Outsourcing Competition and Information Sharing with Asymmetrically Informed Suppliers

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Abstract

This paper studies an outsourcing problem where two service providers (suppliers) compete for the service contract from a client. The suppliers face uncertain cost for providing the service because they do not have perfect information about the client's type. The suppliers receive differential private signals about the client type and thus compete under asymmetric information. We first characterize the equilibrium of the supplier competition. Then we investigate two of the client's information sharing decisions. The first decision is about whether the client should help the less-informed supplier get better information. It is shown that less information asymmetry between the suppliers may dampen their competition. Therefore, the client does not necessarily have the incentive to reduce information asymmetry between the suppliers. We characterize the conditions under which leveling the informational ground is beneficial to the client. The second decision is about how much information the client should share with both suppliers so as to improve the quality of their signals. Under the presence of information asymmetry (e.g., when the suppliers have different learning abilities), sharing more information with both suppliers may enhance the advantage of one supplier over the other and at the same time increase the upper bound of the suppliers' quotes in equilibrium. As a result, the suppliers compete less aggressively and the client's payoff decreases in the amount of shared information. The findings from this paper provide useful managerial implications on information management for outsourcing firms.

Keywords: Service outsourcing, asymmetric information, common value auction, information sharing

1. Introduction

The past few decades have witnessed the boom of outsourcing in which firms transfer their noncore business activities to third-party suppliers. Typical outsourcing areas include information technology (IT) management, services, manufacturing, logistics, and customer support (Kakabadse and Kakabadse 2005; Halvey and Melby 2007; Goles et al. 2008). The primary motivation for outsourcing is to maintain a competitive edge by reducing costs and focusing on core competencies. Today outsourcing has become a strategic lever in the global economy (Friedman 2005), and it is widely expected that the increasing trend of outsourcing will continue in the near future (Cohen and Young 2006; Stevens 2009).

While the benefits of outsourcing are evident, its success hinges on how well the relationships between the outsourcing firm (client) and her suppliers are managed. This poses challenges for the client because the suppliers are usually independent entities with different information and self-interested objectives. One of the difficulties in outsourcing management is caused by the cost uncertainties involved in the transaction. In most outsourcing relationships, either the buyer, the suppliers, or both may possess some information that is not publicly known to the other parties. For instance, when a client outsources a certain task, she may not know the suppliers' exact costs for undertaking the task. The reason could be simply that the suppliers have private information about their technological capabilities and operational efficiency. We call this supplier-related cost uncertainty. As we will discuss in the literature review, this type of cost uncertainty is quite intuitive and has received enormous attention among practitioners and academics.

Much less attention has been paid to the so-called client-related cost uncertainty, i.e., the suppliers do not have full information on certain aspects of the transaction. Consider multiple suppliers bidding for an outsourcing contract from a client. Due to the complexity of the outsourced business process, none of the suppliers has perfect information about the actual cost for serving the client. In addition, the suppliers may have disparate information due to their different backgrounds, industry experiences, and information learning abilities. This type of cost uncertainty is prevalent in practice and may also play an important role in outsourcing decision making.

A typical example of client-related cost uncertainty is IT security outsourcing. An increasing number of companies rely on Managed Security Service Providers (MSSPs) to provide cost-efficient solutions for their information security management. MSSPs offer a range of Managed Security Services (MSS), including security monitoring, vulnerability and penetration testing, network boundary protection, data archiving and restoration, and etc. (Allen et al. 2003). The MSS market has been undergoing rapid growth in recent years. The global market of security outsourcing is forecasted to nearly double between 2011 and 2015, when it will reach a total value of $16.8 billion (Infonetics 2011). In IT security outsourcing, a MSSP's cost of providing MSS often depends on numerous factors, including the MSSP's own capabilities, the characteristics of the client he serves, and the match between the corporate cultures of the two firms. For instance, a client with a robust computer network, strict internal security policies and well-trained employees may encounter fewer security problems (Allen et al. 2003); also a good match between the firms may foster cooperation and make it easier to develop collaborative solutions. It is therefore less costly for the MSSP to meet the performance expectation specified in the service level agreements (SLA). Although these factors are critical to the MSSP's service cost, usually the MSSP does not have perfect knowledge about them and therefore faces cost uncertainties in serving the client.

The presence of client-related cost uncertainty may lead to information asymmetry among potential MSSPs in their competition for service contracts. Such information asymmetry can be attributed to two possible reasons. First, MSSPs may collect information and learn about service cost from different sources. For instance, some MSSPs develop better knowledge of their client from prior business interactions with the client (Gefen et al. 2008); some MSSPs try to learn about their clients through on-site pre-contract inspection (Allen et al. 2003); and some MSSPs obtain information about their clients via third-party information services, such as security ratings (Scalet 2008). Second, MSSPs may not have equal learning abilities even when they have access to the same information source. For instance, the insights gained from the same factual data depend on a MSSP's information processing capability and prior experience. It has been reported that tacit knowledge derived from social interactions cannot be fully captured in formal documents and reports (Gopal and Gosain 2010). Therefore, when competing for the service contract from a single client, potential MSSPs may have disparate information about the client and the uncertain service cost.

Similar situations may occur in other outsourcing contexts as well. In the outsourcing of consulting and financial services, the output is usually determined jointly by the inputs from both the service provider and the client (Roels et al. 2010). Thus the service provider's cost for achieving a certain output level depends on how diligent and responsible the client is, which could be unknown to the service provider. In customer care outsourcing (e.g., call center outsourcing), the cost for meeting contractual performance depends critically on the characteristics of the service offered to end customers (e.g., service complexity, customer demographics, and demand volume). Call center vendors may not have perfect information about these characteristics. The same issue may also arise in manufacturing outsourcing. For example, the original equipment manufacturer (outsourcer) may have superior information on products (e.g., the design and complexity of a new product) or market conditions (e.g., the potential market size) than the contract manufacturer (supplier). This information may affect the production cost as well as the revenue associated with the contract (Tan 1996). As in IT security outsourcing, in the above industries the external suppliers are often uncertain and asymmetrically informed about the cost for delivering the required services or goods to the client. These cost uncertainties may lead to problematic outsourcing relationships because underestimating the service cost may result in the winner's curse, where the winning supplier has to incur a loss from serving the client (see Kern et al. 2002 for a discussion of winner's curse in IT outsourcing). As a result, these cost uncertainties have been ranked as a primary contributing factor to contract renegotiation and termination in outsourcing practices (Halvey and Melby 2007).

The above examples demonstrate that cost uncertainties and asymmetrically informed suppliers represent a common feature of many outsourcing settings. Obviously, when competing for the client's outsourced business (a service contract, for example), suppliers' behaviors are influenced by their different beliefs about the service cost, which in turn determines the value of the contract. Thus it is crucial for an outsourcing firm to understand the impact of this information structure when designing her outsourcing strategy. However, there has been relatively little research in the operations management literature studying the outsourcing problem when suppliers are not equally informed about the uncertain service cost. This paper attempts to shed some light on the problem by developing a game-theoretic model. In this model, two suppliers compete for a service contract from a single client. The service cost can be either high or low. The suppliers do not know the exact service cost, but they have a prior belief about its probability distribution. In addition, each supplier receives a signal about the service cost. The suppliers' signals are correlated and one may be more accurate than the other. The winner of the contract is determined through competitive bidding; specifically, the suppliers simultaneously submit the price they would charge for the service and the lower bidder wins the contract.

