcing structures by taking into consideration the existence of a component spot market.
Results: When two parties negotiate directly, we define their *direct negotiation coefficient* as the ratio of their exogenous bilateral relative bargaining powers. If they negotiate indirectly through a third party, we define their *indirect negotiation coefficient* as the quotient of their respective direct negotiation coefficients with respect to the third party. We show that when parties negotiate over both wholesale prices and quantities, the buyer's preference for $\mathcal{DS}$ and $\mathcal{AS}$ solely depends on the comparison result of her direct negotiation coefficient versus the indirect one with respect to the supplier. When the quantity is determined by the buyer and parties negotiate over wholesale prices, the equilibrium outsourcing structure hinges critically upon the magnitude of the purchasing agent's relative bargaining power over the supplier. Interestingly, the preferences of the three parties for $\mathcal{DS}$ and $\mathcal{AS}$ may be aligned with each other. We also show that it is in the best interest of the buyer to negotiate prices only.
Managerial Implications: Our research identifies the endogenous bargaining powers among parties that dictate the equilibrium outsourcing structure. It indicates that the buyer needs to adjust her procurement outsourcing decision accordingly when the bargaining powers of her upstream partners are altered, especially when the buyer's bargaining power is sufficiently large: we analytically show that the buyer's preference is very *sensitive* to the relative bargaining powers of the purchasing agent and the supplier. This might help explain why Walmart switched from $\mathcal{AS}$ with Li & Fung to $\mathcal{DS}$ within just three years.

Keywords: Procurement Outsourcing; Purchasing Agent; Direct Sourcing; Negotiation.

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1 Introduction

This paper concerns material/goods procurement outsourcing. The procurement function is of strategic importance to firms because the purchased materials/goods account for a large percentage of the total supply chain cost (Ellram 2002, Mishra et al. 2013). As globalization increases and information technology advances, firms can now access ever larger supply bases to acquire materials for better cost and quality. At the same time, however, due to longer geographic distances and larger supply networks with different geopolitical environments, the procurement process can be very complex and time-consuming. As a result, an increasing number of firms outsource material procurement activities to purchasing agents such as Accenture, Global Sources, and ICG Commerce (Rast et al. 2014).

For example, Walmart once relied on Li & Fung, a Hong-Kong-based purchasing agent, for full procurement services. However, in 2015, Walmart terminated procurement contracts with Li & Fung, although it was still using Li & Fung's services, such as quality inspection/control (Chu 2012a, Layne 2015). The question then arises: when should a buyer outsource the entire procurement function, and when should she only outsource some part of that function? This paper explores this issue.

1.1 Supply Chain Setting

We consider a three-player supply chain consisting of a buyer (she), a purchasing agent (he), and a supplier. A unit of the buyer's final product requires both a unit of a component procured from the supplier and a unit of complementary service such as quality inspection and logistics provided by the purchasing agent. There may exist a *spot market* for the component provided by the supplier, which is common for certain raw materials or electronic components. Since the purchasing agent and the supplier must invest in specific resources/capacities such as special equipment, business relationships, raw materials, and worker training before the demand can be observed, such a spot market does not exist for the complementary services that the purchasing agent provides. We assume a single selling season for the final product with random demand. The procurement decision has to be made before observing the demand realization. This setting is suitable for products that are innovative, fashionable, and fast-changing and that have a short sales season, such as fashion apparel, toys, agricultural products, daily goods, influenza vaccines, consumer electronics, and personal computers.

We compare two procurement outsourcing structures. One is *direct sourcing* ($\mathcal{DS}$), under which the buyer retains the purchasing function in-house but relies on the purchasing agent for complementary services. The other is *agent sourcing* ($\mathcal{AS}$), under which the purchasing agent is responsible for both product procurement and complementary services and offers a "one-stop shopping contract" (Sodhi and Tang 2013). Admittedly, numerous factors can affect a firm's procurement outsourcing decision, including supplier relationships, investment budget, lead time, and economies of scale. Here, we do not aim to provide a comprehensive analysis of all of these factors. Instead, we focus on how *contract negotiation* affects the buyer's procurement outsourcing decisions. We choose this factor because empirical studies find that a buyer's bargaining capability is critical in her strategic decision of procurement outsourcing (Amaral et al. 2006, Tsay 2014), and the buyer tends to outsource the procurement function if she has a weak procurement capability (e.g., negotiation skills) (Brewer 2006).

Under both $\mathcal{DS}$ and $\mathcal{AS}$, there exist two bilateral contract negotiations among the three parties. We adopt the generalized Nash bargaining (GNB) framework to model the two bilateral negotiations. This choice of approach stems from the popular negotiation practice being observed in the real world. For example, contracts for agricultural products are usually negotiated (Helmberger and Hoos 1963). The daily goods that Walmart procures (either independently or by relying on Li & Fung) are also delivered based on prenegotiated contracts (Chu 2012b). Compared to the single bilateral negotiation in a two-player supply chain, which is typically assumed in the existing literature, our three-player two bilateral negotiation problem exhibits the following unique endogenous feature: the negotiated terms in one of the bilateral bargaining problems will be influenced by those from the other bilateral bargaining problem. In our context, the professional service provided by the purchasing agent and the component provided by the supplier are eventually assembled into one end product for sale, resulting in the total supply chain profit. Here, the professional service and the component are *complementary*, and we do not allow for the individual sale of either one. Thus, the simple profit allocation rule in a two-player bargaining setting may not hold in our three-player setting. Moreover, the three parties can engage in different sequences of contract negotiation. Specifically, we call the party that negotiates with the other two the *contract coordinator*. Under both $\mathcal{DS}$ and $\mathcal{AS}$, we assume that the contract coordinator negotiates with the other two parties *simultaneously*[1].

[1] We thank the reviewers for pointing out that under $\mathcal{DS}$, it is impractical that the buyer negotiates with the other

Regarding the procurement contract terms, both wholesale price and purchasing quantity need to be determined. In the existing supply chain literature on bargaining, quantity is usually assumed to be determined after the wholesale price negotiation (see, e.g., Feng and Lu (2012, 2013)). However, in practice, it is not uncommon for price to be negotiated together with purchasing quantity. For example, Walmart usually predetermines the procurement quantity and takes its volume advantage in the negotiation with suppliers (Mrunal 2014). Liz Claiborne relies on Li & Fung for purchasing and specifies both the ordering quantity and price of the required items in their agreement (Liz Claiborne 2009). For buyers negotiating with potential suppliers at the latest Oracle sourcing platform, purchasing information such as order quantity need to be filled in first (see Oracle (2015) User Guide via http://docs.oracle.com). For this reason, we study two contract structures when the parties negotiate. We primarily study *Case P&Q*, in which the supply chain parties negotiate over both price and quantity. It can be shown that negotiation of both price and quantity results in the same outcomes as those when the ordering quantity is determined before the wholesale price negotiation. This is due to the property of the Nash bargaining framework that we adopt in this paper; see Nash (1950), Roth (1979), and Nagarajan and Sosic (2008) for more detailed discussions. We then analyze *Case P*, in which the parties first negotiate over price, and then, the buyer makes the quantity decision, i.e., the case when only prices are negotiated.

1.2 Main Findings

Our study uncovers several key factors that dictate the equilibrium procurement oursourcing structure. The first is a new notion that we call the *direct negotiation coefficient* of two parties negotiating directly, which is the ratio of their *exogenous* bilateral relative bargaining powers. The second is a notion that we call the *indirect negotiation coefficient* of two parties negotiating indirectly through a third party, which is the quotient of their respective direct negotiation coefficients with respect to the third party.

For Case P&Q, we show that the buyer's preference over the two outsourcing structures is solely determined by the relative magnitude of her direct and indirect negotiation coefficients with respect to the supplier when the two negotiate indirectly via the purchasing agent. For a powerful buyer who has large bargaining power over both the agent and the supplier, her preference over the two outsourcing structures is very *sensitive* to the relative bargaining power of the other two parties. Thus, the buyer's procurement outsourcing strategy may switch between $\mathcal{AS}$ and $\mathcal{DS}$ when the

two parties sequentially. We also show that it is in the best interest of the contract coordinator to negotiate with the other two parties simultaneously under both $\mathcal{DS}$ and $\mathcal{AS}$; see Remark 3 stated in the online Appendix B.

business relation of her two upstream partners– the supplier and the agent– evolves so that their relative bargaining powers are altered. As a result, a purchase contract with a buyer who has large bargaining power might not be sustainable. This is in sharp contrast to the common wisdom that procurement strategy is long-term oriented and relatively stable (Sako 1992, Graham et al. 1994). This might explain the recent procurement contract change of Walmart from $\mathcal{AS}$ to $\mathcal{DS}$ with Li & Fung within just 3 years (Chu 2012a, Layne 2015). The aforementioned results hold regardless of the existence of a spot market for the component.

For Case P, we find that the preference of the three parties for $\mathcal{DS}$ and $\mathcal{AS}$ hinges critically upon the magnitude of the purchasing agent's relative bargaining power over the supplier. Specifically, the preference of both the buyer and the purchasing agent is determined by a threshold. The supplier's preference exhibits a *U-shaped* curve: it prefers $\mathcal{AS}$ only when the purchasing agent's bargaining power is in a moderate range. Thus, when the purchasing agent's relative bargaining power over the supplier is small enough, all parties prefer $\mathcal{DS}$.

The rest of this paper is organized as follows. Section 2 reviews the most related literature. Section 3 presents the model setting and notation. We examine Case P&Q in Section 4, in which we characterize the equilibrium quantities and wholesale prices under both $\mathcal{DS}$ and $\mathcal{AS}$. We also analyze each party's preference between these two sourcing structures. Section 5 studies Case P. Concluding remarks are provided in Section 6. All of the proofs are relegated to the online Appendix A. We discuss miscellaneous issues in the online Appendix B, including the sequence of contract negotiation, the incentives of the buyer and the purchasing agent to provide untruthful supply information, cost information asymmetry, price-sensitive market demand and what to negotiate (via comparing the supply chain parties' performance under Cases P&Q and P).

2 Literature Review

Our research is related to studies on the value of involving a purchasing agent. Wu (2004) reviews the literature on supply chain intermediation under a negotiation framework. Guo et al. (2010) and Chen et al. (2012) show that it is possible for procurement outsourcing to outperform in-house sourcing with the consideration of issues such as demand information updating, two-echelon contract design, and downstream competition. Bolandifar et al. (2016) study the procurement outsourcing decisions of two competing buyers by incorporating the component supplier's pricing power, while the wholesale price can be either exogenously given or the supplier's decision. Hsu et al. (2017) examine two competing firms' collective purchasing decisions when one firm acts as the purchasing agent. Xu et al. (2018) investigate a multinational firm's strategic decision of whether to rely on the contract manufacturer for component purchasing by taking China's value-added tax policies into account. Tsay (2014) provides an overview of the major issues in the design and control of outsourced supply chains, including the tradeoffs in procurement outsourcing. We note that the literature on common agency is also related; see, e.g., Wang and Zipkin (2009), Kalkanci and Erhun (2012), and Galperti (2015). While the above analytical works employ a noncooperative framework, we employ a GNB framework in a newsvendor setting with random demand and a possible supply spot market.

Our study is also related to the literature on hierarchical contracting in a three-tier supply chain. In the economics literature, representative studies include Baron and Besanko (1992), Segal (2001), and Mookherjee and Tsumagari (2004). See Mookherjee (2006) for an extensive review of the research in this stream. In the operations management literature, Kayiş et al. (2013) assume that the cost information of tier-1 and tier-2 suppliers is private and study the buyer's procurement delegation decision under both quantity discounts and price-only contracts. They find that procurement delegation may induce the tier-1 supplier to design contracts that better reveal the private information and hence benefit the buyer (named the *adjustment effect*). They also find that a complex quantity discount contract induces the buyer to prefer control because contract complexity substitutes the adjustment effect under delegation. Chen et al. (2014) examine the role of local distributors and find that under a two-stage menu contract, the distributors' more accurate information can help retailers obtain the production quantities they need. Yang and Babich (2015) show that the introduction of a procurement service provider may benefit the retailer when its suppliers are unreliable and have private information about their likelihoods of disruption. Huang et al. (2017) consider a three-tier supply chain in which the downstream party may outsource the monitoring and management of its tier-2 supplier's social responsibility. Chen et al. (2018) identify the value of cash flow management in a three-tier supply chain if a buyer outsources its procurement function to a third-party logistics provider. Distinct from the aforementioned studies, we examine the parties' pricing and quantity decisions under a *contract negotiation* framework.

In this stream of research, our work is most related to that of Wang et al. (2014), which compares firms' component sourcing strategies under pull, push and two-wholesale-price contracts. However, unlike Wang et al. (2014) in which the wholesale prices are determined via a *noncooperative* take-it-or-leave-it game, here, the wholesale prices are obtained through a *cooperative* GNB game. Our conclusions also differ greatly. For example, Wang et al. (2014) find that the buyer always prefers in-house sourcing, whereas we find that such a preference depends on how the negotiation power is distributed among the three parties. In particular, the drivers for the buyer's preference between

$\mathcal{DS}$ and $\mathcal{AS}$ are the endogenous bargaining power, the reservation profit spillover effect, and the size of the profit available for allocation after the reservation profit is divided among the three parties.

Another related research stream is the studies on advance quantity commitments among supply chain parties; see Ferguson (2003), Bernstein and DeCroix (2004), Cachon (2004), Ferguson et al. (2005), Dong and Zhu (2007), Li and Scheller-Wolf (2011), Li and Zhang (2013), and the references therein. Similar to the aforementioned studies, we assume that the OEM makes the advance quantity commitment; that is, the OEM places an order before demand realization. However, these studies mainly focus on a two-party supply chain in which the wholesale price is either exogenously given or optimized via a take-it-or-leave-it contract. Here, we consider a three-player supply chain in which the buyer can either directly source from the supplier or indirectly source through her purchasing agent. This provides one more layer of flexibility to the buyer by allowing her to decide which procurement outsourcing structure to adopt.

Our work applies the GNB methodology developed in the economics field. For instance, Cai (2000) considers a noncooperative multilateral bargaining problem and focuses on the multiplicity and inefficiency of the equilibria. Chatterjee and Sabourian (2000) study multilateral bargaining and identify the unique equilibrium. Suh and Wen (2006) study an alternating problem with multiagent bilateral bargaining, where n players negotiate the profit allocation through $n-1$ negotiation sessions. Davidson (1988), Horn and Wolinsky (1988) and Gal-Or (1999) develop the Nash-Nash solution concept when there are two interdependent bilateral negotiations (e.g., two competitors negotiate with the same player simultaneously). In recent years, we have seen increasing applications of GNB in the operations management field; see, e.g., Li et al. (2006), Nagarajan and Bassok (2008), Leng and Parlar (2009), Feng et al. (2015), and Feng and Shanthikumar (2018). Among these applications, Feng and Lu (2012, 2013) and Lovejoy (2010) are the ones most related to ours. Differing from Feng and Lu (2012, 2013) who study three-party supply chains with substitutable products, we consider complementary products here. Compared to Lovejoy (2010) who studies serial bargaining for a single product, we consider two complementary products provided by the supplier and the purchasing agent, respectively.

3 Model Setting and Preliminaries

3.1 The Base Model

Consider a supply chain composed of a buyer (labeled b), a purchasing agent (labeled a), and a supplier (labeled s). A unit of the buyer's final product requires both a unit of a component procured from the supplier and a unit of a complementary service such as quality inspection and logistics provided by the purchasing agent. The buyer can buy the component directly from the supplier, which is the $\mathcal{DS}$ structure, or she can authorize the purchasing agent to buy the component on her behalf from the supplier, which is the $\mathcal{AS}$ structure. In either structure, the buyer relies on the purchasing agent for complementary services. We assume that the supplier incurs a per unit cost c_s, while the purchasing agent incurs a per unit service cost c_a. Since c_a is the purchasing agent's variable cost, it can be viewed as the unit cost. Denote p as the market price for the end product. Naturally, $p > c_a + c_s$ is required to ensure that the end product has a positive profit margin. Let w_i be the unit wholesale price for firm i's product/service, $i = a, s$. Under the $\mathcal{AS}$ structure, the buyer pays the purchasing agent a lump sum wholesale price $\tilde{w}_a$ that covers both the agent's service cost and the wholesale price the agent pays to the supplier.

The demand for the final product is a continuous random variable X with a cumulative density function (cdf) $F(\cdot)$ and a probability density function (pdf) $f(\cdot)$, where $f(x) > 0$ for all $x \geq 0$ and $f(x) = 0$ otherwise. Let $\bar{F}(\cdot) = 1 - F(\cdot)$. We assume that the demand distribution has an increasing generalized failure rate (IGFR). This is a fairly weak requirement that many common distributions satisfy (see Lariviere 2006). In a centralized supply chain, the expected demand that can be satisfied with a production quantity q is

$$\mu(q) = E[\min(X, q)].$$

The expected profit for the whole (centralized) supply chain is $p\mu(q) - (c_a + c_s)q$. The first-best production quantity can then be derived as

$$q^* = \bar{F}^{-1}\left(\frac{c_a + c_s}{p}\right),$$

and the corresponding maximum profit is

$$\Pi = p\mu(q^*) - (c_a + c_s)q^*.$$

In the decentralized chain, we assume that the demand and market price for the final product, the capacity/resource cost of the supplier, and the service cost of the purchasing agent are common knowledge. Such an assumption is reasonable in the context where the players *trust* each other in procurement outsourcing, and they share the information and build a network with long-term relationships (Denning 2011). We discuss the information asymmetry issue in the online Appendix B.