With this model setup, we first derive the equilibrium outcome of supplier competition. The characterization of the competitive outcome has useful implications on vendor selection and outsourcing strategy design for the client. Then we focus on the client's information sharing strategies. The advances in information technology have facilitated the flow of information between trade partners. As a result, information sharing has been lauded in the literature as an effective means to improve supply chain efficiency (Chen 2003) . In our problem setting, the client can influence the suppliers' information structure through information sharing. For example, the client may help the suppliers obtain better information about the service cost by disclosing internal documents and arranging on-site visits. Therefore, we study two important questions related to the client's information sharing decision as follows.

First, what is the impact of supplier information asymmetry on the client's profit? This question has practical significance because a client may wish to know whether she should narrow the information gap via information sharing with the less-informed supplier. Conventional wisdom suggests that the client should benefit from a leveled information ground because it induces more supplier competition. In contrast, we find that reducing information asymmetry between the suppliers may hurt the client's profit under certain conditions. This is because less information asymmetry implies that the suppliers are more likely to receive the same signals, so it may either intensify or dampen the competition depending on the received signals. In particular, when there is a high level of information asymmetry between the suppliers, the dampening effect dominates the intensifying effect and the client's profit may decrease as the information gap diminishes. This result cautions outsourcing managers about their information sharing strategy and provides insights into the circumstances under which a client should strive to level the informational ground for competing suppliers.

Second, how much information should the client share with the suppliers? By disclosing more information, the client may improve the accuracy of the signals observed by both suppliers. Interestingly, in our setting with information asymmetry (e.g., when the suppliers have different learning abilities), it has been found that sharing more information with *both* suppliers is always detrimental to the client. Although information sharing will improve both suppliers' signal accuracies, the quality difference in the suppliers' signals will also increase due to unequal learning abilities. In addition, information sharing also increases the suppliers' expected service cost contingent on bad signals, which is essentially the upper bound of the suppliers' quotes in equilibrium. These two effects lead to less aggressive bidding behaviors from the suppliers. As a result, sharing information with both suppliers has a negative impact on the client's payoff due to dampened supplier competition. This finding indicates that it is not always beneficial for the client to improve suppliers' signal accuracies. In other words, the existence of information asymmetry may hinder the client from improving suppliers' information, which has important implications on the information management policy for outsourcing firms.

The rest of the paper is organized as follows. The next section reviews the related literature. Section 3 introduces the model setup. Section 4 analyzes the suppliers' bidding game. Section 5 studies the client's information sharing strategies and offers detailed answers to the above questions.

Finally, the paper concludes with Section 6.

2. Literature Review

Internet-enabled marketplaces have gained increasing popularity during the past decade. In particular, the use of auctions as a procurement tool has been widely adopted in outsourcing practice due to the advances in information technology. This paper is related to the growing literature in operations management that studies outsourcing and procurement auctions where a buyer procures a certain service or product from external suppliers with heterogeneous private costs. Reviews of this literature can be found in Cachon and Zhang (2006), Chen (2007), Wan and Beil (2009), and Zhang (2010), to name a few. Our model is different in that the suppliers incur uncertain but homogeneous costs in providing the products/services. In particular, the suppliers face uncertainties about the cost for serving the same buyer, which is a common value for different suppliers.

Our study involves information sharing, so it is related to papers that study the impact of information sharing/information leakage in supply chains. Representative studies include Li (2002), Li and Zhang (2008), and Anand and Goyal (2009). Chen (2003) reviews the supply chain management literature on information sharing. A common assumption in this literature is that the supply chain structure is exogenously given. In contrast, the buyer in our model uses an auction for vendor selection, and we study how to improve the effectiveness of the auction through information sharing.

In our model, the suppliers receive different but correlated signals about a common contract value, so their competition represents a common-value auction (CVA). Several papers in the CVA literature study asymmetrically informed bidders (i.e., the auctioned object is of identical value to the bidders but the bidders possess different amounts of information about such a value), and therefore are most relevant to our work. These CVA studies diverge in characterizing the bidders' profitability in competition. Some studies suggest that only the better-informed bidder can make positive expected profit (e.g., Engelbrecht-Wiggans et al. 1983; Hauswald and Marquez 2006), while other studies find that both the better-informed bidder and the less-informed bidder can make positive expected profits (e.g., Hausch 1987; Banerjee 2005). Our study bridges the gap between these two groups by using a unified model to capture both cases and characterizing the conditions for each case to arise.

A few CVA studies look into the issue of information sharing, i.e., whether the seller has incentives to help improve the less-informed bidder's information. Wilson (1975) suggests that decreasing information asymmetry between the bidders would intensify their competition. Milgrom and Weber

(1982b) also find that if the seller has access to some of the better-informed bidder's information, he can increase its profit by publicizing that information. Hausch (1987) and Banerjee (2005), however, find that decreasing the information asymmetry level may soften bidder competition and hence lead to lower seller revenue. Such a finding, though interesting, is based on some restrictive conditions. Hausch (1987) assumes that the better-informed bidder's estimate of the object value is negatively affected by the improved precision of the less-informed bidder's information. Due to the lack of tractability, Hasusch (1987) relies on a numerical example to illustrate the finding. To simplify analysis, Banerjee (2005) assumes that the bidders never bid when receiving a bad signal. These approaches undermine the robustness of the results because they are either based on numerical analysis or constrained bidding behavior. In view of these limitations, we develop an analytical model that is not subject to these restrictions. By solving the suppliers' equilibrium bidding strategies, we analytically characterize the conditions under which information asymmetry may either intensify or dampen bidder competition.

In addition to information asymmetry between the suppliers, we also study the sharing of information between the client and the suppliers. Milgrom and Weber (1982a) suggest that the seller should always honestly publicize all information she has. This is because honest reporting can reduce the bidders' private information and thus lower their information rent. However, in another Milgrom and Weber (1982b)'s paper, they show that the seller may lower her expected profit by disclosing her own information when the seller's information is complementary to the better-informed bidder. In that paper complementarity essentially implies that the disclosure of the seller's private information increases the information asymmetry between the bidders, which dampens the competition in the auction. In our paper we find that when the client's information is complementary to both suppliers' information but the suppliers are equipped with different learning abilities, the client will not share her information with the suppliers either. Such a finding, though based on a different problem setting, is consistent with the insight from Milgrom and Weber (1982b).

3. Model Setup

A firm (client) needs to outsource her service process to an outside service provider (supplier). For ease of exposition, we consider the example of IT security outsourcing. The service has a value V for the client and there are two pre-qualified suppliers from whom the client can choose. The suppliers face uncertain cost for serving the client due to the reasons discussed in the introduction. To focus on the information asymmetry issue, we assume that the suppliers are identical (e.g., they have the same technology and are equally efficient in delivering the required service) except that they may be asymmetrically informed about the client's service cost. There are two possible service costs, c_l and c_h ($c_l < c_h < V$). The low cost c_l is associated with situations where the client would be less costly to serve (e.g., it is equipped with a sufficiently robust IT system) while c_h is associated with the opposite situations. For easy reference, call the client a good (G) type if her service cost is c_l, and a bad (B) type if her cost is c_h. We use T to denote the client type and assume that $T = G$ with probability $\Pr(G) = \gamma$ ($0 < \gamma < 1$) and $T = B$ with probability $\Pr(B) = 1 - \gamma$. One may view γ as the fraction of low-cost clients in the market, which is public information.

The suppliers possess asymmetric information about the client and the associated service cost. As mentioned earlier, such information asymmetry may be due to the differences in the suppliers' information sources and their learning abilities. Without loss of generality, suppose supplier 1 is better informed about the client than supplier 2. We model information asymmetry between the two suppliers as follows. Supplier 1 receives a signal S about the client type. The signal can be either good (g) or bad (b). Let $\Pr(g|T)$ and $\Pr(b|T)$ denote the probabilities of $S = g$ and $S = b$, respectively, conditional on $T \in \{G, B\}$. Define

$$\Pr(g|G) = \lambda, \ \ \Pr(b|G) = 1 - \lambda, \ \ \Pr(g|B) = 0, \ \text{and} \ \Pr(b|B) = 1. \tag{1}$$

That is, for a good type, the signal is g with probability λ ($0 \leq \lambda \leq 1$) and b with probability $1 - \lambda$; however, the signal from a bad type is always b. For instance, the bad client does not have the necessary infrastructure and managerial capability to provide a friendly task environment, so the better-informed supplier seldom receives a good signal based on the client's reputation in the industry.

The assumption in (1) is used to improve the transparency of the analysis, and it can be generalized without affecting our main results. For instance, we have also analyzed a more general model where the signal from a bad-type client is g with probability β ($0 \leq \beta \leq \lambda$) and b with probability $1 - \beta$. Our main model corresponds to the special case with $\beta = 0$. Another special case is when $\lambda = 1 - \beta = \frac{1+\psi}{2}$, where supplier 1 receives symmetric signals from the two types of clients, i.e., the signal from a good-type (bad-type) client is g (b) with probability $\frac{1+\psi}{2}$ ($0 \leq \psi \leq 1$) and b (g) with probability $\frac{1-\psi}{2}$. It has been found that the qualitative insights remain unchanged in these more general models.

We may view λ as the quality of the signal. When $\lambda = 1$, the signal provides perfect information about the client's type; when $\lambda = 0$, the signal is useless because it is always bad regardless of the client type. Throughout the paper we focus on $\lambda > 0$ to avoid the trivial case. Let $\Pr(g)$

and $\Pr(b)$ denote the probabilities of $S = g$ and $S = b$, respectively. Then we have $\Pr(g) = \gamma \Pr(g|G) + (1-\gamma)\Pr(g|B) = \gamma\lambda$, $\Pr(b) = 1 - \Pr(g) = 1 - \gamma\lambda$. We emphasize that the signal S is informative in the sense that the supplier will be more certain about the client's true type after observing S. To see this, let $\Pr(T|S)$ represent the posterior probability that the cost type is $T \in \{G, B\}$, given the signal $S \in \{g, b\}$. Based on the Bayes' rule, we may calculate

$$\Pr(G|g) = \frac{\Pr(g|G)\Pr(G)}{\Pr(g|G)\Pr(G) + \Pr(g|B)\Pr(B)} = 1 \geq \gamma, \tag{2}$$

$$\Pr(B|b) = \frac{\Pr(b|B)\Pr(B)}{\Pr(b|G)\Pr(G) + \Pr(b|B)\Pr(B)} = \frac{1-\gamma}{1-\gamma\lambda} \geq 1 - \gamma. \tag{3}$$

Thus a good signal $S = g$ indicates that the client has a low cost for sure, while a bad signal suggests that the client is more likely to have a high cost.

Let $E[C]$ be the supplier's expected service cost without any signal, and $E[C|S]$ be the expected service cost with a signal S. It can be readily shown that

$$\begin{aligned} E[C] &= \Pr(G)c_l + (1 - \Pr(G))c_h = \gamma c_l + (1-\gamma)c_h, && (4) \\ E[C|g] &= \Pr(G|g)c_l + \Pr(B|g)c_h = c_l < E[C], \\ E[C|b] &= \Pr(G|b)c_l + \Pr(B|b)c_h = \frac{(1-\lambda)\gamma c_l}{1-\gamma\lambda} + \frac{(1-\gamma)c_h}{1-\gamma\lambda} = \frac{E[C] - \gamma\lambda c_l}{1-\gamma\lambda} > E[C]. \end{aligned}$$

That is, a good (bad) signal g (b) implies a lower (higher) expected cost. Note that the signal is unbiased since $E[C] = E[C|g]\Pr(g) + E[C|b]\Pr(b)$.

Supplier 2 cannot observe the signal S. For instance, supplier 2 is a new entrant and does not have much information about the client's type. We assume he receives a garbling of supplier 1's signal, denoted $\tilde{S}$. The value of $\tilde{S}$ can be either good ($\tilde{g}$) or bad ($\tilde{b}$). Let $\Pr(\tilde{g}|S)$ and $\Pr\left(\tilde{b}|S\right)$ be the probabilities of $\tilde{S} = \tilde{g}$ and $\tilde{S} = \tilde{b}$ respectively, conditional on S. Define

$$\Pr(\tilde{g}|g) = \Pr\left(\tilde{b}|b\right) = \frac{1+\rho}{2}, \text{and } \Pr\left(\tilde{b}|g\right) = \Pr(\tilde{g}|b) = \frac{1-\rho}{2}, \tag{5}$$

where $0 \leq \rho \leq 1$ captures the extent of the garbling. When $\rho = 0$, the signal $\tilde{S}$ is useless for supplier 2 because for a given S, he receives $\tilde{S} = \tilde{b}$ or $\tilde{S} = \tilde{g}$ with equal probabilities. However, as ρ increases, it becomes more likely that $\tilde{S}$ represents the same signal as S, i.e., the information asymmetry between the suppliers diminishes. When $\rho = 1$, the suppliers are equally informed and there is no information asymmetry anymore. Hence we may use ρ as a control of asymmetric supplier information. Note that with $\rho = 1$, the suppliers are identical ex ante and the game reduces to Bertrand competition.

To examine the quality of the signal $\tilde{S}$, we derive the posterior probabilities of the client type conditional on supplier 2's noisy signal:

$$\Pr(G|\tilde{g}) = \Pr(G|g)\Pr(g|\tilde{g}) + \Pr(G|b)\Pr(b|\tilde{g}) = \frac{\gamma(2\rho\lambda + 1 - \rho)}{1 - \rho + 2\rho\gamma\lambda}, \tag{6}$$

$$\Pr\left(B|\tilde{b}\right) = \Pr(B|g)\Pr\left(g|\tilde{b}\right) + \Pr(B|b)\Pr\left(b|\tilde{b}\right) = \frac{(1-\gamma)(1+\rho)}{1 + \rho - 2\rho\gamma\lambda}. \tag{7}$$

It can be readily shown that $\Pr(G|\tilde{g}) \leq \Pr(G|g)$ and $\Pr\left(B|\tilde{b}\right) \leq \Pr(B|b)$, where the equality holds only when $\rho = 1$. This means that S is indeed a more accurate indicator of the client's type than $\tilde{S}$. A couple of points are worth noting here. First, due to the stochastic nature of the signals, S does not necessarily dominate $\tilde{S}$ for all possible realizations, e.g., supplier 1 may receive a bad signal $S = b$ while supplier 2 may receive a good signal $\tilde{S} = \tilde{g}$ from a good type client. Second, although a bad type client always sends a bad signal $S = b$ to supplier 1, supplier 2 may still receive a good signal $\tilde{S} = \tilde{g}$. This is again because supplier 2's signal is more noisy than supplier 1's.