The bilateral contract outcomes among the three parties are determined via the GNB scheme, which provides a unique negotiation solution that can be obtained by solving the following optimization problem:

$$\underset{\pi_i \geq d_i, \pi_j \geq d_j}{\text{Max}} \quad \Omega_{ij} = (\pi_i - d_i)^{\theta} (\pi_j - d_j)^{1-\theta}, i \neq j,$$

where Ω_{ij} is the *Nash product*, π_i is player i's profit (its expected payoff when the agreement is reached between the two parties), and d_i is its disagreement point (its payoff with the outside option). Parameters θ and $1-\theta$, $\theta \in [0,1]$, are the relative negotiation powers of players i and j, respectively. Note that the extreme values $\theta = 0$ and $\theta = 1$ reduce the two-player negotiation setting to a centralized one-player setting, under which the total profit Ω_{ij} is allocated to one player. We assume that the supply chain parties are rational and risk-neutral and that their negotiation powers are exogenously given. We further denote α and $1-\alpha$ as the relative negotiation power of the buyer and the purchasing agent, respectively, when these two players negotiate. Similarly, we denote β and $1-\beta$ as the relative negotiation power of the buyer and the supplier when they negotiate with each other and γ and $1-\gamma$ as the relative negotiation power of the purchasing agent and the supplier when they negotiate, respectively.

We assume that there exists a spot market for the component provided by the supplier and that the components procured from the spot market are easily distinguishable from the supplier's components because of logos, packages, and factory locations. Therefore, it is generally difficult for a party to provide untruthful information about where the component is bought, with unit price c_p. We also assume that there is no such spot market for the professional services provided by the purchasing agent. This assumption can be practical. For example, Nagappan (2009) and Anjoran (2010) report that sourcing firms such as Li & Fung usually build their quality control departments to conduct factory audits, product inspections, and even very professional laboratory tests. Such services are difficult to purchase in a spot market.

Under $\mathcal{DS}$, when the buyer and the supplier negotiate, we have $d_s = 0$, but $d_b > 0$. Here, d_b is the buyer's *endogenous reservation profit*, which is the buyer's profit in the buyer-agent bargaining game when the component is fully purchased from the spot market. Similarly, under $\mathcal{AS}$, when the purchasing agent and the supplier negotiate, $d_s = 0$, but $d_a > 0$, where d_a is the agent's endogenous reservation profit, which is the agent's profit in the buyer-agent bargaining game when the component is fully purchased from the spot market. However, when the buyer and the agent negotiate, due to the uniqueness of the agent's professional service and the nonexistence of an outside option for that service, the status quo of both parties shall be zero. Let Π_i ($i = b$, a, s) represent firm i's expected profit. We require $\Pi_i \geq d_i$ to guarantee the success of the GNB bargaining.

4 Contracting over Both Price and Quantity

In this section, we consider the Case P&Q, in which both wholesale prices and quantities are contracted and negotiated by the three parties.

In a two-player supply chain, it has been shown in the literature that the negotiation outcome over quantity is a global optimum that coordinates the whole supply chain (Feng and Lu 2012, 2013). Whether the same conclusion still holds when bilateral contract negotiation occurs among three parties is not obvious. However, our analysis below confirms that this is still true. We will take the $\mathcal{DS}$ structure as an example to illustrate this point. The same rationale applies to the $\mathcal{AS}$ structure.

4.1 Direct Sourcing ($\mathcal{DS}$)

Under $\mathcal{DS}$, the game sequence is as follows. The buyer, as the contract coordinator, simultaneously negotiates the wholesale price w_a and service quantity q_a with the purchasing agent and the wholesale price w_s and production quantity q_s with the supplier. Then, the effective capacity for the whole supply chain must be the minimum of the two quantities, i.e., $q_a \wedge q_s$, where $x \wedge y$ stands for $\min\{x, y\}$. Consequently, the respective profit functions of the three parties are as follows:

$$\Pi_b = p\mu(q_a \wedge q_s) - w_a q_a - w_s q_s, \quad \Pi_a = (w_a - c_a)q_a, \quad \text{and} \quad \Pi_s = (w_s - c_s)q_s. \tag{1}$$

The negotiated wholesale prices and quantities can be obtained by maximizing the following *Nash products*[2]:

$$\underset{(w_a,q_a)}{\text{Max}} \quad \Omega_{ba} = [\Pi_b]^\alpha[\Pi_a]^{1-\alpha} = [p\mu(q_a \wedge q_s) - w_a q_a - w_s q_s]^\alpha[(w_a - c_a)q_a]^{1-\alpha}, \tag{2}$$

$$\underset{(w_s,q_s)}{\text{Max}} \quad \Omega_{bs} = [\Pi_b - d_b]^\beta[\Pi_s]^{1-\beta} = [p\mu(q_a \wedge q_s) - w_a q_a - w_s q_s - d_b]^\beta[(w_s - c_s)q_s]^{1-\beta}. \tag{3}$$

[2]It is worth mentioning that our conclusion would be unchanged if we allow for the supplier to sell to the spot market at a wholesale price w'_s, where w'_s is exogenously given and lower than the negotiated component price under $\mathcal{DS}$, which can be shown equal to $c_s + \frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}\frac{\Pi-\Pi^r}{q^*}$, where Π^r is the supply chain's total profit when purchasing from the spot market. The reason is the following. In this scenario, the supplier's reservation profit is $(w'_s - c_s)q_s$ and the Nash product between the buyer and the supplier is $\text{Max}_{(w_s,q_s)} \quad \Omega_{bs} = [p\mu(q_a \wedge q_s) - w_a q_a - w_s q_s - d_b]^\beta[(w_s - w'_s)q_s]^{1-\beta}$. Clearly, our results are unchanged, except that the constant c_s is replaced by another constant w'_s. The same argument can be applied to the $\mathcal{AS}$ setting.

To solve the above Nash products, we first need to derive the buyer's *endogenous reservation profit* d_b when negotiating with the supplier due to the existence of the outside option, the component spot market. Suppose that the buyer purchases the components from the spot market rather than from the supplier at a unit price c_p. It can be derived that $d_b = \Pi_b^r = \alpha\Pi^r$, where Π^r, the supply chain's total profit when purchasing from the spot market, satisfies

$$\Pi^r = p\mu(q^r) - (c_a + c_p)q^r, \text{ where } q^r = \bar{F}^{-1}\left(\frac{c_p + c_a}{p}\right);$$

see the online Appendix A for a detailed discussion. To avoid trivial and uninteresting cases, we assume that c_p is higher than the negotiated component price under $\mathcal{DS}$, i.e., $c_s + \frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}\frac{\Pi-\Pi^r}{q^*}$. This requirement can be reformulated as $c_p + \frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}\frac{\Pi^r}{q^*} > c_s + \frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}\frac{\Pi}{q^*}$. Define $A(c_p) := c_p + \frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}\frac{\Pi^r}{q^*}$, which can be shown to be increasing in c_p. It then follows that there exists a unique threshold $c_p^{DS*} := A\left(c_s + \frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}\frac{\Pi}{q^*}\right)^{-1}$ such that if $c_p > c_p^{DS*}$, the required assumption always holds.

We now solve the original bilateral negotiations among the buyer, the agent, and the supplier. The pairs maximize the Nash products Ω_{bs} and Ω_{ba} simultaneously to obtain the GNB-characterized wholesale prices w_a and w_s and corresponding quantities q_a and q_s. The following lemma summarizes the equilibrium profits of the three parties.

Lemma 1 *When both prices and quantities are contracted and negotiated, under $\mathcal{DS}$, in equilibrium, the negotiated wholesale prices are*

$$\begin{aligned} w_a^{DS} &= c_a + \frac{1-\alpha}{\alpha+\beta-\alpha\beta}\frac{(\beta\Pi + \alpha(1-\beta)\Pi^r)}{q^*}; \\ w_s^{DS} &= c_s + \frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}\frac{\Pi-\Pi^r}{q^*}. \end{aligned}$$

The corresponding profit allocation among the three parties is as follows:

$$\begin{aligned} \Pi_b^{DS} &= \underbrace{\frac{\alpha\beta}{\alpha+\beta-\alpha\beta}(\Pi - d_b)}_{(i)} + \underbrace{\frac{\alpha}{\alpha+\beta-\alpha\beta}d_b}_{(1)}, \\ \Pi_a^{DS} &= \underbrace{\frac{(1-\alpha)\beta}{\alpha+\beta-\alpha\beta}(\Pi - d_b)}_{(ii)} + \underbrace{\frac{1-\alpha}{\alpha+\beta-\alpha\beta}d_b}_{(2)}, \\ \Pi_s^{DS} &= \underbrace{\frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}(\Pi - d_b)}_{(iii)} \underbrace{- \frac{(1-\alpha)(1-\beta)}{\alpha+\beta-\alpha\beta}d_b}_{(3)}. \end{aligned}$$

Moreover, the negotiation outcome over quantity among the three parties is $q_a = q_s = q^*$ (see the proof of Lemma 1), which is the first best solution, so the supply chain is coordinated.

Substituting $d_b = \alpha\Pi^r$ into the supplier's equilibrium profit, we obtain $\Pi_s^{DS} = \frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}(\Pi - \Pi^r)$, which is undoubtedly positive, as $\Pi > \Pi^r$. Although the existence of a spot market reduces the profitability of the supplier, the supplier still earns a certain profit due to its cost advantage ($c_s < c_p$). A close look at the composition of three profits reveals that

$$(i) + (ii) + (iii) = \Pi - d_b \text{ and } (1) + (2) + (3) = d_b.$$

Note that in the bilateral bargaining in a two-player chain, if one party holds a reservation profit, i.e., the disagreement point d_b, then that amount is first extracted from the total profit resulting from the contractual relationship of the two players and allocated to the concerned party. Next, the remaining profit $\Pi - d_b$ is allocated to the two parties according to their relative bargaining powers. Here, in our three-player two bilateral bargaining setting, we derive the following results that are quite different from those under the two-player setting.

First, due to the complementarity between the component and the professional service, we can derive the *equilibrium bargaining powers* of the three parties, that is, their *endogenous* bargaining powers as a result of two bilateral bargaining under $\mathcal{DS}$. Recall that under $\mathcal{DS}$, the pairwise relative bargaining powers among the three parties are α vs. $1-\alpha$ between the buyer and the agent and β vs. $1-\beta$ between the buyer and the supplier. The equilibrium endogenous bargaining powers of the three parties are the algebraic combination of these exogenous pairwise bargaining powers, as specified below:

$$\underbrace{\frac{\alpha\beta}{\alpha+\beta-\alpha\beta}}_{buyer's\ bargaining\ power} + \underbrace{\frac{(1-\alpha)\beta}{\alpha+\beta-\alpha\beta}}_{agent's\ bargaining\ power} + \underbrace{\frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}}_{supplier's\ bargaining\ power} = 1.$$

The remaining profit $\Pi - d_b$ is allocated to the three parties according to these endogenous bargaining powers. Although the purchasing agent and the supplier have no direct contractual relationship, the complementarity between their component and service induces them to contract *indirectly.*

Second, there exists a *reservation profit spillover effect* in our three-player bilateral bargaining. A close look at the three profit functions stated in Lemma 1 shows that although the buyer is endowed with the outside option and holds a reservation profit d_b when negotiating with the supplier bilaterally, under the three-player setting, only a portion of such reservation profit (that is, $\frac{\alpha}{\alpha+\beta-\alpha\beta}d_b < d_b$) is allocated to the buyer. Meanwhile, the complementarity and uniqueness of the professional service (that is, without a spot market) enhances the bargaining power of the purchasing agent. As a consequence, a share of the reservation profit (that is, $\frac{1-\alpha}{\alpha+\beta-\alpha\beta}d_b$) is allocated to the purchasing agent. This implies that the purchasing agent enjoys an *extra profit gain* due to the monopoly advantage of his professional service. In contrast, the existence of the product spot market dampens the supplier's profit, and the supplier suffers an extra profit loss proportional to the reservation profit, $\frac{(1-\alpha)(1-\beta)}{\alpha+\beta-\alpha\beta}d_b$. In summary, in our three-player setting, the monopolistic position of the purchasing agent (due to his unique professional service) enhances his bargaining power, while it weakens that of the buyer; the existence of the outside option– the component spot market– further impairs the supplier's bargaining position.

The above finding is further manifested by the supply chain parties' shares of the total profit. The ratio of the buyer's profit over that of the supplier and the ratio of the purchasing agent's profit over that of the supplier both *increase* due to the presence of the component spot market. Specifically, the ratio of the buyer's profit over that of the supplier is $\beta/(1-\beta)$ when the spot market does not exist. With the presence of a component spot market, this ratio becomes $\beta/(1-\beta)+(\alpha+\beta-\alpha\beta)\Pi^r/((1-\beta)(\Pi-\Pi^r))$, which is surely larger than $\beta/(1-\beta)$. Similarly, with a component spot market, the ratio of the purchasing agent's profit over that of the supplier is $(1-\alpha)\beta/(\alpha(1-\beta))+(1-\alpha)(\alpha+\beta-\alpha\beta)\Pi^r/(\alpha(1-\beta)(\Pi-\Pi^r))$, which is greater than its counterpart without a spot market, $(1-\alpha)\beta/(\alpha(1-\beta))$.

4.2 Agent Sourcing ($\mathcal{AS}$)

Under $\mathcal{AS}$, the purchasing agent, as the contract coordinator, simultaneously negotiates the wholesale price $\tilde{w}_a$ and ordering quantity q_a with the buyer and the wholesale price w_s and the ordering quantity q_s with the supplier. Because each unit of the component needs one unit of complimentary service, the purchasing agent's effective quantity is $q_a \wedge q_s$. Then, the profit functions of the supply chain parties under $\mathcal{AS}$ can be written as

$$\Pi_b = p\mu(q_a \wedge q_s) - \tilde{w}_a(q_a \wedge q_s), \quad \Pi_a = (\tilde{w}_a - c_a)(q_a \wedge q_s) - w_s q_s \text{ and } \Pi_s = (w_s - c_s)q_s.$$

The negotiated wholesale prices and quantities can be obtained by simultaneously maximizing the following two *Nash products*:

$$\begin{aligned}
\operatorname*{Max}_{\tilde{w}_a, q_a} \ \Omega_{ba} &= [\Pi_b]^{\alpha}[\Pi_a]^{1-\alpha} = [p\mu(q_a \wedge q_s) - \tilde{w}_a(q_a \wedge q_s)]^{\alpha}[(\tilde{w}_a - c_a)(q_a \wedge q_s) - w_s q_s]^{1-\alpha};\\
\operatorname*{Max}_{w_s, q_s} \ \Omega_{as} &= [\Pi_a - d_a]^{\gamma}[\Pi_s]^{1-\gamma} = [(\tilde{w}_a - c_a)(q_a \wedge q_s) - w_s q_s - d_a]^{\gamma}[(w_s - c_s)q_s]^{1-\gamma}.
\end{aligned}$$

To solve the above optimization problem, we need to first derive d_a, the reservation profit of the purchasing agent when negotiating with the supplier. It can be shown that $d_a = \Pi_a^r = (1-\alpha)\Pi^r$; see the online Appendix A for the detailed discussion. To avoid trivial and uninteresting cases, we assume that c_p is higher than the negotiated component price under $\mathcal{AS}$, i.e., $c_s + \frac{(1-\gamma)(1-\alpha)}{1-\alpha+\alpha\gamma}\frac{\Pi-\Pi^r}{q^*}$.

This requirement can be reformulated as $c_p + \frac{(1-\gamma)(1-\alpha)}{1-\alpha+\alpha\gamma}\frac{\Pi^r}{q^*} > c_s + \frac{(1-\gamma)(1-\alpha)}{1-\alpha+\alpha\gamma}\frac{\Pi}{q^*}$. Define $B(c_p) := c_p + \frac{(1-\gamma)(1-\alpha)}{1-\alpha+\alpha\gamma}\frac{\Pi^r}{q^*}$, which can be shown to be increasing in c_p. Then, the assumption holds if and only if (iff) c_p is higher than a unique threshold $c_p^{AS*} := B\left(c_s + \frac{(1-\gamma)(1-\alpha)}{1-\alpha+\alpha\gamma}\frac{\Pi}{q^*}\right)^{-1}$.

We now solve the original bilateral negotiations among the three parties. Similarly, we can show that under $\mathcal{AS}$, as a result of the wholesale price negotiation, the profits of the three parties are proportional to each other. Thus, the Nash bargaining outcome over the production quantity is again $q_a = q_s = q^*$, the first-best solution.

Lemma 2 *When both prices and quantities are contracted and negotiated, under $\mathcal{AS}$, in equilibrium, the negotiated wholesale prices are*

$$\begin{aligned} \tilde{w}_a^{AS} &= c_a + c_s + \frac{1-\alpha}{1-\alpha+\alpha\gamma}\frac{\Pi - \alpha(1-\gamma)\Pi^r}{q^*}; \\ w_s^{AS} &= c_s + \frac{(1-\gamma)(1-\alpha)}{1-\alpha+\alpha\gamma}\frac{\Pi - \Pi^r}{q^*}. \end{aligned}$$

The corresponding profit allocation among the three parties is as follows:

$$\begin{aligned} \Pi_b^{AS} &= \underbrace{\frac{\alpha\gamma}{1-\alpha+\alpha\gamma}(\Pi - d_a)}_{(I)} + \underbrace{\frac{\alpha}{1-\alpha+\alpha\gamma}d_a}_{(a)}; \\ \Pi_a^{AS} &= \underbrace{\frac{\gamma(1-\alpha)}{1-\alpha+\alpha\gamma}(\Pi - d_a)}_{(II)} + \underbrace{\frac{1-\alpha}{1-\alpha+\alpha\gamma}d_a}_{(b)}; \\ \Pi_s^{AS} &= \underbrace{\frac{(1-\gamma)(1-\alpha)}{1-\alpha+\alpha\gamma}(\Pi - d_a)}_{(III)} - \underbrace{\frac{\alpha(1-\gamma)}{1-\alpha+\alpha\gamma}d_a}_{(c)}. \end{aligned}$$

A close look at the three profit functions yields that

$$(I) + (II) + (III) = \Pi - d_a \text{ and } (a) + (b) + (c) = d_a.$$

Similar to that in §4.1, here, we can show that in our three-party supply network, as a result of two bilateral bargaining, the *equilibrium endogenous bargaining powers* of the three parties under $\mathcal{AS}$ are again the algebraic combination of their exogenous pairwise bargaining powers, as specified below:

$$\underbrace{\frac{\alpha\gamma}{1-\alpha+\alpha\gamma}}_{buyer's\ bargaining\ power} + \underbrace{\frac{\gamma(1-\alpha)}{1-\alpha+\alpha\gamma}}_{agent's\ bargaining\ power} + \underbrace{\frac{(1-\gamma)(1-\alpha)}{1-\alpha+\alpha\gamma}}_{supplier's\ bargaining\ power} = 1.$$

Those equilibrium bargaining powers determine the allocation of $\Pi - d_a$, the remaining profit after extracting the reservation profit (the disagreement point) d_a, among the three parties. Similar to $\mathcal{DS}$, there exists a *reservation profit spillover effect* under $\mathcal{AS}$. That is, although the purchasing agent is endowed with the outside option and holds a reservation profit d_a when negotiating with the supplier bilaterally, only a portion of such reservation profit (that is, $\frac{1-\alpha}{1-\alpha+\alpha\gamma}d_a < d_a$) is realized by the purchasing agent. Meanwhile, a share of the reservation profit (that is, $\frac{\alpha}{1-\alpha+\alpha\gamma}d_a$) is allocated to the buyer due to the contractual relationship with the purchasing agent. The existence of a component spot market further undermines the supplier's bargaining position, causing the supplier to incur an extra profit loss, $\frac{\alpha(1-\gamma)}{1-\alpha+\alpha\gamma}d_a$. That is, in our three-player setting, the buying power of the buyer (note that the three parties engage in trade due to the buyer's order) enhances her profitability, while the existence of the outside option impairs the supplier's profit. Again, the ratio of the buyer's (or the purchasing agent's) profit over that of the supplier becomes larger with a component spot market than without, a result similar to that under $\mathcal{DS}$.