Given the signal $\tilde{S}$, the expected service cost perceived by supplier 2 is $E[C|\tilde{S}] = \Pr(g|\tilde{S})E[C|g] + \Pr(b|\tilde{S})E[C|b]$, where $\Pr(g|\tilde{S})$ and $\Pr(b|\tilde{S})$ are the posterior probabilities of $S = g$ and $S = b$ respectively, conditional on $\tilde{S} \in \left\{\tilde{g}, \tilde{b}\right\}$. Based on the Bayes' rule, there are

$$\Pr(g|\tilde{S}) = \frac{\Pr(\tilde{S}|g)\Pr(g)}{\Pr(\tilde{S}|g)\Pr(g) + \Pr(\tilde{S}|b)\Pr(b)} \text{ and } \Pr(b|\tilde{S}) = \frac{\Pr(\tilde{S}|b)\Pr(b)}{\Pr(\tilde{S}|g)\Pr(g) + \Pr(\tilde{S}|b)\Pr(b)}. \tag{8}$$

Then we can show the following relationship among the expected service costs (all proofs are presented in the Appendix).

Lemma 1 $c_l = E[C|g] \leq E[C|\tilde{g}] \leq E[C] \leq E[C|\tilde{b}] \leq E[C|b] < c_h$.

The client knows that supplier 1 has superior information about the service cost than supplier 2. However, like the suppliers, the client does not have perfect information about the service cost. Recall that the service cost depends on numerous factors, many of which are random and not perfectly known to the client (e.g., service complexity, suppliers' capabilities, match between the firms, and demand uncertainties). Therefore, we assume that the client knows the probability distribution (i.e., γ) but not her exact type. This is a standard treatment in the common-value auction literature that assumes the seller does not know the *exact* value of the auctioned object. We have also examined the other extreme case where the client has perfect information about her own type. The qualitative insights from the main model are quite robust in both extreme cases.

The sequence of events in our model is as follows. First, the client announces the request for quote (RFQ); second, both suppliers receive their private signals about the client's type (i.e., supplier 1 observes S and supplier 2 observes $\tilde{S}$); third, both suppliers simultaneously send their quotes to the client, each specifying a fixed fee (price) p_i ($i = 1, 2$) that the supplier would like to charge for the service; next, the client awards the service contract to the supplier with the lower quote (in case of a tie, the client awards the contract by flipping a fair coin); lastly, the winning supplier delivers the service as required to the client.

We focus on the fixed-fee contract because it is quite simple and relatively easy to implement in practice. In fact, it has been commonly used in service outsourcing: The client announces a service contract to outsource (the contract may provide details about the outsourced service and specify the required service levels), then the suppliers bid for the contract on price. We assume that both the client and the suppliers are risk-neutral and aim to maximize their expected payoffs. In addition, everything is common knowledge except the cost type T and the two signals S and $\tilde{S}$.

Define social surplus as the sum of the payoffs of all parties in the system. In our setting, it is $V - E[C]$, where $E[C] = \gamma c_l + (1-\gamma) c_h$. Let π_1 and π_2 denote the two suppliers' expected payoffs, respectively. Then the client's expected payoff is equal to the difference between the social surplus and the sum of the suppliers' payoffs, i.e., $\Pi = V - E[C] - \pi_1 - \pi_2$.

4. Supplier Competition

This section studies the equilibrium outcome of the Bayesian game played by the suppliers. In our model setting, the suppliers' game can be characterized by a common-value auction. In this auction, supplier i ($i = 1, 2$) chooses a quote p_i to maximize his expected payoff π_i. When $\rho = 1$, the signals S and $\tilde{S}$ are identical, i.e., the suppliers always obtain the same information. They engage in Bertrand competition and the equilibrium strategy is to quote $E[C|g]$ when receiving signal g and $E[C|b]$ when receiving signal b. Information asymmetry is present when $0 \leq \rho < 1$. The following proposition states that there is no pure-strategy equilibrium in the game in the presence of information asymmetry between the suppliers.

Proposition 1 *No pure-strategy equilibrium exists in the suppliers' quoting game when $\rho < 1$.*

Next we derive the mixed-strategy equilibrium for such a game. Let $G_1(p|S) = \Pr(p_1 \leq p|S)$ denote supplier 1's mixed strategy in equilibrium, where $G_1(p|S)$ is a cumulative distribution function conditional on the signal S. Similarly, let $G_2\left(p|\tilde{S}\right) = \Pr\left(p_2 \leq p|\tilde{S}\right)$ denote supplier 2's mixed strategy in equilibrium. Then supplier 1's expected payoff function can be written as

$$\pi_1(p_1|S) = \Pr(\tilde{g}|S)(p_1 - E[C|S])(1 - G_2(p_1|\tilde{g})) + \Pr(\tilde{b}|S)(p_1 - E[C|S])\left(1 - G_2(p_1|\tilde{b})\right). \quad (9)$$

The first term on the right-hand side of Eq. (9) is supplier 1's expected payoff when supplier 2 receives a signal $\tilde{S} = \tilde{g}$, and the second term is the expected payoff when supplier 2 receives $\tilde{S} = \tilde{b}$. Supplier 2's expected payoff function is given by

$$\pi_2\left(p_2|\tilde{S}\right) = \Pr(g|\tilde{S})\left(p_2 - E\left[C|g\right]\right)\left(1 - G_1\left(p_2|g\right)\right) + \Pr\left(b|\tilde{S}\right)\left(p_2 - E\left[C|b\right]\right)\left(1 - G_1\left(p_2|b\right)\right). \quad (10)$$

The first term on the right-hand side of Eq. (10) is supplier 2's expected payoff when supplier 1 receives a signal $S = g$, and the second term is the expected payoff when supplier 1 receives $S = b$. Eq. (10) differs from Eq. (9) in that the expected service cost changes with supplier 1's signal. This is because supplier 1's signal is more accurate than supplier 2's.