4.3 Comparison of Procurement Outsourcing Structures

In this section, we study each party's preference between the two sourcing structures, $\mathcal{DS}$ and $\mathcal{AS}$. Specifically, we consider the following two cases depending on whether a component spot market exists. When there is no component spot market, the profits of the buyer under $\mathcal{DS}$ and $\mathcal{AS}$ degenerate to

$$\Pi_b^{DS} = \frac{\alpha\beta}{\alpha+\beta-\alpha\beta}\Pi; \quad \Pi_b^{AS} = \frac{\alpha\gamma}{1-\alpha+\alpha\gamma}\Pi.$$

Thus, the buyer's preference for $\mathcal{DS}$ and $\mathcal{AS}$ solely depends on the relative magnitude of her endogenous bargaining powers under the two procurement structures. The same conclusion holds for the purchasing agent and the supplier. When there is a component spot market, there exists an endogenous reservation profit level when the contract coordinator negotiates with the supplier. Thus, the profit of each party is composed of two parts: (1) the allocation of the leftover contractual profit after extracting the reservation profit, that is, $\Pi - d_b$ under $\mathcal{DS}$ and $\Pi - d_a$ under $\mathcal{AS}$, among the three parties, and (2) the additional profit gain/loss due to the reallocation of the reservation profit d_b or d_a (the so-called reservation profit spillover effect). See the buyer's profits under the two sourcing structures as an example:

$$\begin{aligned}
\Pi_b^{DS} &= \frac{\alpha\beta}{\alpha+\beta-\alpha\beta}(\Pi - d_b) + \frac{\alpha}{\alpha+\beta-\alpha\beta}d_b; \\
\Pi_b^{AS} &= \frac{\alpha\gamma}{1-\alpha+\alpha\gamma}(\Pi - d_a) + \frac{\alpha}{1-\alpha+\alpha\gamma}d_a.
\end{aligned}$$

We then derive the following decision rules with respect to the preferences of the three parties over $\mathcal{DS}$ and $\mathcal{AS}$. To ensure comparability, $c_p > max(c_p^{AS*}, c_p^{DS*})$ is required.

Proposition 1 *When the parties contract over both prices and quantities, regardless of the existence of a spot market, if* $\frac{\alpha}{1-\alpha} \cdot \frac{\gamma}{1-\gamma} \geq (<, respectively) \frac{\beta}{1-\beta}$*, the buyer and the purchasing agent both prefer the sourcing structure* $\mathcal{AS}$ *(*$\mathcal{DS}$*, respectively), while the reverse holds for the supplier.*

To better understand Proposition 1, we first define the term $\frac{\beta}{1-\beta}$ as the *direct negotiation coefficient* of the buyer over the supplier when they negotiate directly with each other. This coefficient increases in the buyer's relative bargaining power β. Specifically, it equals 1 if the two parties have equal relative bargaining powers. It is greater (smaller) than 1 if the buyer has a higher (lower) relative bargaining power than the supplier. We also define the following *indirect negotiation coefficient* when two parties do not negotiate directly:

$$\begin{aligned}
&\text{Indirect negotiation coefficient of party } a \text{ over party } b\\
&= \text{direct negotiation coefficient of party } a \text{ over party } c\\
&\div \text{ direct negotiation coefficient of party } b \text{ over party } c\\
&= \text{direct negotiation coefficient of party } a \text{ over party } c\\
&\times \text{ direct negotiation coefficient of party } c \text{ over party } b.
\end{aligned}$$

Under this definition, the product term $\frac{\alpha}{1-\alpha} \cdot \frac{\gamma}{1-\gamma}$, as the product of the buyer's direct negotiation coefficient over the purchasing agent and that of the purchasing agent over the supplier, can be understood as the *indirect* negotiation coefficient of the buyer over the supplier under $\mathcal{AS}$. Proposition 1 then implies that the buyer prefers the sourcing structure $\mathcal{AS}$ iff her direct negotiation coefficient over the supplier under $\mathcal{DS}$ is less than her indirect negotiation coefficient over the supplier under $\mathcal{AS}$. Note that $\frac{\alpha}{1-\alpha} \cdot \frac{\gamma}{1-\gamma} > (=, <) \frac{\beta}{1-\beta}$ is equivalent to $\frac{\gamma}{1-\gamma} > (=, <) \frac{1-\alpha}{\alpha} \cdot \frac{\beta}{1-\beta}$ and $\frac{1-\beta}{\beta} > (=, <) \frac{1-\gamma}{\gamma} \cdot \frac{1-\alpha}{\alpha}$. Therefore, the purchasing agent prefers the sourcing structure $\mathcal{AS}$ over $\mathcal{DS}$ iff his direct negotiation coefficient over the supplier under $\mathcal{AS}$ ($\frac{\gamma}{1-\gamma}$) is higher than his indirect negotiation coefficient over the supplier under $\mathcal{DS}$ ($\frac{1-\alpha}{\alpha} \cdot \frac{\beta}{1-\beta}$). Similar results apply to the supplier. This implies that party i will have the bargaining advantage over party j if party i's direct negotiation coefficient over party j is greater than its indirect counterpart. This result can be insightful for practice. In particular, Walmart may believe that its direct negotiation advantage is sufficiently large, which can help it obtain a favorable price from the supplier. Therefore, it has migrated to the direct sourcing strategy in recent years, relying on Li & Fung's only for complementary services (Chu 2012a, 2012b, Anjoran 2010).

Remark 1 *Based on Proposition 1, we can check the stability of a buyer's purchasing strategy. Note that the direct negotiation coefficients* $\frac{\alpha}{1-\alpha}$*,* $\frac{\beta}{1-\beta}$ *and* $\frac{\gamma}{1-\gamma}$ *are the fractional functions of the* *original bargaining power parameters α, β, and γ, respectively. This kind of convex transformation of the bargaining power parameters augments the impact of bargaining power changes when α, β, and/or γ are sufficiently large: a one unit of bargaining power increase can dramatically increase the corresponding coefficient.*

Figure 1 depicts the indifference curves regarding the buyer's preference between $\mathcal{AS}$ and $\mathcal{DS}$ by varying parameter β, below which $\mathcal{DS}$ is preferred, and above which $\mathcal{AS}$ is preferred. One interesting observation from Figure 1 is that as β increases from 0.3 to 0.9, the shape of the indifference curve changes from convex to concave. This shape change provides the following insights regarding a buyer's procurement outsourcing strategy. First, consider the concave curve with $\beta = 0.9$, which can capture the procurement strategy for a powerful buyer such as Walmart. A powerful buyer is likely to have a large α value over the agent, and at this large α value point, the tangent line of the indifference curve becomes very steep due to concavity. Hence, to stay in the indifference curve, a slight disturbance of the buyer's bargaining power over the agent (i.e., α changes slightly) must be coupled with a sharp reverse-directional change in the bargaining power of the agent over the supplier (i.e., γ must change dramatically in a reverse direction). Failing to do that can easily drive the buyer to switch between $\mathcal{AS}$ and $\mathcal{DS}$. We can also interpret the figure by fixing α and checking the interplay between β and γ. As illustrated with arrows in Figure 1, fixing $\alpha = 0.8$, when β changes from 0.6 to 0.9 (50% increase), the corresponding γ must be increased from 0.27 to 0.69 (156% increase) to sustain $\mathcal{AS}$. This finding is in sharp contrast to the conventional wisdom that the procurement strategy is relatively stable (Sako 1992, Graham et al. 1994). Indeed, Walmart switched from $\mathcal{AS}$ to $\mathcal{DS}$ in its procurement outsourcing with Li & Fung within just 3 years (Chu 2012a, Layne 2015). The corresponding industrial evidence is that during the 2013-2015 period, Walmart established four global merchandising centers that helped it gain negotiation advantages over the supplier (Mrunal 2014). As a result, Walmart's bargaining power over the supplier β increased, while Li & Fung's bargaining power over the supplier did not, which drove Walmart to change its procurement outsourcing strategy. Second, consider the curve with $\beta = 0.3$, which represents a weak buyer. Note that a weak buyer is likely to have a small value of α, at which point the tangent line of the indifference curve is quite steep due to convexity. This implies that the procurement strategy for a weak buyer is also highly unstable. Finally, we consider the curve with $\beta = 0.6$, which represents a buyer with a moderate level of bargaining power. Clearly, this curve is nearly linear and hence, to stay on the indifference curve, a change in α only needs to be counterfired with a similar degree of reverse-directional change in γ. Therefore, the procurement strategy is relatively stable for a buyer with a moderate level of bargaining power.

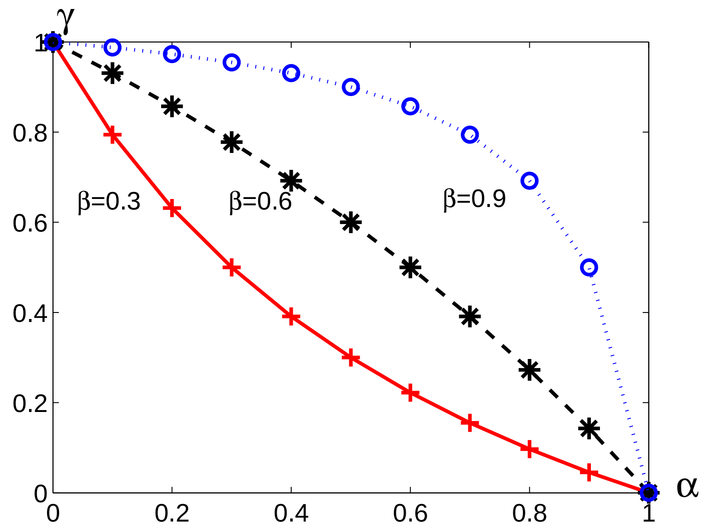

Figure 1: Indifference curves regarding the buyer's preference between $\mathcal{DS}$ and $\mathcal{AS}$

Remark 2 *Note that in our supply chain setting, each party is allowed to negotiate with the other two independently and separately. This assumption is realistic because many supply networks are essentially based on multiple dyadic exchange and contracting relationships (see, e.g., Choi and Hong (2002), Rossetti and Choi (2005), and Choi and Linton (2011)). The contract coordinators (the buyers and purchasing agents under our setting) often do not wish their supply chain partners, such as their upstream suppliers and downstream customers, to directly interact with each other, for concerns of losing control of these relationships and of information leakage.*

The surprising result is that *the decision rule stated in Proposition 1 holds regardless of the existence of a component spot market.* Undoubtedly, the spot market plays different roles under the two outsourcing structures. Under $\mathcal{DS}$, the existence of a spot market *directly* benefits the buyer by increasing the buyer's reservation profit. Its impact on the agent is indirect via the complementarity between the component and the agent's service, and the result is the reservation profit spillover. Under $\mathcal{AS}$, it is the agent who negotiates with the supplier directly, and thus, the existence of a spot market benefits the agent *directly* by increasing the agent's reservation profit. The indirect benefit for the buyer is realized through the "one-stop shopping contract" (Sodhi and Tang 2013), which can be more influential than that for the agent under $\mathcal{DS}$. To understand why the existence of the spot market does not impact the supply chain parties' procurement outsourcing strategies, we shall take a closer look at the underlying tradeoff between how the reservation profit is spilled over and how the remaining supply chain profit is shared among the three parties. Below, we first compare the endogenized reservation profit levels under the two sourcing structures and obtain the following results.

Lemma 3 *If* $\alpha \geq (<, respectively)\ 0.5$*,* $d_b \geq (<, respectively)\ d_a$*.*

Thus, if $\frac{\alpha}{1-\alpha} \geq (<)1$, we have $\Pi - d_b \leq (>)\Pi - d_a$. That is, the size of the leftover profit is smaller under $\mathcal{DS}$ than under $\mathcal{AS}$ when the relative negotiation power of the buyer over the purchasing agent is greater than one. We further compare the impact of the *reservation profit spillover* on the parties under these two structures.

Lemma 4 *If* $\frac{\alpha}{1-\alpha} \leq (>, respectively)\sqrt{\frac{\beta}{\gamma}}$*, the additional profit gains of the buyer and the purchasing agent due to the reallocation of the reservation profit are weakly higher (lower, respectively) under* $\mathcal{AS}$ *than under* $\mathcal{DS}$*.*

Lemma 4 implies that the buyer is likely to enjoy a higher reservation profit spillover under $\mathcal{AS}$ when her relative bargaining power over the purchasing agent, $\alpha/(1-\alpha)$, is not greater than the *square root* of β/γ. A close look at Lemmas 3 and 4 reveals that when the coefficient $\alpha/(1-\alpha)$ is small, the leftover profit is large under $\mathcal{DS}$ than under $\mathcal{AS}$, but the spillover effect under $\mathcal{AS}$ is weaker than that under $\mathcal{DS}$. Therefore, there exists a *substitutable* relationship between the gains derived from the leftover profit and the reservation profit spillover: if there is a larger leftover profit, the buyer may be allocated more leftover profit but obtain less reservation profit spillover. These two forces counteract each other, leading to the robustness of the decision rule.

5 Contracting over Price Only

In this section, we consider Case P, in which the parties contract and negotiate over the wholesale prices only, and the quantity decision is made by the buyer after the price negotiation. This case involves a mixture of cooperative games (price negotiations) and noncooperative games (quantity decision by one party only).

When the buyer prebooks after the price negotiation, the optimal ordering quantities under $\mathcal{DS}$ and $\mathcal{AS}$ are, respectively,

$$q^{DS} = \bar{F}^{-1}\left(\frac{w_a + w_s}{p}\right) \text{ and } q^{AS} = \bar{F}^{-1}\left(\frac{\tilde{w}_a}{p}\right).$$

However, when plugging these optimal ordering quantities into the respective Nash products, the Nash products are in general neither concave nor quasi-concave in wholesale prices. The corresponding analysis is thus complex. To derive analytical results, we assume a uniform demand distribution over the interval $[0,1]$. Note that our results can be easily extended to a uniform distribution over the interval $[0,D]$.

5.1 Direct Sourcing ($\mathcal{DS}$)

Under $\mathcal{DS}$, the sequence of events is similar to that in §4.1, except that, now, the buyer simultaneously negotiates the wholesale prices with the purchasing agent and the supplier first. The buyer then decides on the prebook quantity. We solve this problem by backward induction. When the demand is uniformly distributed between zero and one, the optimal ordering quantity can be derived as $q^{DS} = (p - w_a - w_s)/p$, and correspondingly, $\mu(q^{DS}) = q^{DS} - (q^{DS})^2/2 = [p^2 - (w_a + w_s)^2]/2p^2$. Substituting them into the supply chain parties' profit functions as stated in (1) yields

$$\Pi_b = \frac{(p - w_a - w_s)^2}{2p}, \ \Pi_a = \frac{(w_a - c_a)(p - w_a - w_s)}{p} \text{ and } \Pi_s = \frac{(w_s - c_s)(p - w_a - w_s)}{p}.$$

When there exists a component spot market, the buyer endogenously holds a reservation profit d_b when she negotiates with the supplier under $\mathcal{DS}$. We thereby first compute d_b. Suppose now that the buyer purchases the product from the spot market at price c_p (assume that $p > c_p + c_a$). Then, the profit functions of the buyer and the purchasing agent can be written, respectively, as

$$\Pi_b = \frac{(p - w_a - c_p)^2}{2p} \text{ and } \Pi_a = \frac{(w_a - c_a)(p - w_a - c_p)}{p}.$$

Then, the negotiation problem between the buyer and the purchasing agent becomes

$$\underset{w_a}{\text{Max}} \quad \Omega_{ba} = [\Pi_b]^{\alpha}[\Pi_a]^{1-\alpha} = \frac{1}{2^{\alpha}p}(p - w_a - c_p)^{1+\alpha}(w_a - c_a)^{1-\alpha}.$$

Solving it yields $w_a = ((1-\alpha)(p - c_p) + (1+\alpha)c_a)/2$, and the corresponding buyer profit $\Pi_b^r = (1+\alpha)^2(p - c_a - c_p)^2/8p$. Thus, $d_b = \Pi_b^r = (1+\alpha)^2(p - c_a - c_p)^2/8p$.

We now return to the original three-player two bilateral bargaining problem. The buyer negotiates with the supplier and the purchasing agent over the wholesale prices simultaneously by solving the following optimization problems:

$$\underset{w_a}{\text{Max}} \quad \Omega_{ba} = [\Pi_b]^{\alpha}[\Pi_a]^{1-\alpha} = \left[\frac{(p - w_a - w_s)^2}{2p}\right]^{\alpha}\left[\frac{(w_a - c_a)(p - w_a - w_s)}{p}\right]^{1-\alpha},$$

$$\underset{w_s}{\text{Max}} \quad \Omega_{bs} = [\Pi_b - d_b]^{\beta}[\Pi_s]^{1-\beta} = \left[\frac{(p - w_a - w_s)^2}{2p} - d_b\right]^{\beta}\left[\frac{(w_s - c_s)(p - w_a - w_s)}{p}\right]^{1-\beta}.$$

It is easy to derive that $w_a(w_s) = ((1-\alpha)(p - w_s) + (1+\alpha)c_a)/2$; however, Ω_{bs} is not necessarily concave/unimodal in w_s when the reservation profit level $d_b \neq 0$. We hereby derive some analytical results by assuming no component spot market. We will investigate the case when there exists a component spot market via the numerical experiments later in this section.

Lemma 5 *Assume that there is no component spot market, the supply chain parties negotiate over wholesale prices only, and the demand is uniformly distributed in* $[0, 1]$. *Under* $\mathcal{DS}$,

(1) the equilibrium wholesale prices and the buyer's optimal ordering quantity are, respectively,

$$w_a^{DS} = \frac{(1-\alpha)(1+\beta)}{3+\alpha+\beta-\alpha\beta}(p-c_a-c_s)+c_a; w_s^{DS} = \frac{(1+\alpha)(1-\beta)}{3+\alpha+\beta-\alpha\beta}(p-c_a-c_s)+c_s; q^{DS} = \frac{(1+\alpha)(1+\beta)(p-c_a-c_s)}{(3+\alpha+\beta-\alpha\beta)p}.$$

(2) the entire supply chain cannot achieve the centralized supply chain performance, and the profit allocation among the three parties is

$$\Pi_b^{DS} = \frac{(1+\alpha)^2(1+\beta)^2(p-c_a-c_s)^2}{2(3+\alpha+\beta-\beta\alpha)^2 p}; \Pi_a^{DS} = \frac{(1-\alpha^2)(1+\beta)^2(p-c_a-c_s)^2}{(3+\alpha+\beta-\beta\alpha)^2 p}; \Pi_s^{DS} = \frac{(1+\alpha)^2(1-\beta^2)(p-c_a-c_s)^2}{(3+\alpha+\beta-\alpha\beta)^2 p}.$$

Therefore, when the ordering decision is made after the wholesale price negotiation, negotiation on wholesale prices only does not coordinate the supply chain to achieve the centralized performance, and the double marginalization effect arises. We can show that the profit margins of the purchasing agent ($w_a^{DS} - c_a$) and the supplier ($w_s^{DS} - c_s$) are both *proportional* to that of the entire supply chain ($p - c_a - c_s$), and the degree of corresponding double marginalization can be represented by the coefficients $(1-\alpha)(1+\beta)/(3+\alpha+\beta-\alpha\beta)$ and $(1+\alpha)(1-\beta)/(3+\alpha+\beta-\alpha\beta)$, respectively. Note that the former coefficient is decreasing in α, the relative negotiation power of the buyer over the purchasing agent, while the latter coefficient is decreasing in β, the relative negotiation power of the buyer over the supplier. These findings imply that *the presence of a powerful buyer under* $\mathcal{DS}$ *might help mitigate the adverse effect of double marginalization and reduce overall supply chain loss.*

Next, we derive each party's endogenous bargaining power. From Lemma 5, we obtain that when the parties negotiate prices only, the total supply chain profit is

$$\Pi_b^{DS} + \Pi_a^{DS} + \Pi_s^{DS} = \frac{(3+\alpha+\beta-\beta\alpha)^2 - 4(1-\alpha\beta)^2}{(3+\alpha+\beta-\beta\alpha)^2}\frac{(p-c_a-c_s)^2}{2p},$$

which is undoubtedly smaller than that when the parties negotiate over both quantities and prices. Thus, we can rewrite the buyer's profit as

$$\Pi_b^{DS} = \underbrace{\frac{(1+\alpha)^2(1+\beta)^2}{(3+\alpha+\beta-\beta\alpha)^2 - 4(1-\alpha\beta)^2}}_{(1)} \underbrace{\frac{(3+\alpha+\beta-\beta\alpha)^2 - 4(1-\alpha\beta)^2}{(3+\alpha+\beta-\beta\alpha)^2}\frac{(p-c_a-c_s)^2}{2p}}_{(2)},$$

where the first term is the endogenous bargaining power of the buyer under the current setting, which determines her share of the total profit, and the second term is the total profit available for allocation. Similarly, we can derive the endogenous bargaining power of the other two parties. We can further show that when the parties negotiate prices only, the endogenous relative negotiation power of the buyer over the purchasing agent is $(1+\alpha)$ vs. $2(1-\alpha)$. From §4.1, we know that the endogenous relative negotiation power of the buyer over the purchasing agent is α vs. $1-\alpha$ when they negotiate over both prices and quantities. Clearly, $(1+\alpha)/2(1-\alpha) > \alpha/(1-\alpha)$. This implies that the buyer's bargaining power is *enhanced* when the parties negotiate prices only. That is, a weak buyer can benefit from negotiation over prices only. The major driving force is that in this game, the buyer now has the right to determine the ordering quantity q, which helps her gain the negotiation advantage. Note that if the negotiated wholesale prices do not favor the buyer, the buyer can always respond by placing a small order. This in turn hurts the profitability of the purchasing agent and the supplier.

5.2 Agent Sourcing ($\mathcal{AS}$)

Under $\mathcal{AS}$, the sequence of events is similar to that in §4.2, except that now the purchasing agent simultaneously negotiates the wholesale prices with the buyer and the supplier. The buyer then decides the ordering quantity. We solve this problem also by backward induction. When the demand is uniformly distributed between zero and one, the optimal ordering quantity can be derived as $q^{AS} = (p - \tilde{w}_a)/p$, and consequently, $\mu(q^{AS}) = [p^2 - \tilde{w}_a^2]/2p^2$. Thus, the profit functions of the three supply chain parties are, respectively,

$$\Pi_b = \frac{(p-\tilde{w}_a)^2}{2p},\ \Pi_a = \frac{(\tilde{w}_a - w_s - c_a)(p-\tilde{w}_a)}{p},\ \text{and } \Pi_s = \frac{(w_s - c_s)(p-\tilde{w}_a)}{p}.$$

Note that when there exists a component spot market, the purchasing agent holds an endogenous reservation profit d_a when negotiating with the supplier. We therefore compute d_a first. When the purchasing agent purchases the product from the spot market at a unit price c_p, the profits of the buyer and the purchasing agent become, respectively,

$$\Pi_b = \frac{(p-\tilde{w}_a)^2}{2p},\ \Pi_a = \frac{(\tilde{w}_a - c_p - c_a)(p-\tilde{w}_a)}{p}.$$

They negotiate the wholesale price by solving the following Nash product:

$$\operatorname*{Max}_{\tilde{w}_a} \quad \Omega_{ba} = [\Pi_b]^{\alpha}[\Pi_a]^{1-\alpha} = \frac{1}{2^{\alpha}p}(p-\tilde{w}_a)^{1+\alpha}(\tilde{w}_a - c_a - c_p)^{1-\alpha}.$$

Consequently, the negotiated wholesale price $\tilde{w}_a = ((1-\alpha)p + (1+\alpha)(c_p + c_a))/2$ and the corresponding profit of the purchasing agent $\Pi_a^r = (1-\alpha^2)(p - c_a - c_p)^2/4p$. Therefore, the reservation profit of the purchasing agent is $d_a = \Pi_a^r = (1-\alpha^2)(p-c_a-c_p)^2/4p$.

We now solve the two bilateral bargaining games among the three players. The purchasing agent negotiates with the buyer and the supplier over the wholesale prices simultaneously by solving the following optimization problems:

$$\underset{\tilde{w}_a}{\text{Max}} \quad \Omega_{ba} = [\Pi_b]^\alpha [\Pi_a]^{1-\alpha} = \left[\frac{(p-\tilde{w}_a)^2}{2p}\right]^\alpha \left[\frac{(\tilde{w}_a - w_s - c_a)(p-\tilde{w}_a)}{p}\right]^{1-\alpha},$$

$$\underset{w_s}{\text{Max}} \quad \Omega_{as} = [\Pi_a - d_a]^\gamma [\Pi_s]^{1-\gamma} = \left[\frac{(\tilde{w}_a - w_s - c_a)(p-\tilde{w}_a)}{p} - d_a\right]^\gamma \left[\frac{(w_s - c_s)(p-\tilde{w}_a)}{p}\right]^{1-\gamma}.$$

Again, unfortunately, Ω_{as} is not necessarily concave/unimodal in w_s when the reservation profit level $d_a \neq 0$. We thus assume that there does not exist a product spot market to derive some analytical results. We rely on the numerical experiments to examine the case when there exists a product spot market in the later section.

Lemma 6 *Assume that there is no component spot market, the supply chain parties negotiate over wholesale prices only, and the demand is uniformly distributed in* $[0, 1]$*. Under* $\mathcal{AS}$*,*

(1) the equilibrium wholesale prices and the optimal ordering quantity are, respectively,

$$\tilde{w}_a^{AS} = \frac{1-\alpha}{1+\gamma-\alpha+\alpha\gamma}(p-c_a-c_s)+(c_a+c_s);\, w_s^{AS} = \frac{(1-\gamma)(1-\alpha)}{1+\gamma-\alpha+\alpha\gamma}(p-c_a-c_s)+c_s;\, q^{AS} = \frac{\gamma(1+\alpha)(p-c_a-c_s)}{(1+\gamma-\alpha+\alpha\gamma)p}.$$

(2) the entire supply chain cannot achieve the centralized supply chain performance, and the profit allocation among the three parties is

$$\Pi_b^{AS} = \frac{\gamma^2(1+\alpha)^2(p-c_a-c_s)^2}{2p(1+\gamma-\alpha+\alpha\gamma)^2};\, \Pi_a^{AS} = \frac{(1-\alpha^2)\gamma^2(p-c_a-c_s)^2}{(1+\gamma-\alpha+\alpha\gamma)^2 p};\, \Pi_s^{AS} = \frac{\gamma(1-\gamma)(1-\alpha^2)(p-c_a-c_s)^2}{(1+\gamma-\alpha+\alpha\gamma)^2 p}.$$

Similar to that under $\mathcal{DS}$ (see §5.1), the profit margins of the purchasing agent ($\tilde{w}_a^{AS} - c_a - w_s^{AS}$) and the supplier ($w_s^{AS} - c_s$) under $\mathcal{AS}$ are also *proportional* to that of the entire supply chain ($p - c_a - c_s$). We can also rewrite the profits of three parties to derive their endogenized bargaining powers. Take the buyer as an example. Her profit can be rewritten as

$$\Pi_b^{AS} = \underbrace{\frac{\gamma^2(1+\alpha)^2}{(1+\gamma-\alpha+\alpha\gamma)^2-(1-\alpha)^2}}_{(1)} \underbrace{\frac{(1+\gamma-\alpha+\alpha\gamma)^2-(1-\alpha)^2}{(1+\gamma-\alpha+\alpha\gamma)^2}\frac{(p-c_a-c_s)^2}{2p}}_{(2)},$$

where the first term is her endogenized bargaining power under $\mathcal{AS}$, and the second term is the total profit available for allocation among the three parties. It can be shown that the endogenized relative bargaining power of the buyer over the purchasing agent remains $(1+\alpha)$ vs. $2(1-\alpha)$, the same as that under $\mathcal{DS}$. Again, negotiation over price only enables the buyer to enhance her negotiation power over the purchasing agent.

5.3 Comparison of Two Procurement Outsourcing Structures

We now compare the supply chain parties' preferences between $\mathcal{DS}$ and $\mathcal{AS}$ when they negotiate over the prices only.

5.3.1 Without a spot market

When there is no component spot market, a comparison of the three parties' expected profits under $\mathcal{DS}$ and $\mathcal{AS}$ leads to the following result.

Proposition 2 *Assume that there is no component spot market. When the parties contract over prices only, the buyer and the purchasing agent prefer* $\mathcal{AS}$ *if* $\gamma \in \left[\frac{(1-\alpha)(1-\beta)}{2(1-\alpha\beta)}, 1\right]$*; otherwise, they prefer* $\mathcal{DS}$*. The supplier prefers* $\mathcal{AS}$ *if* $\gamma \in \left[\frac{1-\beta+\alpha^2\beta-\alpha^2}{5+3\beta+\alpha^2\beta-\alpha^2}, \frac{(1-\alpha)(1-\beta)}{2(1-\alpha\beta)}\right]$*; otherwise, the supplier prefers* $\mathcal{DS}$*.*

Proposition 2 shows that given the parameter values of α and β, there exists a threshold with respect to γ (the pairwise relative bargaining power of the purchasing agent over the supplier), above which both the buyer and the purchasing agent prefer $\mathcal{AS}$. The supplier's preference for $\mathcal{AS}$ exhibits a U-shaped curve in γ: when γ is in a moderate range, the supplier prefers $\mathcal{AS}$ and, otherwise, prefers $\mathcal{DS}$. Note that the preference of the supplier is driven by a tradeoff between the profit margin and the ordering quantity. If γ is too large, the supplier could not negotiate a favorable wholesale price with the purchasing agent; if γ is too small, although the supplier's negotiated profit margin can be high, the optimal ordering quantity q^{AS} is small, as q^{AS} increases in γ. Both hurt the supplier's profitability, and hence, the supplier prefers $\mathcal{DS}$. It is worth noting that when γ is small ($\gamma < (1-\beta+\alpha^2\beta-\alpha^2)/(5+3\beta+\alpha^2\beta-\alpha^2)$), the incentives of the three parties are *aligned*, and they all prefer $\mathcal{DS}$.

The forgoing findings are qualitatively similar to those in Proposition 1. The only difference lies in the *degree of the sensitivity* of the parties's preferences over the two procurement outsourcing structures when their relative bargaining powers change.

5.3.2 With a spot market

When there exists a component spot market and the negotiation is over prices only, the three-party bilateral bargaining problem cannot be analytically solved. We thus compare the performance of two sourcing structures based on observations in a numerical study. We conduct extensive numerical experiments by varying the bargaining power parameters while fixing the production costs, the retail price and the spot market price, as listed in Table 1. The parameter values are set in alignment with the 2009-2018 statistical data from *Financial Times*, where the average profit margin of Li & Fung in the past ten years is 12.93% and that of Walmart is 25.13%. In all scenarios studied, the market demand is uniformly distributed between zero and one. A positive unit profit margin for each party and a high component price from the spot market[3] are required to ensure the participation of the supply chain parties. In total, we have 307,885 feasible combinations.

Table 1: Summary of Parameters

Spot Price:	$c_p \in [2, 2.3]$, step length=0.05
Retail Price	$p = 3.5, 4, 4.5, 5$
Bargaining Powers:	$\alpha \in [0, 1]$, step length=0.01 $\gamma \in [0, 1]$, step length=0.01
Costs:	$c_a \in [1, 1.3]$, step length=0.05 $c_s \in [1, 1.3]$, step length=0.05

The numerical results show that the preference of each party when there is a component spot market remains the same as that stated in Proposition 2 when there is no such spot market. That is, there exist some threshold values over γ, above which the buyer and the purchasing agent prefer $\mathcal{AS}$, and below which they prefer $\mathcal{DS}$. In contrast, the supplier prefers $\mathcal{AS}$ when γ is in a moderate range. See Figure 2 for an illustration.

Figure 2: Preference between $\mathcal{DS}$ and $\mathcal{AS}$: $p = 4.5$, $\alpha = 0.55$, $\beta = 0.45$, $c_p = 2.3$, $c_a = 1.3$ and $c_s = 1.3$

6 Concluding Remarks

In this paper, we consider a supply chain consisting of a buyer, a purchasing agent, and a supplier and study whether the buyer shall outsource the procurement function to the purchasing agent ($\mathcal{AS}$) or keep it in-house ($\mathcal{DS}$). The players contract pairwisely and are engaged in bilateral negotiation.

Assume that there exists a spot market for the supplier's component. When the parties negotiate over both wholesale prices and production quantities, we show that the GNB can coordinate

[3]Here, the negotiated component price from the supplier is the equilibrium result, which is a function of the exogenously given parameters. Since there is no analytical solution, we posit a requirement of high component price from the spot market in our numerical analysis.

the entire supply chain to achieve the centralized performance under both sourcing structures. We derive the endogenous bargaining powers of the three parties under both sourcing structures and show that there exists a reservation profit spillover effect. The reservation profit arising from the spot market hurts the supplier's bargaining position and impairs its profitability. The allocation of the total supply chain profit (after extracting the reservation profit) among the three parties is fully determined by their endogenous bargaining powers. The preference over the two outsourcing structures solely depends on the comparison result of a party's direct negotiation coefficient with another party versus their indirect negotiation coefficient when they contract indirectly. We show that the buyer's procurement outsourcing decisions can be very sensitive to the relative bargaining powers of the supply chain parties, especially when the buyer is powerful. This might help explain why Walmart switched from outsourcing its procurement function to Li & Fung to in-house procurement within just three years. The results regarding the buyer's preference over the two sourcing structures remain robust, regardless of whether the demand is price-independent or iso-price-elastic.

When the parties negotiate over wholesale prices only and the production quantity is decided by the buyer afterwards, the GNB-induced wholesale price fails to coordinate the entire supply chain. Regarding a party's preference for a procurement outsourcing structure, we find that the incentives of the buyer and the purchasing agent are aligned, following a threshold-type policy with respect to the purchasing agent's relative bargaining power over the supplier, assuming that other parameters are fixed. In contrast, the supplier's preference is U-shaped: it prefers agent sourcing when the purchasing agent's relative bargaining power over it is moderate and prefers direct sourcing otherwise. Interestingly, there are scenarios where the incentives of the three parties are aligned with respect to their preferences over the procurement structures.

In Sections 4 and 5, we consider bargaining over both price and quantity and bargaining over price only, respectively. A natural research question thus arises: which contract structure does the buyer prefer for bargaining? As shown in our online Appendix B, we find that the buyer prefers to negotiate prices only. The key driving force behind this is the buyer's decision power over the ordering quantity. When parties negotiate over both prices and quantities, the ordering quantity is always the optimal centralized quantity, which coordinates the whole supply chain. When parties negotiate over prices only, the ordering quantity from the buyer, however, is different from the system-optimal one. This implies that the buyer's quantity decision power improves her profitability. As the total profit under Case P is smaller than that under Case P&Q, keeping the quantity decision to the buyer undoubtedly has an adverse effect on the purchasing agent and/or the supplier.