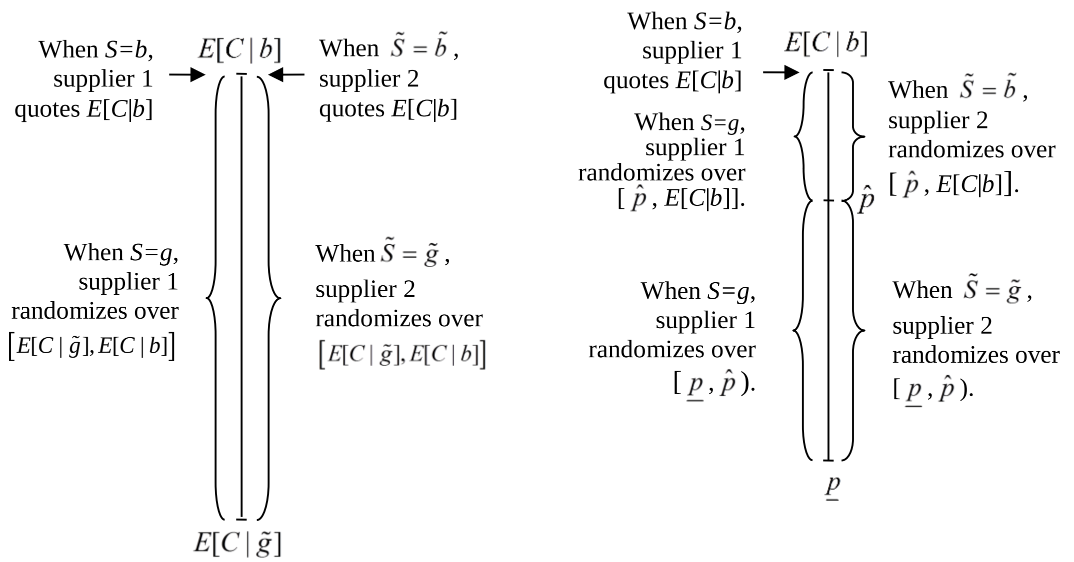
We first characterize the equilibrium of the supplier game for $\rho = 0$. When $\rho = 0$, supplier 2 does not obtain any meaningful information from the signal. The distribution of supplier 2's signal reduces to $\Pr(\tilde{g}|g) = \Pr(\tilde{b}|g) = \Pr(\tilde{g}|b) = \Pr(\tilde{b}|b) = \frac{1}{2}$. Supplier 2's posterior beliefs are the same as his prior beliefs. In particular, $\Pr(g|\tilde{g}) = \Pr(g|\tilde{b}) = \Pr(g), \Pr(b|\tilde{g}) = \Pr(b|\tilde{b}) = \Pr(b)$ and $E[C|\tilde{g}] = E\left[C|\tilde{b}\right] = E\left[C\right]$. The competition is essentially between a privately informed supplier and an uninformed supplier. The next proposition presents the suppliers' equilibrium quoting strategies.

Proposition 2 *Suppose $\rho = 0$. The suppliers' equilibrium strategies can be characterized as follows: (1) Supplier 1 quotes $p_1 = E\left[C|b\right]$ when observing $S = b$, and quotes according to $G_1\left(p|g\right) = 1 + \frac{\Pr(b)(p - E[C|b])}{\Pr(g)(p - E[C|g])},\ p \in \left[E\left[C\right], E\left[C|b\right]\right]$ when observing $S = g$. (2) Supplier 2 ignores the signal $\tilde{S}$ and quotes according to $G_2\left(p\right) = 1 - \frac{E[C] - E[C|g]}{p - E[C|g]},\ p \in \left[E\left[C\right], E\left[C|b\right]\right]$.*

We next consider $0 < \rho < 1$. It turns out that for any given pair of probabilities $\Pr(g)$ and $\Pr(b)$, a unique equilibrium exists and the equilibrium structure depends on the relationship between $\Pr(g)$ and $\Pr(b)$. Proposition 3 presents the firms' equilibrium strategies for the case $\Pr(g) \leq \Pr(b)$ (or equivalently, $\gamma\lambda \leq \frac{1}{2}$), i.e., supplier 1 is more likely to receive a bad signal.

Proposition 3 *Suppose $0 < \rho < 1$ and $\Pr(g) \leq \Pr(b)$. The suppliers' equilibrium strategies can be characterized as follows: (1) Supplier 1 quotes $p_1 = E\left[C|b\right]$ when observing $S = b$, and quotes according to $G_1\left(p|g\right) = 1 + \frac{\Pr(b|\tilde{g})(p - E[C|b])}{\Pr(g|\tilde{g})(p - E[C|g])}$, where $p \in [E[C|\tilde{g}], E\left[C|b\right]]$ when observing $S = g$; (2) Supplier 2 quotes $p_2 = E\left[C|b\right]$ when observing $\tilde{S} = \tilde{b}$, and quotes according to $G_2(p|\tilde{g}) = 1 - \frac{(E[C|\tilde{g}] - E[C|g]) - \Pr(\tilde{b}|g)(p - E[C|g])}{\Pr(\tilde{g}|g)(p - E[C|g])}$, where $p \in [E[C|\tilde{g}], E\left[C|b\right]]$ when observing $\tilde{S} = \tilde{g}$.*

It is worth mentioning that for $\Pr(g) \leq \Pr(b)$, supplier 2's expected payoff is always zero regardless of his signal. However, supplier 1's expected payoff is $E\left[C|\tilde{g}\right] - E\left[C|g\right] \geq 0$ when he receives a good signal and 0 when he receives a bad signal. That is, less accurate information about the client type puts supplier 2 in a disadvantageous position. To help understand Proposition 3, Figure 1(a) depicts the support of the suppliers' quotes.



(a) Supplier Competition When $\Pr(g) \leq \Pr(b)$ (b) Supplier Competition When $\Pr(g) > \Pr(b)$

Figure 1: An illustration of the suppliers' equilibrium quoting strategies.

Proposition 4 characterizes the suppliers' equilibrium strategies for the case $\Pr(g) > \Pr(b)$ (or equivalently, $\gamma\lambda > \frac{1}{2}$), i.e., supplier 1 is more likely to receive a good signal.

Proposition 4 *Suppose $0 < \rho < 1$ and $\Pr(g) > \Pr(b)$. The suppliers' equilibrium strategies can be characterized as follows: (1) Supplier 1 quotes $p_1 = E[C|b]$ when observing $S = b$, and quotes according to* $G_1(p|g) = \begin{cases} 1 - \frac{\left(p - E[C|\tilde{g}]\right) - \Pr(b|\tilde{g})(p - E[C|b])}{\Pr(g|\tilde{g})(p - E[C|g])}, & p \in [\underline{p}, \hat{p}) \\ 1 + \frac{\Pr(b|\tilde{b})(p - E[C|b])}{\Pr(g|\tilde{b})(p - E[C|g])}, & p \in [\hat{p}, E[C|b]] \end{cases}$ *when observing $S = g$, where the cutoff levels $\hat{p}$ and $\underline{p}$ ($\hat{p} > \underline{p}$) are defined in the proof. (2) Supplier 2 quotes according to* $G_2\left(p|\tilde{b}\right) = 1 - \frac{\left(p - E[C|g]\right)}{\Pr(\tilde{b}|g)(p - E[C|g])}$, $p \in [\hat{p}, E[C|b]]$ *when observing $\tilde{S} = \tilde{b}$, and quotes according to* $G_2(p|\tilde{g}) = 1 - \frac{\left(p - E[C|g]\right) - \Pr(\tilde{b}|g)(p - E[C|g])}{\Pr(\tilde{g}|g)(p - E[C|g])}$, $p \in [\underline{p}, \hat{p}]$, *when observing $\tilde{S} = \tilde{g}$, where the cutoff levels $\hat{p}$ and $\underline{p}$ ($\hat{p} > \underline{p}$) are defined in the proof.*

Figure 1(b) illustrates the support of the suppliers' quotes for $\Pr(g) > \Pr(b)$. Similar to the previous case with $\Pr(g) \leq \Pr(b)$, supplier 1 will quote $E[C|b]$ when observing a signal $S = b$. However, when supplier 1 observes a signal $S = g$, he will randomize his quote over $\left[\underline{p}, E[C|b]\right]$, whose lower bound $\underline{p}$ is higher than its counterpart $E[C|\tilde{g}]$ under $\Pr(g) \leq \Pr(b)$. This suggests that supplier 1 competes less aggressively than in the previous case. To see what causes this difference, we may examine the condition $\Pr(g) > \Pr(b)$. This condition can be rewritten as

$$\Pr\left(\tilde{b}|g\right)\left(E\left[C|b\right]-E\left[C|g\right]\right) > E\left[C|\tilde{g}\right]-E\left[C|g\right]. \tag{11}$$

Note that the left-hand side of (11) is supplier 1's expected payoff if he undercuts the quote $E\left[C|b\right]$ and only wins when supplier 2 receives $\tilde{S}=\tilde{b}$. The right-hand side is supplier 1's payoff if he quotes $p_1 = E\left[C|\tilde{g}\right]$ and wins for sure regardless of supplier 2's signal. The inequality in (11) indicates that unlike in the case $\Pr(g) \leq \Pr(b)$, now it is not optimal for supplier 1 to always beat supplier 2. Instead, supplier 1 would rather bet on the chance that supplier 2 receives $\tilde{S}=\tilde{b}$ and only win in that case. Therefore, supplier 1 competes less aggressively when he receives $S=g$.

Given the above equilibrium outcomes, Proposition 5 characterizes the suppliers' expected payoffs in equilibrium.

Proposition 5 *(1) Suppose* $\rho = 1$. *Both suppliers' payoffs are zero in the equilibrium. (2) Suppose* $0 < \rho < 1$. *In the equilibrium, supplier 1's expected payoff is always positive, while supplier 2's expected payoff is positive if* $\Pr(g) > \Pr(b)$, *and is zero otherwise. Supplier 1's expected payoff is always higher than that of supplier 2's. (3) Suppose* $\rho = 0$. *Supplier 1's payoff is positive while supplier 2's payoff is zero in the equilibrium.*

Consider the general situation $0 < \rho < 1$. When $\Pr(g) \leq \Pr(b)$, only supplier 1 (i.e., the more informed supplier) earns a positive rent. This is the case where the more informed supplier has a single-side information advantage (SIA) as observed in the auction literature (e.g., Engelbrecht-Wiggans et al. 1983; Hauswald and Marquez 2006). When $\Pr(g) > \Pr(b)$, both suppliers can enjoy positive expected payoffs. This is the case with double-side information advantages (DIA). The fact that supplier 1 does not observe supplier 2's private signal enables supplier 2 to also earn an information rent, even though supplier 2's signal is not as good as supplier 1's.

The above result reveals that the client has to leave a positive information rent to the suppliers as long as $\rho < 1$ (i.e., the suppliers have asymmetric information about the service cost). Nevertheless, having two suppliers is always better than having just a single supplier from the client's perspective. When there is no supplier competition, a single supplier with strong bargaining power will quote V and extract all the surplus. However, when there are two suppliers competing against each other, they will bid down to $E[C|b]$ or lower. That is, supplier competition ensures that the client makes a positive profit, even if the supplier are asymmetrically informed.

5. Information Sharing

The preceding section characterizes the equilibrium outcome of supplier competition. It has been shown that the outcome of the bidding game hinges upon the suppliers' information structure. In most practical situations, the client can influence the suppliers' information structure through information sharing. For example, the client may help the suppliers obtain better information about the service cost by disclosing internal documents and arranging on-site visits. This section proceeds to study the client's information sharing strategies. Specifically, we are interested in the two questions raised in the introduction: First, what is the impact of information asymmetry between the suppliers on the client's profit? Second, how much information should the client share with both suppliers? The following two subsections analyze these two questions and derive some useful managerial insights. For simplicity, we assume that the cost of information sharing is negligible for the client.

5.1 Changing ρ via Information Sharing

In our model, information asymmetry exists because supplier 2's information is not as accurate as supplier 1's. The difference between the suppliers' signals S and $\tilde{S}$ is defined by the parameter ρ as in Eq. (5). When ρ is larger (smaller), the two signals are more (less) similar, or the degree of information asymmetry between the suppliers is lower (higher). Thus we use $\rho \in [0, 1]$ to measure the similarity between the suppliers' signals. This subsection examines the impact of this information asymmetry on the client's profit. Clearly, if less information asymmetry leads to higher profit, then the client would have incentives to reduce information asymmetry between suppliers (increase ρ) via information sharing. For instance, if the client has access to some of supplier 1's information, then the client may increase ρ by sharing that information with supplier 2. We next analyze the client's optimal information sharing strategy on ρ.

A natural conjecture would be that decreasing information asymmetry will intensify competition because it levels the ground for the suppliers. For example, the suppliers' bidding game boils down to Bertrand competition when $\rho = 1$, which erodes the suppliers' payoffs. As a result, the client may always want to reduce information asymmetry between the suppliers, for example, by sharing supplier 1's information that is available to her with the less-informed supplier. The intuition is consistent with the findings in the auction literature (e.g., Milgrom and Weber 1982b; Wilson 1975), and appears to be a prevalent view among practitioners as well. The IT outsourcing case study by Kern et al. (2002) links weak competition to ex ante supplier asymmetries and recommends that the client should assist the disadvantageous supplier with information gathering. However, we find that this intuitive idea is not always valid in our model setting. Propositions 6 and 7 illustrate how the suppliers' and the client's expected payoffs vary with ρ.

Proposition 6 *(1) When* $\Pr(g) \leq \Pr(b)$*, supplier 1's expected payoff is decreasing in* ρ*, and supplier 2's expected payoff is always zero (independent of* ρ*). (2) When* $\Pr(g) > \Pr(b)$*, there exist* ρ_1 *and* ρ_2 $(0 \leq \rho_1 < \rho_2 < 1)$ *such that supplier 1's expected payoff is increasing in* ρ *for* $\rho \in [0, \rho_1]$ *and decreasing in* ρ *for* $\rho \in (\rho_1, 1]$*, and supplier 2's expected payoff is increasing in* ρ *for* $\rho \in [0, \rho_2]$ *and decreasing in* ρ *for* $\rho \in (\rho_2, 1]$*.*

The above result indicates that the supplier competition is not necessarily more intense when there is less information asymmetry. The explanation for this result is as follows. As ρ increases, there is less information asymmetry between the two suppliers, so they are more likely to receive the same signal. Consequently, supplier 2 will quote more aggressively when receiving a good signal, because he is more confident that supplier 1 also receives a good signal. On the other hand, supplier 2 will compete less aggressively when receiving a bad signal, because it is more likely that supplier 1 also receives a bad signal. Therefore, an increase in ρ generates two countervailing effects on the supplier competition: an intensifying effect and a dampening effect.

When $\Pr(g) \leq \Pr(b)$, the dampening effect does not exist. This is because Proposition 3 shows that supplier 2 (and supplier 1) will always quote the highest possible bid $E[C|b]$ when receiving a bad signal. Due to the intensifying effect, an increase in ρ always leads to more intense supplier competition and drives down supplier 1's profit. When $\Pr(g) > \Pr(b)$, both the dampening effect and the intensifying effect exist. In this case, supplier 1 is likely to receive a good signal. When ρ is large, supplier 2 is also more likely to receive a good signal due to the low level of information asymmetry. Consequently, the intensifying effect dominates the damping effect and an increase in ρ intensifies the supplier competition. Whereas, when ρ is small, supplier 2 is more likely to receive a bad signal due to the high level of information asymmetry between the suppliers. As a result, the dampening effect dominates the intensifying effect and an increase in ρ softens the supplier competition. Overall, the suppliers' payoffs are quasi-concave in ρ in this case, i.e., they first increase and then decrease to zero at $\rho = 1$.