We conclude by some discussions on our model's limitations and their implications. First, in our baseline model, we have assumed that the component purchaser truthfully reports where the component is bought. We note that the verification of the supply source may be difficult under certain circumstances, and the purchaser may report its supply source untruthfully. Being aware of this, we provide an initial attempt to discuss such a scenario in the online Appendix B.2. We find that the incentive of reporting untruthfully, however, is highly affected by the cost difference between the spot market price and the supplier's production cost. This indicates that agent sourcing might result in a loss of control of the component price. Under such a scenario, the buyer may never adopt procurement outsourcing. Second, when the supplier's production cost is private information and the purchasing agent has better knowledge about it than the buyer, the presence of a product spot market actually bounds the information rent that the purchasing agent can extract from the buyer. This is because the component's spot market price acts as a reference price when a party negotiates with the supplier. This subsequently narrows the feasible range of the wholesale price offered to the supplier and thus reduces the information asymmetry arising from the unknown supplier production cost. We note that Chen et al. (2012) name this spot price "street price" and show that it plays an important role in contract design under procurement outsourcing. Third, we have assumed uniformly distributed demand under Case P for tractability. Generalizing this assumption would result in interesting results, which we leave for future research.

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Online Appendices

"Direct Sourcing or Agent Sourcing?

Contract Negotiation in Procurement Outsourcing "

Online Appendix A: Proofs

We first derive the buyer's reservation profit when purchasing from the spot market. Under $\mathcal{DS}$, the negotiation problem between the buyer and the purchasing agent becomes

$$\underset{(w_a,q_a)}{\text{Max}} \quad \Omega_{ba} = [\Pi_b]^\alpha [\Pi_a]^{1-\alpha} = [p\mu(q_a) - w_a q_a - c_p q_a]^\alpha [(w_a - c_a)q_a]^{1-\alpha}, \tag{4}$$

due to the ample capacity of the spot market. Solving (4) yields $w_a = c_a + (1-\alpha)(p\mu(q_a)/q_a - c_p - c_a)$. Thus, the buyer's profit function becomes $\Pi_b(q_a) = \alpha[p\mu(q_a) - (c_a + c_p)q_a]$ and the corresponding optimal ordering quantity is $q_a^* = q^r = \bar{F}^{-1}\left(\frac{c_p+c_a}{p}\right)$, where $q^r < q^*$. Thus, when the buyer purchases the component from the spot market, the supply chain profit

$$\Pi^r = p\mu(q^r) - (c_a + c_p)q^r$$

and the buyer's profit $\Pi_b^r = \alpha\Pi^r$. Therefore,

$$d_b = \Pi_b^r = \alpha\Pi^r.$$

Under $\mathcal{AS}$, if the purchasing agent purchases the component from the spot market rather than from the supplier, as the spot market is uncapacitated, the negotiation problem between the agent and the buyer becomes

$$\underset{(\tilde{w}_a,q_a)}{\text{Max}} \quad \Omega_{ba} = [\Pi_b]^\alpha [\Pi_a]^{1-\alpha} = [p\mu(q_a) - \tilde{w}_a q_a]^\alpha [(\tilde{w}_a - c_a - c_p)q_a]^{1-\alpha}.$$

Similarly, it can be shown that as the result of bargaining, the agent's profit is $\Pi_a^r = (1-\alpha)\Pi^r$. Consequently, $d_a = \Pi_a^r = (1-\alpha)\Pi^r$.

Proof of Lemma 1:

For each optimization problem jointly defined by (2) and (3), we adopt the following sequential optimization approach. First, we fix the quantity to derive the optimal wholesale price. Then we substitute this optimal price back into the Nash product to derive the optimal quantity. It can be easily shown that Nash products Ω_{ba} and Ω_{bs} are both log-concave in their respective wholesale prices. Taking the first-order conditions of $\log\Omega_{ba}$ and $\log\Omega_{bs}$ with respect to w_a and w_s, respectively, yields

$$\frac{(1-\alpha)q_a}{\Pi_a} - \frac{\alpha q_a}{\Pi_b} = 0 \Rightarrow \frac{\Pi_a}{\Pi_b} = \frac{1-\alpha}{\alpha}; \tag{5}$$

$$\frac{(1-\beta)q_s}{\Pi_s} - \frac{\beta q_s}{\Pi_b - d_b} = 0 \Rightarrow \frac{\Pi_s}{\Pi_b - d_b} = \frac{1-\beta}{\beta}. \tag{6}$$

Recall that $d_b = \alpha\Pi^r$. Therefore, as a result of price negotiation, the profits of three parties are all proportional to each other. Consequently, an ordering quantity that maximizes the sum of the three parties' profits also maximizes the sum of any pair's profits. In other words, the negotiation outcome over quantity among the three parties is $q_a = q_s = q^*$, which is the first best solution, so the supply chain is coordinated.

We now derive the wholesale prices as follows:

$$\begin{aligned} w_s q^* &= \beta c_s q^* + (1-\beta)(p\mu(q^*) - w_a q^* - d_b); \\ w_a q^* &= \alpha c_a q^* + (1-\alpha)(p\mu(q^*) - w_s q^*). \end{aligned}$$

Solving them simultaneously yields

$$w_a^{DS} = c_a + \frac{(1-\alpha)\beta}{\alpha+\beta-\alpha\beta}\left(p\frac{\mu(q^*)}{q^*} - c_a - c_s\right) + \frac{(1-\alpha)(1-\beta)}{\alpha+\beta-\alpha\beta}\frac{d_b}{q^*} = c_a + \frac{(1-\alpha)\left(\beta\Pi + (1-\beta)\alpha\Pi^r\right)}{(\alpha+\beta-\alpha\beta)q^*}; \quad (7)$$

$$w_s^{DS} = c_s + \frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}\left(p\frac{\mu(q^*)}{q^*} - c_a - c_s\right) - \frac{1-\beta}{\alpha+\beta-\alpha\beta}\frac{d_b}{q^*} = c_s + \frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}\frac{\Pi - \Pi^r}{q^*}. \quad (8)$$

Taking a close look at (7) and (8) shows that the negotiated wholesale price of the purchasing agent/supplier under $\mathcal{DS}$ is composed of three components: the unit cost of the party of concern, a share of the unit-expected supply chain profit margin $p\frac{\mu(q^*)}{q^*} - c_a - c_s$, and a price increment/reduction term due to the existence of the outside option. Compared to the case when there is no component spot market ($d_b = 0$), the existence of such a market ($d_b > 0$) entices the purchasing agent to negotiate a higher wholesale price while dampens the price negotiation of the supplier. We can also show that the optimal wholesale prices w_a^{Di} and w_s^{Di} decrease in the buyer's pair-specific negotiation power α and β, respectively. That is, the buyer pays lower wholesale prices when her negotiation power is larger.

By plugging w_a^{DS} and w_s^{DS} into the supply chain parties' profit functions, the outcomes in Lemma 1 can be easily obtained.

Proof of Lemma 2 The derivation of the GNB-induced wholesale prices and corresponding ordering quantities and profits is similar to that of Lemma 1. Thus, we omit the details here.

Proof of Proposition 1: As the optimal negotiation sequence for the purchasing agent is simultaneous negotiation (Remark 3). Below we compare the profits of the three parties under $\mathcal{DS}$ and

$\mathcal{AS}$ considering the simultaneous negotiation and the non-existence of the spot market.

$$\begin{aligned}
\Pi_b^{AS} - \Pi_b^{DS} &= \frac{\frac{\alpha}{1-\alpha}\frac{\gamma}{1-\gamma}\frac{\beta}{1-\beta}}{(1-\alpha+\alpha\gamma)(\alpha+\beta-\alpha\beta)}\alpha(1-\alpha)(1-\beta)(1-\gamma)\Pi; \\
\Pi_a^{AS} - \Pi_a^{DS} &= \frac{\frac{\alpha}{1-\alpha}\frac{\gamma}{1-\gamma} - \frac{\beta}{1-\beta}}{(1-\alpha+\alpha\gamma)(\alpha+\beta-\alpha\beta)}(1-\alpha)^2(1-\beta)(1-\gamma)\Pi; \\
\Pi_s^{DS} - \Pi_s^{AS} &= \frac{\frac{\beta}{1-\beta} - \frac{\alpha}{1-\alpha}\frac{\gamma}{1-\gamma}}{(1-\alpha+\alpha\gamma)(\alpha+\beta-\alpha\beta)}(1-\alpha)(1-\beta)(1-\gamma)\Pi.
\end{aligned}$$

Easily we can derive the decision rule stated in the proposition.

When there is a spot market, we compare the supply chain parties' preferences over $\mathcal{DS}$ and $\mathcal{AS}$, finding that

$$\begin{aligned}
\Pi_b^{DS} - \Pi_b^{AS} &= \left[\frac{\alpha\beta}{\alpha+\beta-\alpha\beta}(\Pi - d_b) + \frac{\alpha}{\alpha+\beta-\alpha\beta}d_b\right] - \left[\frac{\alpha\gamma}{1-\alpha+\alpha\gamma}(\Pi - d_a) + \frac{\alpha}{1-\alpha+\alpha\gamma}d_a\right] \\
&= \left[\frac{\alpha\beta}{\alpha+\beta-\alpha\beta}\Pi + \frac{\alpha(1-\beta)}{\alpha+\beta-\alpha\beta}\alpha\Pi^r\right] - \left[\frac{\alpha\gamma}{1-\alpha+\alpha\gamma}\Pi + \frac{\alpha(1-\gamma)}{1-\alpha+\alpha\gamma}(1-\alpha)\Pi^r\right] \\
&= \left(\beta - \frac{\alpha\gamma}{1-\alpha-\gamma+2\alpha\gamma}\right)\frac{(1-\alpha-\gamma+2\alpha\gamma)\alpha}{(\alpha+\beta-\alpha\beta)(1-\alpha+\alpha\gamma)}(\Pi - \Pi^r).
\end{aligned}$$

Therefore, the buyer prefers adopting $\mathcal{AS}$ ($\mathcal{DS}$) if $\beta \le (>) \frac{\alpha\gamma}{1-\alpha-\gamma+2\alpha\gamma}$, which is equivalent to $\frac{\alpha}{1-\alpha}\cdot\frac{\gamma}{1-\gamma} \ge (<) \frac{\beta}{1-\beta}$. Similarly, we have

$$\begin{aligned}
\Pi_a^{DS} - \Pi_a^{AS} &= \left[\frac{(1-\alpha)\beta}{\alpha+\beta-\alpha\beta}(\Pi - d_b) + \frac{1-\alpha}{\alpha+\beta-\alpha\beta}d_b\right] - \left[\frac{\gamma(1-\alpha)}{1-\alpha+\alpha\gamma}(\Pi - d_a) + \frac{1-\alpha}{1-\alpha+\alpha\gamma}d_a\right] \\
&= \left[\frac{(1-\alpha)\beta}{\alpha+\beta-\alpha\beta}\Pi + \frac{(1-\alpha)(1-\beta)}{\alpha+\beta-\alpha\beta}\alpha\Pi^r\right] - \left[\frac{\gamma(1-\alpha)}{1-\alpha+\alpha\gamma}\Pi + \frac{(1-\alpha)(1-\gamma)}{1-\alpha+\alpha\gamma}(1-\alpha)\Pi^r\right] \\
&= \left(\beta - \frac{\alpha\gamma}{1-\alpha-\gamma+2\alpha\gamma}\right)\frac{(1-\alpha-\gamma+2\alpha\gamma)(1-\alpha)}{(\alpha+\beta-\alpha\beta)(1-\alpha+\alpha\gamma)}(\Pi - \Pi^r); \\
\Pi_s^{DS} - \Pi_s^{AS} &= \left[\frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}(\Pi - d_b) - \frac{(1-\alpha)(1-\beta)}{\alpha+\beta-\alpha\beta}d_b\right] - \left[\frac{(1-\gamma)(1-\alpha)}{1-\alpha+\alpha\gamma}(\Pi - d_a) - \frac{\alpha(1-\gamma)}{1-\alpha+\alpha\gamma}d_a\right] \\
&= \left[\frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}\Pi - \frac{1-\beta}{\alpha+\beta-\alpha\beta}\alpha\Pi^r\right] - \left[\frac{(1-\gamma)(1-\alpha)}{1-\alpha+\alpha\gamma}\Pi - \frac{(1-\alpha)(1-\gamma)}{1-\alpha+\alpha\gamma}\Pi^r\right] \\
&= -\left(\beta - \frac{\alpha\gamma}{1-\alpha-\gamma+2\alpha\gamma}\right)\frac{1-\alpha-\gamma+2\alpha\gamma}{(\alpha+\beta-\alpha\beta)(1-\alpha+\alpha\gamma)}(\Pi - \Pi^r).
\end{aligned}$$

It can be easily shown that the preference of the purchasing agent over $\mathcal{AS}$ and $\mathcal{DS}$ is the same as that of the buyer, while that of the supplier is just the opposite.

Proof of Lemma 3: As $d_b = \alpha\Pi^r$ and $d_a = (1-\alpha)\Pi^r$, Lemma 3 can be easily derived.

Proof of Lemma 4: Let's start with the buyer. The buyer's effective reservation profit under $\mathcal{DS}$ is $\frac{\alpha}{\alpha+\beta-\alpha\beta}d_b = \frac{\alpha^2}{\alpha+\beta-\alpha\beta}\Pi^r$. Her additional profit gain due to the reservation profit spillover effect under $\mathcal{AS}$ is $\frac{\alpha}{1-\alpha+\alpha\gamma}d_a = \frac{\alpha(1-\alpha)}{1-\alpha+\alpha\gamma}\Pi^r$. We can show that

$$\begin{aligned}\frac{\alpha}{1-\alpha+\alpha\gamma}d_a - \frac{\alpha}{\alpha+\beta-\alpha\beta}d_b &= \frac{\alpha[(1-\alpha)(\alpha+\beta-\alpha\beta)-\alpha(1-\alpha+\alpha\gamma)]}{(\alpha+\beta-\alpha\beta)(1-\alpha+\alpha\gamma)}\Pi^r \\ &= \frac{\alpha[\beta(1-\alpha)^2-\alpha^2\gamma]}{(\alpha+\beta-\alpha\beta)(1-\alpha+\alpha\gamma)}\Pi^r \\ &= -\frac{\alpha\gamma(1-\alpha)^2\left[\left(\frac{\alpha}{1-\alpha}\right)^2-\frac{\beta}{\gamma}\right]}{(\alpha+\beta-\alpha\beta)(1-\alpha+\alpha\gamma)}\Pi^r.\end{aligned}$$

Thus the buyer's additional profit under $\mathcal{AS}$ is weakly higher (lower) than that under $\mathcal{DS}$ if $\frac{\alpha}{1-\alpha} \le (>)\sqrt{\frac{\beta}{\gamma}}$.

Similarly, the purchasing agent's additional profit gains due to the reservation profit spillover effect under $\mathcal{DS}$ is $\frac{1-\alpha}{\alpha+\beta-\alpha\beta}d_b = \frac{\alpha(1-\alpha)}{\alpha+\beta-\alpha\beta}\Pi^r$. His effective reservation profit under $\mathcal{AS}$ is $\frac{1-\alpha}{1-\alpha+\alpha\gamma}d_a = \frac{(1-\alpha)^2}{1-\alpha+\alpha\gamma}\Pi^r$. We have

$$\begin{aligned}\frac{1-\alpha}{1-\alpha+\alpha\gamma}d_a - \frac{1-\alpha}{\alpha+\beta-\alpha\beta}d_b &= -\frac{(1-\alpha)[\alpha(1-\alpha+\alpha\gamma)-(1-\alpha)(\alpha+\beta-\alpha\beta)]}{(\alpha+\beta-\alpha\beta)(1-\alpha+\alpha\gamma)}\Pi^r \\ &= -\frac{(1-\alpha)[\alpha^2\gamma-\beta(1-\alpha)^2]}{(\alpha+\beta-\alpha\beta)(1-\alpha+\alpha\gamma)}\Pi^r \\ &= -\frac{\gamma(1-\alpha)^3\left[\left(\frac{\alpha}{1-\alpha}\right)^2-\frac{\beta}{\gamma}\right]}{(\alpha+\beta-\alpha\beta)(1-\alpha+\alpha\gamma)}\Pi^r.\end{aligned}$$

Thus, the purchasing agent's additional profit under $\mathcal{AS}$ is weakly higher (lower) than that under $\mathcal{DS}$ if $\frac{\alpha}{1-\alpha} \le (>)\sqrt{\frac{\beta}{\gamma}}$.

Proof of Lemma 5: When the parties negotiate over prices only, the buyer negotiates with the purchasing agent over w_a and the supplier over w_s simultaneously. Solving the Nash product between the buyer and the purchasing agent

$$\begin{aligned}\underset{w_a}{\text{Max}} \quad \Omega_{ba} &= [\Pi_b]^\alpha[\Pi_a]^{1-\alpha} = \left[\frac{(p-w_a-w_s)^2}{2p}\right]^\alpha \left[\frac{(w_a-c_a)(p-w_a-w_s)}{p}\right]^{1-\alpha} \\ &= \frac{(p-w_a-w_s)^{1+\alpha}(w_a-c_a)^{1-\alpha}}{2^\alpha p},\end{aligned}$$

yields $w_a(w_s) = \frac{(1-\alpha)(p-w_s)+(1+\alpha)c_a}{2}$. Similarly, solving the Nash product between the buyer and the supplier

$$\begin{aligned}\underset{(w_s)}{\text{Max}} \quad \Omega_{bs} &= [\Pi_b]^\alpha[\Pi_s]^{1-\beta} = \left[\frac{(p-w_a-w_s)^2}{2p}\right]^\beta \left[\frac{(w_s-c_s)(p-w_a-w_s)}{p}\right]^{1-\beta} \\ &= \frac{(p-w_a-w_s)^{1+\beta}(w_s-c_s)^{1-\beta}}{2^\beta p},\end{aligned}$$

yields $w_s(w_a) = \frac{(1-\beta)(p-w_a)+(1+\beta)c_s}{2}$. Solving $w_a(w_s)$ and $w_s(w_a)$ simultaneously, we have

$$w_a^{DS} = \frac{(1-\alpha)(1+\beta)}{3+\alpha+\beta-\alpha\beta}(p-c_a-c_s)+c_a; \quad w_s^{DS} = \frac{(1+\alpha)(1-\beta)}{3+\alpha+\beta-\alpha\beta}(p-c_a-c_s)+c_s.$$

Correspondingly, we get $q^{DS} = \frac{(1+\alpha)(1+\beta)(p-c_a-c_s)}{(3+\alpha+\beta-\alpha\beta)p}$. The profits of three parties can then be derived via substituting them into their profit functions.