An interesting implication of Proposition 6 is that under $\Pr(g) > \Pr(b)$, it might be in the suppliers' best interest to bilaterally share their information. When the level of information asymmetry is high (i.e., $\rho < \rho_1$), both suppliers will benefit if the better-informed supplier reveals his information to the less-informed party (until $\rho = \rho_1$ is achieved). Further, when the level of information asymmetry is low (i.e., $\rho > \rho_2$), the less-informed supplier prefers to ignore some of the available information and doing this also benefits the better-informed supplier as well.

Proposition 7 *(1) When* $\Pr(g) \leq \Pr(b)$*, the client's expected payoff is increasing in* ρ*. (2) When* $\Pr(g) > \Pr(b)$*, there exists* ρ_0 *(*$0 \leq \rho_1 \leq \rho_0 < \rho_2 < 1$*, where* ρ_1 *and* ρ_2 *are given in Proposition 6 such that the client's payoff is decreasing in* ρ *for* $\rho \in [0, \rho_0]$ *and increasing in* ρ *for* $\rho \in (\rho_0, 1]$*.*

Proposition 7 shows that the client's payoff is not always monotonically increasing in ρ. In other words, reducing information asymmetry between the suppliers may hurt the client's payoff. This yields useful insight on how the client should manage supplier information asymmetry. In an ideal situation where the client can fully control the parameter ρ, she should remove supplier information asymmetry completely by setting $\rho = 1$. That is, the client can help the less-informed supplier achieve a signal that is as accurate as the better-informed supplier's. The suppliers' payoffs are squeezed to zero and the client extracts all the surplus from the system. However, a more realistic assumption is that the client only has limited control of information asymmetry. In many practical situations, it might be hard to completely eliminate information asymmetry between the suppliers. Consider the example where one of the suppliers is an incumbent with prior business experience with the client. There are many factors that prevent an entrant supplier from gaining exactly the same client information as the incumbent. For instance, the client may not have access to all of the incumbent supplier's information; it is very likely that the information acquired from third-party information sources is not as accurate as the information inferred from the first-hand data. In addition, even if the entrant supplier can use pre-contract on-site investigation to learn about the client, it is still unable to obtain certain tacit knowledge, e.g., the employee conduct and organizational culture at the client firm. The incumbent supplier, however, may have a better understanding of these intricacies through his past interactions with the client. Under these circumstances where the client can only slightly reduce information asymmetry (e.g., ρ is always smaller than ρ_0), it might be optimal for the client to maintain a high level of information asymmetry between the suppliers, especially when $\Pr(g) > \Pr(b)$. Such information asymmetry can intensify the supplier competition. Our result cautions the client about her information disclosure strategy under these situations. Interestingly, reducing information asymmetry between the suppliers may make the client worse off if the current level of information asymmetry is relatively high ($\rho < \rho_0$). In other words, helping the less-informed supplier is beneficial to the client only when the supplier's information disadvantage is not very significant.

The above result also illustrates how the client's information disclosure strategy depends on the distribution of the client type (measured by γ) and the signal quality (measured by λ). The above counterintuitive result holds only for $\Pr(g) > \Pr(b)$, or $\gamma\lambda > \frac{1}{2}$. So if there is a large proportion of high-cost clients or the signal quality is sufficiently low (i.e., $\Pr(g) \leq \Pr(b)$ because $\gamma\lambda$ is small), then the client always has incentives to help the less-informed supplier achieve a more accurate signal. This can level the competition ground and thus induce more aggressive quoting from the suppliers. Otherwise (i.e., $\Pr(g) > \Pr(b)$ because $\gamma\lambda$ is large) the client's payoff does *not* necessarily increase as the level of information asymmetry between suppliers decreases. A useful implication is that if the client could make investments to either become a better type (increase γ) or improve the signal quality (increase λ), her information disclosure strategy may change accordingly as $\gamma\lambda$ passes the threshold value $\frac{1}{2}$.

5.2 Changing λ via Information Sharing

The above subsection studies the first question, i.e., whether the client wants to reduce information asymmetry between the suppliers. This is essentially about information sharing with the less-informed supplier. In this subsection, we continue to address the second question, i.e., whether the client wants to disclose information to *both* suppliers. By disclosing more information, the client may improve the accuracy of the signals observed by both suppliers. This can be done through various means, such as clarifying the service requirements and disclosing more internal documents to the suppliers. However, as discussed earlier, the suppliers may have different learning abilities, i.e., they may not generate the same understanding of the service cost from the disclosed information. For example, a supplier who has more industry experience or is located closer to the client can better interpret the data shared by the client. Hence, under the presence of information asymmetry between the suppliers (e.g., when the suppliers have different learning abilities), it is not clear whether sharing more information is always beneficial to the client.

This question can be addressed by examining the impact of λ on the client's profit. Notice that in our model, λ is a proxy of the quality of the suppliers' signals. When $\lambda = 0$, supplier 1 always receives bad signals and his posterior beliefs about a client's type after receiving a signal, S, are the same as the prior beliefs. That is, $\Pr(G|g) = \gamma$ and $\Pr(B|b) = 1 - \gamma$ for $\lambda = 0$. Similarly, from (6) and (7) we know $\Pr(G|\tilde{g}) = \gamma$ and $\Pr\left(B|\tilde{b}\right) = 1 - \gamma$ for $\lambda = 0$. When $0 < \lambda < 1$, with a bad type, supplier 1 always receives a bad signal; but for a good type, he receives a good signal with probability $\lambda < 1$. So a good signal ($S = g$) confirms a good-type client, whereas a bad signal ($S = b$) indicates a bad-type client with probability of $\frac{1-\gamma}{1-\gamma\lambda}$ (see Eqs. (2) and (3)). This probability

$\frac{1-\gamma}{1-\gamma\lambda}$ increases with λ, i.e., a higher λ leads to a more accurate signal for supplier 1. To illustrate the effect of λ on supplier 2's signal quality, we may examine the posterior probabilities of the client type given in Eqs. (6) and (7). It can be verified that both $\Pr(G|\tilde{g})$ and $\Pr\left(B|\tilde{b}\right)$ are increasing in λ. That is, a higher λ also leads to a more accurate signal for supplier 2. When $\lambda = 1$, supplier 1's signals are perfect and supplier 2's signals are least noisy.

From the above discussion, we may use λ as the extent to which the client shares information with both suppliers. Sharing more information improves λ, which implies that the quality of both suppliers' signals improves. Generally speaking, ρ may also change as the client shares more information; however, allowing a variable ρ introduces significant difficulties into analysis. So, for the analysis below, we focus on the benchmark case where ρ is fixed. In fact, now we may view ρ as a measure of the difference in the suppliers' learning capabilities, which are exogenously determined.

Proposition 8 *Consider a fixed $\rho < 1$, i.e., there is information asymmetry between the suppliers. (1) When $\Pr(g) \leq \Pr(b)$, supplier 1's payoff is increasing in λ, and supplier 2's payoff is always zero. (2) When $\Pr(g) > \Pr(b)$, both suppliers' payoffs are increasing in λ. (3) The client's expected payoff is always decreasing in λ. Therefore, the client's optimal decision is to choose the lowest possible λ.*

Proposition 8 presents a surprising result: improving the suppliers' information *always* negatively impacts the client's payoff. Why does the client suffer from more accurate supplier signals? Intuitively, the client should be willing to send more accurate signals. This will motivate the suppliers to quote more aggressively because a good signal is associated with a low service cost. However, we find that the opposite is true in our model setting. The competitive intensity between suppliers are lower given more accurate signals.