Proof of Lemma 6: The derivation of the GNB-induced wholesale prices and corresponding ordering quantities and profits is similar to that of Lemma 5. Thus we omit the details here.

Proof of Proposition 2: We now compare the profits of three parties under $\mathcal{DS}$ and $\mathcal{AS}$. As to the buyer, we have

$$\begin{aligned}\Pi_b^{DS} - \Pi_b^{AS} &= \frac{(1+\alpha)^2[(1+\beta)(1+\gamma-\alpha+\alpha\gamma)+\gamma(3+\alpha+\beta-\alpha\beta)]}{2p(3+\alpha+\beta-\alpha\beta)^2} \\ &\quad \times \frac{(p-c_a-c_s)^2[(1+\beta)(1+\gamma-\alpha+\alpha\gamma)-\gamma(3+\alpha+\beta-\alpha\beta)]}{(1+\gamma-\alpha+\alpha\gamma)^2}.\end{aligned}$$

Therefore, $\Pi_b^{DS} - \Pi_b^{AS} \le 0$ if $\gamma(3+\alpha+\beta-\alpha\beta) \ge (1+\beta)(1+\gamma-\alpha+\alpha\gamma)$, which can be further simplified to $\gamma \ge \frac{(1-\alpha)(1-\beta)}{2(1-\alpha\beta)}$. It can be shown that $\frac{(1-\alpha)(1-\beta)}{2(1-\alpha\beta)} \le 1$. Thus, the buyer prefers $\mathcal{AS}$ over $\mathcal{DS}$ if $\gamma \in \left[\frac{(1-\alpha)(1-\beta)}{2(1-\alpha\beta)}, 1\right]$.

Next we compare Π_a^{DS} with Π_a^{AS} for the purchasing agent and can derive the same result as that of the buyer. As to the supplier,

$$\begin{aligned}\Pi_s^{AS} - \Pi_s^{DS} &= -\frac{(1+\alpha)[2(1-\alpha\beta)\gamma-(1-\alpha)(1-\beta)]}{(1+\gamma-\alpha+\alpha\gamma)^2 p} \\ &\quad \times \frac{(p-c_a-c_s)^2[(5+3\beta+\alpha^2\beta-\alpha^2)\gamma-(1-\beta+\alpha^2\beta-\alpha^2)]}{(3+\alpha+\beta-\alpha\beta)^2}.\end{aligned}$$

Letting $\Pi_s^{AS} - \Pi_s^{DS} = 0$, we obtain two roots $\gamma_1 = \frac{(1-\alpha)(1-\beta)}{2(1-\alpha\beta)}$, $\gamma_2 = \frac{1-\beta+\alpha^2\beta-\alpha^2}{5+3\beta+\alpha^2\beta-\alpha^2}$. Note that

$$\gamma_2 - \gamma_1 = \frac{(1-\alpha)(1-\beta)(-3-3\beta-3\alpha^2\beta-2\alpha\beta+2\alpha+\alpha^2)}{2(1-\alpha\beta)(5+3\beta+\alpha^2\beta-\alpha^2)} < 0.$$

Thus, the supplier prefers $\mathcal{AS}$ over $\mathcal{DS}$ if $\gamma \in (\gamma_2, \gamma_1)$.

Appendix B: Further Discussions

B.1: Sequence of Contract Negotiation

There are two bilateral negotiation processes under either $\mathcal{DS}$ or $\mathcal{AS}$. The party involved in both negotiation processes and in contracting with the other two parties is the *contract coordinator*. The other two parties only contract/negotiate with the contract coordinator and are called *non-coordinators*. Specifically, the contract coordinator is the buyer under $\mathcal{DS}$ and the purchasing agent under $\mathcal{AS}$. Ideally, the contract coordinator can negotiate *sequentially* or *simultaneously* with the non-coordinators, resulting in three possible contracting processes. Take the $\mathcal{DS}$ sourcing structure as an example. The following three sequences of contract negotiation are possible. (1) $\mathcal{DS}$ *sequence 1*: the buyer contracts and negotiates with the purchasing agent and the supplier simultaneously; (2) $\mathcal{DS}$ *sequence 2*: the buyer contracts and negotiates with the purchasing agent first, then the buyer contracts and negotiates with the supplier; and (3) $\mathcal{DS}$ *sequence 3*: the buyer contracts and negotiates with the supplier first, then the buyer contracts and negotiates with the purchasing agent. Similar sequences can be defined for the $\mathcal{AS}$ sourcing structure.

Having said that, in practice, not all aforementioned negotiation sequences are reasonable. Under $\mathcal{DS}$, the buyer usually negotiates with the supplier (for its component) and the purchasing agent (for his complementary services) simultaneously. Under $\mathcal{AS}$, the purchasing agent, acting as the contract coordinator, is less likely to negotiate with the supplier first. In Remark 3, we investigate the possible negotiation sequences and assume that the contract coordinator decides which sequence to adopt. That is, *the contract negotiation sequence is an endogenous decision made by the contract coordinator*. This is a natural setup because the contract coordinator in question negotiates with the other two parties and thus should have the discretion of selecting the sequence.

Remark 3 *When the parties negotiate over both price and quantity, under $\mathcal{DS}$, the buyer is better off with negotiating with the other two parties simultaneously than sequentially; and under $\mathcal{AS}$, the purchasing agent also prefers negotiating with other parties simultaneously.*

The above remark shows that in equilibrium the buyer under $\mathcal{DS}$ and the purchasing agent under $\mathcal{AS}$ both prefer simultaneous negotiation. The main reason is that the contract coordinator enjoys a larger endogenous bargaining power under the simultaneous negotiation.

If the buyer and the agent negotiate over price-only, we first study the scenario without a spot market and have the following Remark 4.

Remark 4 *Suppose the supply chain parties negotiate over wholesale prices only. When the demand is uniformly distributed in* $[0, 1]$ *and there is no component spot market, under $\mathcal{DS}$ ($\mathcal{AS}$, respectively) the buyer (the purchasing agent, respectively) prefers simultaneously negotiating with the other two parties. This result is consistent with that in Remark 3.*

In the presence of a spot market, we use the parameters shown in Table 1 to conduct extensive numerical studies under $\mathcal{AS}$. We observe that with a component spot market, *the purchasing agent* *still prefers simultaneously negotiating with the other two parties*, which is the same as when there is no such a spot market (see Remark 4). In all the 307,885 feasible combinations, compared with the sequential negotiation, the purchasing agent's profit under the simultaneous negotiation improves by 4.39% on average, with a maximum of 8.61%, a minimum of 0%, and a median of 4.41%. We further study the impact of demand uncertainty by letting the demand variance σ^2 be the x-axis and $\Pi_a^{AS} - \Pi_a^{Aq}$ be the y-axis (Π_a^{Aq} is the agent's profit under sequential negotiation). We observe that the advantage of simultaneous negotiation becomes large when the demand variance is high. This is because the total order size is reduced due to the high demand uncertainty, which weakens the agent's bargaining advantage over the supplier in sequential negotiation and hence, makes simultaneous negotiation more attractive. See Figure 3 for an illustration, in which we assume that demand follows a normal distribution with mean $\mu = 0.5$ but truncated at point zero due to its non-negativity.

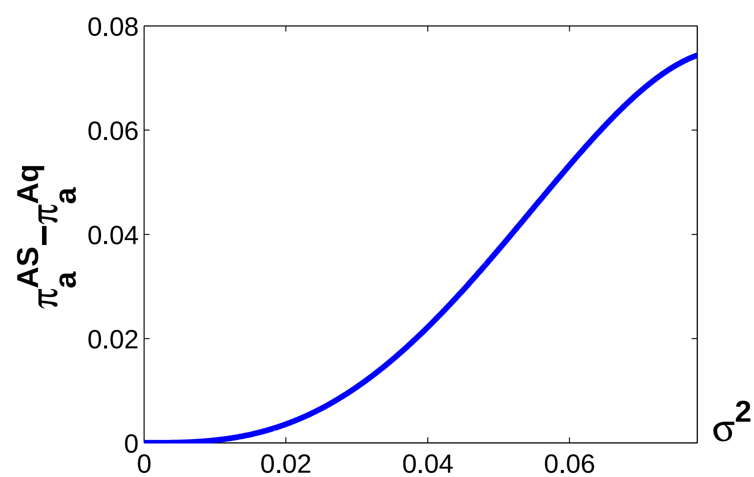

Figure 3: Impact of demand variance on the agent's preference of negotiation sequence: $\alpha = 0.51$; $\gamma = 0.57$; $c_a = 1.3$; $c_s = 1.3$; $c_p = 2.3$; $p = 5$; $\mu = 0.5$

Next, we extend our baseline model to discuss other related issues. First, with the existence of a spot market, will the buyer/agent provide the untruthful supply information to the purchasing agent/buyer that the negotiated price is simply the spot market price although she/he actually purchases the component from the supplier? Second, if the component cost information is private and the purchasing agent has better information about it than the buyer, how will it affect our baseline results? Third, we extend the analysis to the price-sensitive demand. Last, we discuss *what to negotiate*.

B.2: Will the Buyer Provide Untruthful Supply Information?

In the main content, we have assumed that parties are honest and the negotiated outcome between one pair of players is honestly revealed to the third party. Here, we relax this assumption and examine whether the buyer has the incentive to provide untruthful supply information about where she buys the component, from the supplier or from the spot market. We also assume that the supplier knows the buyer's intention to misrepresent. Without loss of generality, c_p is required to be sufficiently high, because, otherwise, the buyer simply buys the component from the spot market. We now investigate whether the buyer will provide untruthful information to the purchasing agent that she buys the component from the spot market with price c_p. Note that in practice, *it might be difficult to do so when the components purchased from the spot market have different logos and packages and delivered from different locations from those purchased from the supplier.*

B.2.1: Negotiation over both prices and quantities

First, we consider that the buyer purchases the component from the spot market and informs the purchasing agent honestly. Then, regarding the negotiation between the buyer and the purchasing agent, according to the analysis in §4.1, it can be shown that $w_a^{DS} = c_a + (1-\alpha)\left(p\mu(q_a^{DS})/q_a^{DS} - c_p - c_a\right)$, and the buyer's ordering quantity $q_a^{DS} = \bar{F}^{-1}\left((c_p + c_a)/p\right)$, which is smaller than q^*.

Now, consider that the buyer purchases the component from the supplier. If the buyer decides to provide untruthful information to the purchasing agent that she buys the component from the spot market with price c_p, to make the untruthful supply information "credible", she has to order q_a^{DS} unit professional services from the purchasing agent. Keeping this in mind, the buyer shall order q_a^{DS} units from the supplier as well. We now solve the negotiation problem between the buyer and the supplier as follows:

$$\underset{w_s}{\text{Max}} \quad \Omega_{bs} \quad = \quad [\Pi_b - d_b]^\beta \, [\Pi_s]^{1-\beta} = \left[p\mu(q_a^{DS}) - w_a^{DS} q_a^{DS} - w_s q_a^{DS} - d_b\right]^\beta \left[(w_s - c_s) q_a^{DS}\right]^{1-\beta}.$$

Let the superscript DS' denote the results when the buyer provides untruthful supply information. Then, it can be shown that

$$w_s^{DS'} = \beta c_s + (1-\beta)\left[\frac{p\mu(q_a^{DS}) - w_a^{DS} q_a^{DS} - d_b}{q_a^{DS}}\right].$$

Thus, the buyer's profit becomes

$$\Pi_b^{DS'} = p\mu(q_a^{DS}) - w_a^{DS} q_a^{DS} - w_s^{DS'} q_a^{DS}.$$

In contrast, if the buyer purchases from the supplier and reveals this information honestly to the purchasing agent, then according to §4.1, her profit shall be

$$\Pi_b^{DS} = \frac{\alpha\beta}{\alpha+\beta-\alpha\beta}(\Pi - d_b) + \frac{\alpha}{\alpha+\beta-\alpha\beta}d_b.$$

By assuming demand follows a uniform distribution over the interval [0, 1], a comparison of $\Pi_b^{DS'}$ and Π_b^{DS} reveals that

$$\Pi_b^{DS'} \geq \Pi_b^{DS} \text{ if and only if (iff) } c_p - c_s \leq \frac{2\beta(1-\alpha)(p-c_a-c_s)}{\alpha+2\beta(1-\alpha)}.$$

This indicates that only when the difference between the spot market price and the supplier's production cost, $c_p - c_s$, is small will the buyer have the incentive to provide untruthful supply information. The underlying driving force is the tradeoff between the *diminished order quantity* and the *reduced wholesale price* from the buyer's untruthful supply information. The saving from a smaller wholesale price will dominate the loss from the reduced order quantity only when the difference is small. In addition, it can be easily verified that the condition for the preference of providing untruthful supply information is more likely to hold when the relative bargaining power of the buyer over the purchasing agent (α) is smaller and/or the relative bargaining power of the buyer over the purchasing agent (β) is larger. This is quite intuitive: a larger α indicates a smaller w_a, which reduces the buyer's incentive to provide untruthful supply information, while a larger β indicates a smaller w_s, which increases the buyer's incentive to provide untruthful supply information.

Next, we check how the buyer's untruthful supply information affects the profitability of the purchasing agent. We can show that

$$\Pi_a^{DS'} - \Pi_a^{DS} = -\frac{(1-\alpha)\beta[(p-c_a-c_p)+(p-c_a-c_s)](c_p-c_s)}{2p(\alpha+\beta-\alpha\beta)} < 0.$$

That is, the buyer's untruthful supply information always impairs the agent profitability. Again, the underlying driving forces are the diminished order quantity and the reduced wholesale price. Keeping this in mind, the purchasing agent has a stronger preference over $\mathcal{AS}$ when the buyer tends to provide untruthful supply information as

$$\Pi_a^{DS'} - \Pi_a^{AS} = -\frac{(1-\alpha)\gamma(c_p-c_s)[(p-c_a-c_p)+(p-c_a-c_s)]}{2p(1-\alpha+\alpha\gamma)} < 0.$$

B.2.2: Negotiation over prices only

Similarly, here we first consider that the buyer purchases the component from the spot market and informs the purchasing agent honestly. Assume the demand is uniformly distributed between zero and one. Then, regarding the negotiation between the buyer and the purchasing agent, according to the analysis in §5.1, it can be shown that $w_a^{DS} = ((1-\alpha)(p-c_p)+(1+\alpha)c_a)/2$ and the buyer's ordering quantity $q_a^{DS} = (1+\alpha)(p-c_p-c_a)/2p$, which is smaller than q^*. Then, the reservation profit of the buyer is $\Pi_b^r = (1+\alpha)^2(p-c_a-c_p)/8p$.

Now, consider that the buyer purchases the component from the supplier. If the buyer decides to provide untruthful supply information to the purchasing agent that she buys the component from the spot market with price c_p, to make the untruthful supply information "credible", she has to order q_a^{DS} unit professional services from the purchasing agent. Keeping this in mind, the buyer shall order q_a^{DS} units from the supplier as well. We then solve the negotiation problem between the buyer and the supplier. The buyer and the supplier negotiate over w_s and it can be derived that the negotiated price

$$w_s^{DS'} = \beta c_s + (1-\beta)\left[\frac{p-w_a^{DS}+c_p}{2} - \frac{p\Pi_b^r}{p-w_a^{DS}-c_p}\right].$$

Regarding the buyer's profit, it is hard to derive the exact expression. In contrast, if the buyer purchases from the supplier and reveals this information honestly to the purchasing agent, the analysis remains the same as that in §5.1, so they will not be repeated here.

Next, we rely on the numerical experiments to compare the buyer's profit when she provides untruthful supply information, $\Pi_b^{DS'}$ to that when she is honest, Π_b^{DS}. Our numerical results show that the buyer has the incentive of providing untruthful supply information iff the difference between the spot market price and the supplier's production cost, $c_p - c_s$ is in a moderate range, a result different from that when the parties negotiate over both prices and quantities. Note that a smaller $c_p - c_s$ indicates a lower spot price, which undoubtedly enhances the buyer's bargaining power. Besides, as stated in §5, negotiation over price only also enhances her bargaining power. These two combined together reduce the buyer's incentive to provide untruthful supply information when $c_p - c_s$ is small. When $c_p - c_s$ is very large, the spot price is large, thus the saving from the *reduced wholesale price* will be small, under which the buyer has no incentive to provide untruthful supply information as well. Only when $c_p - c_s$ is moderate will the buyer prefer providing untruthful supply information. We further study the purchasing agent's profits with and without the buyer's untruthful supply information, observing that the agent's profit is always hurt when the buyer provides untruthful supply information. This also induces the purchasing agent to prefer $\mathcal{AS}$ more.

B.3: Will the Agent Provide Untruthful Supply Information?

Similar to the discussion in §B.2, under $\mathcal{AS}$, the purchasing agent might buy components from the supplier at a low wholesale price but provide untruthful supply information that he buys components from the spot market. We also assume that the supplier knows the purchasing agent's intention to misrepresent. Again, it is worth noting that *in practice, it might be difficult to do so when the components purchased from the spot market have different logos and packages and delivered from different locations from those purchased from the supplier.*

B.3.1: Negotiation over both prices and quantities

Clearly, the purchasing agent's motivation to provide untruthful supply information is to negotiate a high wholesale price $\tilde{w}_a$ with the buyer because the spot market price c_p is high. However, the cost of such behavior is that the buyer makes the corresponding ordering decision by trusting that the agent's component price is c_p. Regarding the negotiation between the buyer and the purchasing agent, according to the analysis in §4.2, we can show that the negotiated wholesale price with the buyer is $\tilde{w}_a^{AS} = c_p + c_a + (1-\alpha)(p\mu(q_a^{AS})/q_a^{AS} - c_p - c_a)$, and the buyer's ordering quantity $q_a^{AS} = \bar{F}^{-1}\left((c_p + c_a)/p\right)$, which is smaller than q^*. That is, if the agent provides untruthful supply information to the buyer that he buys components from the spot market with price c_p, the buyer will order q_a^{AS}. We now solve the negotiation problem between the agent and the supplier as follows:

$$\underset{w_s}{\text{Max}} \quad \Omega_{as} = [\Pi_a - d_a]^\gamma [\Pi_s]^{1-\gamma} = \left[(\tilde{w}_a^{AS} - w_s - c_a)q_a^{AS} - d_a\right]^\gamma \left[(w_s - c_s)q_a^{AS}\right]^{1-\gamma}.$$

Let the superscript AS' denote the results when the agent buys components from the supplier but provides untruthful supply information. Then, it can be shown that

$$w_s^{AS'} = c_s + (1-\gamma)\left[\frac{(\tilde{w}_a^{AS} - c_a - c_s)q_a^{AS} - d_a}{q_a^{AS}}\right].$$

Correspondingly, the agent's profit becomes

$$\Pi_a^{AS'} = (\tilde{w}_a^{AS} - w_s^{AS'} - c_a)q_a^{AS}.$$

According to §4.2, if the agent purchases from the supplier and reveals this information honestly, then his profit shall be

$$\Pi_a^{AS} = \frac{\gamma(1-\alpha)}{1-\alpha+\alpha\gamma}(\Pi - d_a) + \frac{1-\alpha}{1-\alpha+\alpha\gamma}d_a.$$

We now compare $\Pi_a^{AS'}$ and Π_a^{AS} assuming demand follows a uniform distribution over the interval [0, 1]. Then, we find that

$$\Pi_a^{AS'} \geq \Pi_a^{AS} \text{ iff } c_p - c_s \leq \frac{2\alpha\gamma(p - c_a - c_s)}{1-\alpha+2\alpha\gamma}.$$

Similar to that in §B.2, this indicates that only when the difference between the spot market price and the supplier's production cost, $c_p - c_s$, is small will the agent have the incentive to provide untruthful supply information. The underlying driving force is the tradeoff between the *diminished order quantity* and the *reduced wholesale price* from the agent's untruthful supply information.

We finally check how the agent's untruthful supply information affects the buyer's profitability. We can show that

$$\Pi_b^{AS'} - \Pi_b^{AS} = -\frac{\alpha\gamma[(p-c_a-c_p)+(p-c_a-c_s)](c_p-c_s)}{2p(1-\alpha+\alpha\gamma)} < 0.$$

Therefore, the agent's untruthful supply information always impairs the buyer's profitability. Keeping this in mind, the buyer has a stronger preference over $\mathcal{DS}$ when the agent tends to provide untruthful supply information as

$$\Pi_b^{AS'} - \Pi_b^{DS} = -\frac{\alpha\beta[(p-c_a-c_p)+(p-c_a-c_s)](c_p-c_s)}{2p(\alpha+\beta-\alpha\beta)} < 0.$$

B.3.2: Negotiation over prices only

In this scenario, we first consider that the agent purchases the component from the spot market and informs the buyer honestly. Assume the demand is uniformly distributed between zero and one. Then, we can show that the negotiated wholesale price between the buyer and the purchasing agent is $\tilde{w}_a^{AS} = ((1-\alpha)p+(1+\alpha)(c_a+c_p))/2$ and the buyer's ordering quantity $q_a^{AS} = (1+\alpha)(p-c_a-c_p)/2p$, which is smaller than q^*. Then, the reservation profit of the agent is $\Pi_a^r = ((1-\alpha^2)(p-c_p+c_a)^2)/4p$.

Now, consider that the purchasing agent purchases the component from the supplier. If the purchasing agent decides to provide untruthful supply information to the buyer that the components are from the spot market with price c_p, the buyer will order q_a^{AS} correspondingly. Being aware of this, the purchasing agent and the supplier negotiate over the wholesale price w_s. It can be shown that

$$w_s^{AS'} = \gamma c_s + (1-\gamma)\left[(\tilde{w}_a^{AS} - c_a) - \frac{2p\Pi_a^r}{(1+\alpha)(p-c_a-c_p)}\right].$$

Regarding the purchasing agent's profit, it is hard to derive the exact expression. In contrast, if the agent purchases from the supplier and reveals this information honestly, the analysis remains the same as that in §5.2.

Next, we rely on the numerical experiments to compare the purchasing agent's profit when he provides untruthful supply information, $\Pi_a^{AS'}$ to that when he is honest, Π_a^{AS}. Our numerical results show that the findings in §B.2.2 qualitatively hold here as well; that is, the purchasing agent has the incentive of providing untruthful supply information iff the difference between the spot market price and the supplier's production cost $(c_p - c_s)$ is in a moderate range. The explanations are also similar: a small $c_p - c_s$ enhances the agent's bargaining position, resulting his low incentive to provide untruthful supply information. When $c_p - c_s$ is very large, the saving from the price difference by providing untruthful supply information becomes limited. Therefore, the agent chooses to be honest. Only when $c_p - c_s$ is moderate will untruthful supply information be provided. We further study the buyer's profits with and without the untruthful supply information, and find that the buyer's profit is always hurt. This induces the buyer to prefer $\mathcal{DS}$ more.

B.4: Asymmetric information about the supplier's cost

The existing literature on procurement outsourcing has focused on information asymmetry about suppliers' production costs; see, for example, Mookherjee and Tsumagari (2004), Mookherjee (2006), Chen et al. (2012), and Kayiş et al. (2013). Under our setting, the purchasing agent is a well-known company such as Li & Fung and provides very professional complementary services. Thus, we assume that his service costs are public information. For example, Li & Fung is a publicly listed company and his cost information can be estimated from the historical listing documents. However, the supplier's cost information can be private. Note that Yang and Babich (2015) assume that the purchasing agent has better information regarding the suppliers' disruption risk as in the purchasing practice, the purchasing agents usually accumulate a lot of information about suppliers. Following the same argument of Yang and Babich (2015), we assume that compared to the buyer, the purchasing agent has better information about the supplier's private production cost.

Now, due to the asymmetrical cost information, when facing the issue of which outsourcing structure to adopt, the buyer needs to take into consideration the following tradeoff besides the bargaining issues we investigated in the main context: the *information rent over the supplier's private production cost* when directly purchasing from the supplier vs. the total cost of relying on the purchasing agent for procurement which is composed of the *cost of loss of direct control* and the *information rent over the purchasing agent's unit purchasing price.* Obviously, because of asymmetric information, the supply chain can no longer be fully coordinated no matter which contract structure is adopted.

In our main context, we assume that there exists a spot market for the supplier's component. Naturally, the component's spot market price acts as a reference price when a party negotiates with the supplier. This consequently *bounds* the purchasing agent's informant rent over his unit purchasing price. A lower spot price enables the buyer to improve her endogenized bargaining power as it narrows the feasible range of the wholesale price offered to the supplier and thus reduces the information asymmetry arising from the unknown supplier production cost. Note that

Chen et al. (2012) name this spot price *street price*, and it plays an important role in the contract design under procurement outsourcing. We can also predict that simultaneous contract negotiation (without information revealing) will be strongly preferred by the purchasing agent under $\mathcal{AS}$ as such approach further enhances his information advantage. In a separate note, when a buyer gathers more information about the supplier's private information and becomes as well-informed as a purchasing agent, it is more likely for her to adopt $\mathcal{DS}$. In 2015, Walmart announced to bring certain product sourcing in-house (which the company relied on Li & Fung before) (Layne 2015). One reason behind such move is that Walmart believed that the company can communicate with the suppliers better after setting up four global merchandising centers (Mrunal 2014).

B.5: Newsvendor with price-sensitive demand

In the main context, we assume that the retail price is exogenous. Here, we consider the situation where the random demand is price-dependent and the buyer decides the retail price p. How will this affect the main analysis and results? To answer this question, we consider a price-dependent random demand X in the following multiplicative form: $X = ap^{-b}\xi$ $(a > 0, b > 1)$, where ξ is a random variable and ap^{-b} represents an iso-elastic demand curve. Following Petruzzi and Dada (1999), we define $z = q/ap^{-b}$ as the stocking factor decision, which is a transformation of the ordering quantity.

We first reexamine $\mathcal{DS}$. Now the buyer's profit function becomes

$$\Pi_b = pE[min(ap^{-b}\xi, q)] - (w_a + w_s)q = ap^{-b}[p\mu(z) - (w_a + w_s)z].$$

Similarly, we can rewrite the profit functions of the other two parties. Then we apply the sequential solving approach proposed by Wang et al. (2004) to determine the optimal stocking factor z first and the retail price p next. The results are summarized in the following proposition.

Proposition 3 *When demand is uncertain and iso-price-elastic, under $\mathcal{DS}$,*

i. if the buyer determines the retail price p before contract negotiations, the entire supply chain is coordinated. The optimal stocking factor and the corresponding optimal retail price uniquely satisfy

$$\frac{\mu(z^{DS})}{z^{DS}\bar{F}(z^{DS})} = \frac{b}{b-1} \text{ and } p^{DS} = \frac{b(c_a + c_s)}{b-1}\frac{z^{DS}}{\mu(z^{DS})}.$$

ii. if the buyer determines the retail price p after contract negotiations, the entire supply chain cannot be coordinated. The optimal stocking factor and the corresponding optimal retail price *uniquely satisfy*

$$\frac{\mu(z^{DS})}{z^{DS}\bar{F}(z^{DS})} = \frac{b}{b-1} \text{ and } p^{DS} = \frac{(b-\alpha)(b-\beta)}{(b-1)^2-(1-\alpha)(1-\beta)}\frac{b(c_a+c_s)}{b-1}\frac{z^{DS}}{\mu(z^{DS})}.$$

When demand is uncertain and iso-price-elastic, under $\mathcal{AS}$,

i. if the buyer determines the retail price p before contract negotiations, the entire supply chain is coordinated. The optimal stocking factor and the corresponding optimal retail price uniquely satisfy

$$\frac{\mu(z^{AS})}{z^{AS}\bar{F}(z^{AS})} = \frac{b}{b-1} \text{ and } p^{AS} = \frac{b(c_a+c_s)}{b-1}\frac{z^{AS}}{\mu(z^{AS})}.$$

ii. if the buyer determines p after contract negotiations, the entire supply chain cannot be coordinated. The optimal stocking factor and the corresponding optimal retail price uniquely satisfy

$$\frac{\mu(z^{AS})}{z^{AS}\bar{F}(z^{AS})} = \frac{b}{b-1} \text{ and } p^{AS} = \frac{(b-\alpha)\gamma}{\alpha+b\gamma-\alpha\gamma-1}\frac{b(c_a+c_s)}{b-1}\frac{z^{AS}}{\mu(z^{AS})}.$$

Proposition B1 shows that under both $\mathcal{DS}$ and $\mathcal{AS}$, the optimal stocking factor z^{DS} remains intact no matter whether the retail price p^{DS} is determined before or after the contract negotiation. However, for both outsourcing structures, the retail price p^{DS} is higher when it is determined after the contract negotiation than when it is determined before the contract negotiations as the two coefficients

$$\frac{(b-\alpha)(b-\beta)}{(b-1)^2-(1-\alpha)(1-\beta)} > 1 \text{ and } \frac{(b-\alpha)\gamma}{\alpha+b\gamma-\alpha\gamma-1} > 1.$$

This implies that under both $\mathcal{DS}$ and $\mathcal{AS}$, the optimal ordering quantity q^{DS} is lower when the retail price is determined after the contract negotiation than when the retail price is determined before the contract negotiations because $q^{DS} = ap^{-b}z^{DS}$. Moreover, a comparison of the buyer's profits under the two sourcing strategies shows that *the decision rule stated in Proposition 1 holds here* as well when the retail price p is decided before the negotiations over w_a and w_s; when the retail price p is decided after the negotiations over w_a and w_s, her preference is a *threshold policy* with respect to γ, a result similar to that stated in Proposition 2 (see Appendix C for the detailed proof).

B.6: The Preference on What to Negotiate

We here answer the research question: which contract structure does the buyer prefer to bargain over? To explore this issue, we consider a baseline case where the market demand is uniformly distributed between zero and one and there is no component spot market. To differentiate the optimal results under the two contract structures for a given sourcing structure, we let superscript $'$ to denote those under the negotiation over price only (Case P). Based on the aforementioned analysis, we can obtain that under $\mathcal{DS}$, the buyer's profits under two contract structures are, respectively,

$$\Pi_b^{DS} = \underbrace{\frac{\alpha\beta}{\alpha+\beta-\alpha\beta}}_{(1)}\underbrace{\frac{(p-c_a-c_s)^2}{2p}}_{(2)};$$

$$\Pi_b^{DS'} = \underbrace{\frac{(1+\alpha)^2(1+\beta)^2}{(3+\alpha+\beta-\beta\alpha)^2-4(1-\alpha\beta)^2}}_{(1')}\underbrace{\frac{(3+\alpha+\beta-\beta\alpha)^2-4(1-\alpha\beta)^2}{(3+\alpha+\beta-\beta\alpha)^2}\frac{(p-c_a-c_s)^2}{2p}}_{(2')},$$

where term (1) and term (1') are the buyer's respective endogenous bargaining powers under the two contract structures. Similarly, under $\mathcal{AS}$, the buyer's profits under the two contract structures are, respectively,

$$\Pi_b^{AS} = \underbrace{\frac{\alpha\gamma}{1-\alpha+\alpha\gamma}}_{(1)}\underbrace{\frac{(p-c_a-c_s)^2}{2p}}_{(2)};$$

$$\Pi_b^{AS'} = \underbrace{\frac{\gamma^2(1+\alpha)^2}{(1+\gamma-\alpha+\alpha\gamma)^2-(1-\alpha)^2}}_{(1')}\underbrace{\frac{(1+\gamma-\alpha+\alpha\gamma)^2-(1-\alpha)^2}{(1+\gamma-\alpha+\alpha\gamma)^2}\frac{(p-c_a-c_s)^2}{2p}}_{(2')}.$$

Lemma 7 *Under both $\mathcal{DS}$ and $\mathcal{AS}$, the endogenous bargaining power of the buyer is weaker under Case P&Q than that under Case P.*

Thus, although Case P cannot achieve the first-best performance, it enhances the buyer's bargaining power under both sourcing structures. Moreover, we can obtain the following *distribution-free* results.

Proposition 4 $\Pi_b^{DS} \leq \Pi_b^{DS'}$ *and* $\Pi_b^{AS} \leq \Pi_b^{AS'}$ *regardless of the type of the demand distribution.*

Proposition 4 shows that the buyer always prefers negotiation over prices only no matter which sourcing structure is adopted.

Appendix C: Proof of the Results in Appendix B

Proof of Remark 3: Under $\mathcal{DS}$, here we consider the case in which the buyer negotiates with the purchasing agent first. (The case that the buyer negotiates with the supplier first has similar results, thus we omit the details. The case that the buyer negotiates with the other two parties simultaneously can be found in §4.1) We solve this game backwards. We first maximize the following Nash product of the supplier and the buyer:

$$\underset{(w_s,q_s)}{\text{Max}} \quad \Omega_{bs} = [\Pi_b - d_b]^{\beta}[\Pi_s]^{1-\beta} = [p\mu(q_a \wedge q_s) - w_a q_a - w_s q_s - d_b]^{\beta}[(w_s - c_s)q_s]^{1-\beta}.$$

We then maximize the following Nash product of the purchasing agent and the buyer:

$$\underset{(w_a,q_a)}{\text{Max}} \quad \Omega_{ba} = [\Pi_b]^{\alpha}[\Pi_a]^{1-\alpha} = [p\mu(q_a \wedge q_s) - w_a q_a - w_s q_s]^{\alpha}[(w_a - c_a)q_a]^{1-\alpha}.$$

We can similarly show that the optimal order quantity is q^*, because all the supply chain parties's profits are aligned with that of the supply chain. Then, we can show that the wholesale price of the supplier

$$w_s = \beta c_s + (1-\beta)\left(p\frac{\mu(q^*)}{q^*} - w_a - \frac{d_b}{q^*}\right).$$

Substituting it into the buyer's profit function we get

$$\Pi_b = \beta(p\mu(q^*) - w_a q^* - c_s q^*) + (1-\beta)d_b.$$

Then the buyer and the purchasing agent solve the following Nash product

$$\underset{w_a}{\text{Max}} \quad \Omega_{ba} = [\beta(p\mu(q^*) - w_a q^* - c_s q^*) + (1-\beta)d_b]^{\alpha}[(w_a - c_a)q^*]^{1-\alpha},$$

and the optimal service wholesale price satisfies

$$w_a = c_a + (1-\alpha)\frac{\Pi}{q^*} + \frac{(1-\alpha)(1-\beta)d_b}{\beta q^*}.$$

Correspondingly, the optimal profit of the buyer is $\Pi_b^{DS} = \alpha\beta(\Pi - d_b) + \alpha d_b$. Note that under the simultaneous negotiation, the buyer's profit is $\frac{\alpha\beta}{\alpha+\beta-\alpha\beta}(\Pi - d_b) + \frac{\alpha}{\alpha+\beta-\alpha\beta}d_b$; see §4.1. Thus, it can be easily shown that compared to that under the simultaneous negotiation, the buyer is worse off under this sequential negotiation.