We next take a closer look at how the suppliers' quoting strategies vary with λ. As λ increases, supplier 1 is more likely to receive a good signal given a good type client. Supplier 1 is more confident that a bad signal indicates a bad type client, which suggests a higher $E[C|b]$. Proposition 3 shows that the suppliers randomize their quotes over $[E[C|\tilde{g}], E[C|b]]$ when $\Pr(g) \leq \Pr(b)$. The more accurate signals enable supplier 1 to better estimate $E[C|b]$ and quote more conservatively to avoid losses. This will in turn make supplier 2 compete more cautiously. On the other hand, as λ increases, supplier 2 also receives more accurate signals. Supplier 2 is more confident that a good signal $\tilde{S} = \tilde{g}$ indicates a good type client and is willing to lower his quote when $\tilde{S} = \tilde{g}$. This forces the suppliers to compete more aggressively. The aggressiveness of the suppliers is determined by the trade-off between these two effects. The overall expected prices quoted by the suppliers are monotonically increasing when $\Pr(g) \leq \Pr(b)$. This suggests that the suppliers will compete less aggressively when they are given more accurate signals.

When $\Pr(g) > \Pr(b)$, the suppliers randomize their quotes over $\left[\underline{p}, E[C|b]\right]$ as shown in Proposition 4. Increasing λ results in a higher $E[C|b]$ and a lower $E[C|\tilde{g}]$, suggesting that condition (11) is more likely to be met and the suppliers are less willing to lower their prices. Therefore, the lower bound of the suppliers' quotes, $\underline{p}$, is also increasing. The overall expected prices quoted by the suppliers are monotonically increasing in λ when $\Pr(g) > \Pr(b)$, which again suggests less intense competition between the suppliers.

We emphasize that even though ρ is fixed, changing λ will affect the quality difference between the suppliers' signals. When $\rho < 1$, the suppliers do not benefit symmetrically from the increase in λ (i.e., more accurate signals). When λ increases, both suppliers' information quality improves; but the improvement for supplier 2 has to be discounted by ρ. Therefore, the quality difference between the suppliers' signals becomes greater as λ increases.

However, notice that the change in quality difference caused by λ and that caused by ρ have different implications on supplier competition and the client's payoff. While increasing the quality difference by decreasing ρ is good for the client in certain cases (i.e. when $\rho < \rho_0$ and $\Pr(g) > \Pr(b)$), increasing the quality difference by raising λ is always bad for the client. Such a distinction can be explained as follows. Recall that changing ρ only affects the signal quality of the less-informed party; in contrast, changing λ will improve both firms' signals. In particular, it can be shown that the suppliers' expected service cost, $E[C|b]$, is constant in ρ but convexly increasing in λ. Since $E[C|b]$ is the upper bound of the suppliers' quotes, a higher $E[C|b]$ implies less aggressive bids from the suppliers. Therefore, while the client may benefit from a greater quality difference caused by varying ρ, a greater quality difference caused by increasing λ hurts the client.

This study presents an interesting case in which the client does not strive to improve suppliers' information in service outsourcing. This complements the findings in the literature. Milgrom and Weber (1982b) show that the seller may not share information with all bidders when the seller's information is complementary to only the better informed bidder's information. The complementary information will enhance the better informed bidder's information advantage and thereby hurt the seller's profit. We find that when the client's information is complementary to both suppliers' information and the suppliers have distinct abilities to learn from the released information, information disclosure may widen the information gap between the suppliers and thus dampen the competition. As a result, the client has no incentive to disclose any information to the suppliers.

6. Conclusion

The practice of outsourcing has been increasingly used in the industry as a competitive strategy in the fast-changing, global market environment. Understanding how firms should design their outsourcing strategies and manage the relationships with the suppliers is critical to the success of outsourcing. This paper is motivated by the phenomenon that in many outsourcing contexts, the suppliers' cost for serving a client is dependent on various factors including the characteristics of the client. Since the suppliers do not have perfect knowledge about these factors, they do not know the exact cost for serving the client either. This in turn leads to asymmetrically informed suppliers because they learn about the client through different information sources with diverse information accuracy. In this paper, we study a client's outsourcing problem where two suppliers compete for the client's service contract under asymmetric beliefs about the service cost. The main findings and insights from this study can be summarized as follows.

We first identify the Bayesian Nash equilibrium of the suppliers' game for any given information structure. A pure-strategy equilibrium generally does not exist in the presence of information asymmetry; however, we are able to derive the unique mix-strategy equilibrium. It has been shown that in the equilibrium, the better-informed supplier always enjoys a positive (expected) payoff, and it is higher than that of the less-informed supplier. The less-informed supplier's payoff can be either zero or positive, depending on the parameter values. This means that in our model framework, both single-side information advantage (SIA, where only the better-informed supplier earns an information rent) and double-side information advantages (DIA, where both suppliers have positive expected rents) may arise.

Then we examine how information asymmetry between the suppliers affects the client's performance. It has been found that reducing information asymmetry between the suppliers does not necessarily improve the client's payoff. In particular, helping the less-informed supplier obtain more accurate information about the service cost may hurt the client's payoff. This is because the bidding behavior of the less-informed supplier depends on his signal: he would compete more aggressively when the signal indicates a low service cost, but less aggressively when the signal indicates a high cost. Since improving the signal accuracy will make the less-informed supplier more confident about the true cost, it may induce either more or less competition depending on the realization of the signal. Either of these two effects may be dominant under different circumstances. Therefore, the client does not always benefit from reducing information asymmetry between the suppliers.

The above finding on the impact of information asymmetry provides useful insight into the client's information management strategy. Conventional wisdom suggests that the client should assist the suppliers with more information gathering in order to level the playground of competition (see, for example, Kern et al. 2002). In contrast, we have demonstrated in a reasonable setting that sharing information to reduce supplier information asymmetry may dampen competition and lower the client's payoff. To be specific, when there is a sufficiently large proportion of high-cost clients in the market, the suppliers compete more aggressively when there is a low level of information asymmetry; on the other hand, when the proportion of low-cost clients is large, the supplier competition could be more intense when the supplier information asymmetry is either very high or very low. In IT security outsourcing, for example, this implies that when the client companies generally have a robust IT infrastructure, they need to be careful when sharing information because their profit may not monotonically change with the level of information asymmetry.

In this paper we also study a common situation where the client can improve the quality of the suppliers' signals by disclosing more data to both suppliers. Under the presence of information asymmetry between the suppliers (e.g., when the suppliers have different learning abilities), we address the question whether sharing more information is beneficial to the client. Interestingly, we find that the client has no incentive to share any information with the suppliers. The reason is that the suppliers will not benefit equally from the shared data; in addition, the suppliers' expected service costs contingent on bad signals will be higher, which leads to less aggressive quotes. Therefore, sharing more information with both suppliers is detrimental to the client. This suggests that the existence of supplier information asymmetry may hinder the client's information sharing effort in outsourcing. Thus understanding the information structure between suppliers is critical for a client when devising her information management strategies.

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