Under $\mathcal{AS}$, here we focus on examining the case that the purchasing agent negotiates with the buyer first. We omit the case that the purchasing agent negotiates with the supplier first as it is not realistic. The case that the purchasing agent negotiates with the other two parties simultaneously can be found in §4.2. When the purchasing agent first negotiates with the buyer and then with the supplier, the first contract details between the purchasing agent and the buyer is revealed when the supplier negotiates with the purchasing agent. We solve this game backwards. First, the negotiation problem between the supplier and the purchasing agent can be formulated as follows:

$$\underset{(w_s,q_s)}{\text{Max}} \quad \Omega_{as} = [\Pi_a - d_a]^{\gamma}[\Pi_s]^{1-\gamma} = [(\tilde{w}_a - c_a)(q_a \wedge q_s) - w_s q_s - d_a]^{\gamma}[(w_s - c_s)q_s]^{1-\gamma}. \quad (9)$$

Next, we solve the following Nash product between the purchasing agent and the buyer:

$$\operatorname*{Max}_{(\tilde{w}_a, q_a)} \quad \Omega_{ba} = [\Pi_b]^{\alpha}[\Pi_a]^{1-\alpha} = [p\mu(q_a \wedge q_s) - \tilde{w}_a(q_a \wedge q_s)]^{\alpha}[(\tilde{w}_a - c_a)(q_a \wedge q_s) - w_s q_s]^{1-\alpha}.$$

Following the similar arguments in §4.1, wa can show that under $\mathcal{AS}$ and sequential bargaining, the Nash bargaining outcome over the production quantity is again $q_a = q_s = q^*$. Plugging $q_a = q_s = q^*$ into (9), we have

$$w_s(\tilde{w}_a) = \gamma c_s + (1-\gamma)\left((\tilde{w}_a - c_a) - \frac{d_a}{q^*}\right).$$

Substituting $w_s(\tilde{w}_a)$ into the negotiation problem between the purchasing agent and the buyer, we get

$$\operatorname*{Max}_{\tilde{w}_a} \quad \Omega_{ba} = [\Pi_b]^{\alpha}[\Pi_a]^{1-\alpha} = [p\mu(q^*) - \tilde{w}_a q^*]^{\alpha}[\gamma(\tilde{w}_a - c_a - c_s)q^* + (1-\gamma)d_a]^{1-\alpha}.$$

It can be shown that the Nash product is log-concave with respect to $\tilde{w}_a$, and

$$\tilde{w}_a^{AS} = (1-\alpha)p\frac{\mu(q^*)}{q^*} + \alpha(c_a + c_s) - \frac{\alpha(1-\gamma)}{\gamma}\frac{d_a}{q^*}.$$

And the corresponding profit of the purchasing agent $\Pi_a^{AS} = \gamma(1-\alpha)(\Pi - d_a) + (1-\alpha)d_a$. Note that under the simultaneous negotiation, the purchasing agent's profit is $\Pi_a^{AS} = \frac{\gamma(1-\alpha)(\Pi - d_a)}{1-\alpha+\alpha\gamma} + \frac{1-\alpha}{1-\alpha+\alpha\gamma}d_a$. It can be easily shown that the purchasing agent is better off under the simultaneous negotiation than under the sequential negotiation. We thus complete the proof.

Proof of Remark 4:

We first show that the buyer strictly prefers simultaneous negotiation under $\mathcal{DS}$. Without loss of generality, we assume w_a is negotiated first, followed by the negotiation over w_s. Then the equilibrium outcomes are: $w_a = \frac{(1-\alpha)p + (1+\alpha)c_a - (1-\alpha)c_s}{2}$; $w_s = \frac{(1+\alpha)(1-\beta)(p-c_a) + (3+\beta-\alpha+\alpha\beta)c_s}{4}$; $\Pi_b^{DS'} = \frac{(1+\alpha)^2(1+\beta)^2}{32}\frac{(p-c_a-c_s)^2}{p}$. Comparing with the buyer's profit under simultaneous negotiation $\Pi_b^{DS} = \frac{(1+\alpha)^2(1+\beta)^2(p-c_a-c_s)^2}{2(3+\alpha+\beta-\beta\alpha)^2 p}$, we have the difference

$$\Pi_b^{DS} - \Pi_b^{DS'} = \frac{(1-\alpha)(1-\beta)}{4(3+\alpha+\beta-\beta\alpha)}\left[\frac{1}{3+\alpha+\beta-\beta\alpha} + \frac{1}{4}\right]\frac{(1+\alpha)^2(1+\beta)^2}{2}\frac{(p-c_a-c_s)^2}{p} > 0.$$

Therefore, the buyer's profit under simultaneous negotiation is higher. We can similarly prove that it is also higher than the case with w_s to be negotiated first.

We then show that the purchasing agent also prefers simultaneous negotiation. If the purchasing agent negotiates with the buyer first, then the sequence of events can be defined as follows. First, the purchasing agent negotiates $\tilde{w}_a$ with the buyer; second, the agent negotiates w_s with the supplier (note that here the information of the first negotiation is revealed); finally, the buyer determines the ordering quantity q. Similar to that of Lemma 5, we can derive the following results. When the demand is uniformly distributed between zero and one, there does not exist a product spot market, and the supply chain parties negotiate over wholesale prices only, under $\mathcal{AS}$, if the purchasing agent negotiates with the buyer first,

(1) the equilibrium wholesale prices are, respectively

$$\tilde{w}_a^{AS'} = \frac{(1-\alpha)}{2}(p-c_a-c_s)+(c_a+c_s); \quad w_s^{AS'} = \frac{(1-\gamma)(1-\alpha)}{2}(p-c_a-c_s)+c_s.$$

(2) The buyer's optimal ordering quantity is $q^{AS} = \frac{(1+\alpha)(p-c_a-c_s)}{2p}$. And the profit of the purchasing agent is $\Pi_a^{AS'} = \frac{\gamma(1-\alpha^2)(p-c_a-c_s)^2}{4p}$.

It can be easily shown that the purchasing agent's profits under the sequential negotiation is lower than that under the simultaneous negotiation where $\Pi_a^{AS} = \frac{(1-\alpha^2)\gamma^2(p-c_a-c_s)^2}{(1+\gamma-\alpha+\alpha\gamma)^2 p}$.

Proof of Proposition 3:

We first assume that the retail price p is decided before the negotiations over w_a and w_s. Under $\mathcal{DS}$, the analysis is equivalent to the case when the ordering quantity is determined either before or jointly with the contract negotiations. Under such case, the GNB coordinates the supply chain. The detailed proofs are as follows: Under $\mathcal{DS}$, the supply chain parties' profit functions are

$$\begin{aligned}
\Pi_b &= pE[min(ap^{-b}\xi, q)] - (w_a+w_s)q = ap^{-b}[p\mu(z) - (w_a+w_s)z];\\
\Pi_a &= ap^{-b}(w_a-c_a)z; \quad \Pi_s = ap^{-b}(w_s-c_s)z.
\end{aligned}$$

If p is determined before wholesale price negotiation, we solve the Nash products among the supply chain parties simultaneously, finding the wholesale prices as follows:

$$\begin{aligned}
w_s z &= \beta c_s z + (1-\beta)(p\mu(z) - w_a z);\\
w_a z &= \alpha c_a z + (1-\alpha)(p\mu(z) - w_s z).
\end{aligned}$$

Solving them simultaneously yields

$$w_a^{DS} = c_a + \frac{(1-\alpha)\beta}{\alpha+\beta-\alpha\beta}\left(p\frac{\mu(z)}{z} - c_a - c_s\right); \tag{10}$$

$$w_s^{DS} = c_s + \frac{(1-\beta)\alpha}{\alpha+\beta-\alpha\beta}\left(p\frac{\mu(z)}{z} - c_a - c_s\right). \tag{11}$$

Then, the buyer's profit function becomes

$$\Pi_b = \frac{\alpha\beta}{\alpha+\beta-\alpha\beta}ap^{-b}[p\mu(z) - c_a z - c_s z].$$

We solve it sequentially and find the optimal stocking factor and retail price, which uniquely satisfy

$$\frac{\mu(z^{DS})}{z^{DS}\bar{F}(z^{DS})} = \frac{b}{b-1}; p^{DS} = \frac{b(c_a+c_s)}{b-1}\frac{z^{DS}}{\mu(z^{DS})}.$$

Under $\mathcal{AS}$, as p is determined before contract negotiations, the supply chain parties' profits are

$$\Pi_b = ap^{-b}[p\mu(z) - \tilde{w}_a z]; \Pi_a = ap^{-b}[\tilde{w}_a - w_s - c_a]z; \Pi_s = ap^{-b}[w_s - c_s]z.$$

We focus on the case where $\tilde{w}_a$ and w_s are negotiated simultaneously, and find that

$$\tilde{w}_a = \frac{(1-\alpha)p\mu(z) + \alpha\gamma c_a z + \alpha\gamma c_s z}{(1-\alpha+\alpha\gamma)z}; w_s = \frac{(1-\alpha)(1-\gamma)p\mu(z) - (1-\alpha)(1-\gamma)c_a z + \gamma c_s z}{(1-\alpha+\alpha\gamma)z}.$$

Then the buyer's profit function becomes

$$\Pi_b = \frac{(1-\alpha)\gamma}{1-\alpha+\alpha\gamma}ap^{-b}[p\mu(z) - (c_a+c_s)z],$$

which yields z^{AS} satisfying

$$\frac{\mu(z^{AS})}{z^{AS}\bar{F}(z^{AS})} = \frac{b}{b-1},$$

and

$$p^{AS} = \frac{b(c_a+c_s)}{b-1}\frac{z^{AS}}{\mu(z^{AS})}.$$

Therefore, the buyer's profit is

$$\Pi_b^{AS} = \frac{\alpha\gamma}{1-\alpha+\alpha\gamma}\frac{a}{b}\left(\frac{b-1}{b}\right)^{b-1}(c_a+c_s)^{1-b}\frac{\mu(z)^b}{z^{b-1}}.$$

By comparing Π_b^{DS} with Π_b^{AS}, we find that $z^{DS} = z^{AS}$, and the buyer prefers $\mathcal{AS}$ iff

$$\frac{\alpha}{1-\alpha}\cdot\frac{\gamma}{1-\gamma} \geq (<) \frac{\beta}{1-\beta}.$$

Thus, the decision rule stated in Proposition 1 holds as well when the retail price p is decided before the negotiations over w_a and w_s.

We now consider that the retail price p is decided after the negotiations over w_a and w_s. Under $\mathcal{DS}$, we have

$$p = \frac{b(w_a+w_s)}{b-1}\frac{z}{\mu(z)}.$$

The buyer's profit function is

$$\Pi_b = ap^{-b}\frac{(w_a+w_s)z}{b-1}.$$

The corresponding Nash products are

$$\begin{aligned}
\underset{w_a}{\text{Max}} \quad \Omega_{ba} &= \left[ap^{-b}\frac{(w_a+w_s)z}{b-1}\right]^{\alpha}[ap^{-b}(w_a-c_a)z]^{1-\alpha};\\
\underset{w_s}{\text{Max}} \quad \Omega_{bs} &= \left[ap^{-b}\frac{(w_a+w_s)z}{b-1}\right]^{\beta}[ap^{-b}(w_s-c_s)z]^{1-\beta}.
\end{aligned}$$

Both Nash products are log-concave. We can derive that

$$w_a(w_s) = \frac{(b-\alpha)c_a + (1-\alpha)w_s}{b-1} \text{ and } w_s(w_a) = \frac{(b-\beta)c_s + (1-\beta)w_a}{b-1}.$$

Solving $w_a(w_s)$ and $w_s(w_a)$ simultaneously, we obtain

$$w_a = \frac{(b-1)(b-\alpha)c_a + (1-\alpha)(b-\beta)c_s}{(b-1)^2 - (1-\alpha)(1-\beta)}; \quad w_s = \frac{(b-1)(b-\beta)c_s + (1-\beta)(b-\alpha)c_a}{(b-1)^2 - (1-\alpha)(1-\beta)}.$$

Plugging them into the buyer's profit function yields

$$\Pi_b = \frac{a}{b}\left(\frac{b-1}{b}\right)^{b-1}\left[\frac{(b-1)^2 - (1-\alpha)(1-\beta)}{(b-\alpha)(b-\beta)(c_a+c_s)}\right]^{b-1}\frac{[\mu(z)]^b}{z^{b-1}}.$$

Maximizing Π_b requires that the optimal stocking factor z^{DS} uniquely satisfies

$$\frac{\mu(z^{DS})}{z^{DS}\bar{F}(z^{DS})} = \frac{b}{b-1}.$$

The corresponding optimal retail price is

$$p^{DS} = \frac{(b-\alpha)(b-\beta)}{(b-1)^2 - (1-\alpha)(1-\beta)}\frac{b(c_a+c_s)}{b-1}\frac{z^{DS}}{\mu(z^{DS})}.$$

The buyer's profit is then

$$\Pi_b^{DS} = \frac{a}{b}\left(\frac{b-1}{b(c_a+c_s)}\right)^{b-1}\left[\frac{(b-1)^2 - (1-\alpha)(1-\beta)}{(b-\alpha)(b-\beta)}\right]^{b-1}\frac{\mu(z)^b}{z^{b-1}}.$$

Under $\mathcal{AS}$, where p is determined after contract negotiations, the supply chain parties' profits are still

$$\Pi_b = ap^{-b}[p\mu(z) - \tilde{w}_a z]; \Pi_a = ap^{-b}[\tilde{w}_a - w_s - c_a]z; \Pi_s = ap^{-b}[w_s - c_s]z.$$

Taking the first-order condition of the buyer's profit with respect to p, we have

$$p = \frac{b}{b-1}\frac{z}{\mu(z)}\tilde{w}_a.$$

Substituting it into the supply chain parties' profit functions, we get

$$\begin{aligned}
\Pi_b &= \frac{a}{b}\left(\frac{b-1}{b\tilde{w}_a}\right)^{b-1}\frac{\mu(z)^b}{z^{b-1}};\\
\Pi_a &= a\left(\frac{b-1}{b}\right)^b \tilde{w}_a^{-b}[\tilde{w}_a - w_s - c_a]\frac{\mu(z)^b}{z^{b-1}};\\
\Pi_s &= a\left(\frac{b-1}{b}\right)^b \tilde{w}_a^{-b}[w_s - c_s]\frac{\mu(z)^b}{z^{b-1}}.
\end{aligned}$$

The wholesale prices $\tilde{w}_a$ and w_s are negotiated simultaneously by solving the Nash products bilaterally among the supply chain parties. It can be shown that

$$\tilde{w}_a = \frac{(b-\alpha)\gamma}{\alpha + b\gamma - \alpha\gamma - 1}(c_a + c_s); w_s = \frac{(1-\alpha)(1-\gamma)c_a + (b-1)\gamma c_s}{\alpha + b\gamma - \alpha\gamma - 1}.$$

Correspondingly, the buyer's profit is

$$\Pi_b^{AS} = \frac{a}{b}\left(\frac{b-1}{b(c_a+c_s)}\right)^{b-1}\left[\frac{\alpha + b\gamma - \alpha\gamma - 1}{(b-\alpha)\gamma}\right]^{b-1}\frac{\mu(z)^b}{z^{b-1}},$$

which yields the optimal stocking factor and retail price uniquely satisfy

$$\frac{\mu(z^{AS})}{z^{AS}\bar{F}(z^{AS})} = \frac{b}{b-1}; p^{AS} = \frac{(b-\alpha)\gamma}{\alpha + b\gamma - \alpha\gamma - 1}\frac{b(c_a+c_s)}{b-1}\frac{z^{AS}}{\mu(z^{AS})}.$$

By comparing Π_b^{DS} with Π_b^{AS}, we find that $z^{DS} = z^{AS}$, and the buyer prefers $\mathcal{AS}$ iff

$$\gamma \geq \frac{(b-\beta)(1-\alpha)}{(b-\alpha)(1-\beta) + (b-\beta)(1-\alpha)}.$$

That is, the preference of the buyer over the two sourcing strategies is a threshold policy with respect to γ when the retail price p is decided after the negotiations over w_a and w_s. This result is quite similar to that stated in Proposition 2.

Proof of Lemma 7: Under $\mathcal{DS}$, the buyer's endogenized bargaining power is $\frac{(1+\alpha)^2(1+\beta)^2}{(3+\alpha+\beta-\beta\alpha)^2-4(1-\alpha\beta)^2}$ when the parties negotiate over price only, and is $\frac{\alpha\beta}{\alpha+\beta-\alpha\beta}$ when the parties negotiate over both price and quantity. We can show that

$$\begin{aligned}
&\frac{(1+\alpha)^2(1+\beta)^2}{(3+\alpha+\beta-\beta\alpha)^2 - 4(1-\alpha\beta)^2} - \frac{\alpha\beta}{\alpha+\beta-\alpha\beta} \\
= \; &\frac{(1+\alpha)(1+\beta)[\alpha(1-\beta)(1-\alpha\beta) + \beta(1-\alpha)(1-\alpha\beta) + (\alpha-\beta)^2]}{(\alpha+\beta-\alpha\beta)((3+\alpha+\beta-\beta\alpha)^2 - 4(1-\alpha\beta)^2)} \\
> \; &0.
\end{aligned}$$

Similarly, under $\mathcal{AS}$, the buyer's endogenized bargaining power is $\frac{\gamma^2(1+\alpha)^2}{(1+\gamma-\alpha+\alpha\gamma)^2-(1-\alpha)^2}$ when the parties negotiate over price only, and is $\frac{\alpha\gamma}{1-\alpha+\alpha\gamma}$ when the parties negotiate over both price and quantity. We can show that

$$\begin{aligned}
&\frac{\gamma^2(1+\alpha)^2}{(1+\gamma-\alpha+\alpha\gamma)^2 - (1-\alpha)^2} - \frac{\alpha\gamma}{1-\alpha+\alpha\gamma} \\
= \; &\frac{\gamma^2(1+\alpha)(1-\alpha)^2}{(1-\alpha+\alpha\gamma)((1+\gamma-\alpha+\alpha\gamma)^2 - (1-\alpha)^2)} \\
> \; &0.
\end{aligned}$$

Proof of Proposition 4: When the parties negotiate over both price and quantity, the optimal order quantity is q^* and the supply chain is always coordinated. When the parties negotiate over price only, the buyer holds the right to decide the order quantity. Note that q^* is always a feasible candidate for her to order, however, it turns out that q^* is not her optimal choice. Instead, the optimal quantities are $q^{DS'}$ and $q^{AS'}$ under $\mathcal{DS}$ and $\mathcal{AS}$, respectively. Note that if under Case P the buyer orders q^*, the price negotiation outcome shall be the same as that under Case P&Q. That is, the optimal solution and the corresponding profit allocation under Case P&Q is a feasible solution for Case P. The only reason why the buyer does not order q^* under Case P&Q must be that this brings her a lower profit. This indicates that the buyer's profit under negotiation over price only shall be weakly higher than that under negotiation over both price and quantity. Thus we obtain Proposition 4.