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and Performance Measurement
in Service Outsourcing

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This study compares the efficacy of some commonly observed vendor selection and contracting mechanisms with respect to two key challenges in service outsourcing: vendor selection and contract efficiency. We show that competitive bidding yields good selection but contract inefficiency (positive information rent paid by the client); in this process, the winning vendor’s bid constitutes the terms of the contract between client and vendor. We then show that if instead the client establishes the contract terms then the “menu” it designs yields contract efficiency but poor selection. In one particular case—namely, when the client establishes the contract terms and may work with a previously nonselected vendor if the first vendor reneges—it is possible to attain good selection *and* contract efficiency. We also highlight the implications of performance-based contracts in services.

Key words: service outsourcing; vendor selection; performance measurement; information asymmetry; signaling game; auction

History:

1. Introduction

The involvement of external partners in business processes is a trend that has expanded from conventional manufacturing and procurement activities (Cachon and Zhang 2006, Chen et al. 2005, Wan and Beil 2009) to knowledge-intensive service activities such as offshore call centers (Aksin et al. 2008, Hasija et al. 2008, Ren and Zhou 2008) and information technology (IT) service (Fitoussi and Gurbaxani 2010, Snir and Hitt 2004).

Vendor selection and contracting have been identified as two key challenges in the process of service outsourcing (Bajari and Tadelis 2006, Snir and Hitt 2004). In services, a vendor’s “client specific” capability is especially important for service quality given the customized nature of services (Anand et al. 2010, Snir and Hitt 2004). Unfortunately, a vendor’s client-specific capability cannot be identified simply by checking the general aspects of her track record; instead, client firms must evaluate the extent to which her capabilities “match” their specific needs. It thus remains a challenge for the client to select a vendor with appropriately matched capabilities. For example, the Gartner Group estimates that vendor incompetence led to 10% of failed outsourcing initiatives in 2003 (Bartram 1999, cf.). A survey at Siemens indicates that projects are more than twice as

likely to fail when the vendor does not have client-specific capabilities than when she does (Cui et al. 2011).

Moreover, it is not trivial to design an outsourcing contract with a service vendor. Such design is complicated by the client's incomplete knowledge of vendor capabilities and also by the risks involved in contract renegotiation (DiRomualdo and Gurbaxani 1998). During the third quarter of 2010, for instance, the restructuring of outsourcing contracts (i.e., renegotiation and renewal of the contract terms) cost nearly 34% of the total contract value—compared with about 20% for the previous three years.¹ In practice, many service contracts are poorly written in terms of the transfer payments and the choice of performance measures (Fitoussi and Gurbaxani 2010). A poorly designed contract may result in inefficiency: the large information rent extracted by the vendor (Hasija et al. 2008, Ren and Zhou 2008). According to a survey by TPI, outsourcing contracts typically deliver 28% less value than originally anticipated.²

In this paper, our aim is to study some commonly observed (resp., studied) outsourcing mechanisms in practice (resp., in the literature) and show how they perform in terms of their ability to yield both good vendor selection and high contractual efficiency. First we consider competitive bidding, a mechanism whereby each vendor makes a contractual offer to the client. After evaluating these offers, the client selects a vendor and is bound by the contract terms of that vendor's bid. To be consistent with practice, we consider two cases under competitive bidding: request for quotation (RFQ) and request for proposal (RFP). With RFQ the client invites bids from vendors and these bids determine the transfer payment (price). In contrast, with RFP the client invites bids from vendors but the bids determine not only the transfer payment but also the performance metric. Both RFQ and RFP processes are commonly observed in the procurement of standard services, such as IT maintenance and call centers (Bajari et al. 2009). Competitive bidding is viewed favorably as an outsourcing process and is advocated for several reasons. Most notably, the process is believed to help the client identify the “good” vendor (Bajari and Tadelis 2006) by letting vendors self-reveal their capabilities along specified dimensions (Snir and Hitt 2004).

Broadly speaking, we classify competitive bidding as a mechanism whereby the vendor offers the contract to the client. An alternative mechanism that we consider is one whereby the client offers the contract to the vendors. In this event, the client must select one vendor and then design the contract's transfer payment and performance measurement provisions in accordance with his belief about that vendor's capability. We also consider two cases for this mechanism that are based

¹ <http://www.procurementleaders.com/news/latestnews/4302-contract-renegotiation/>

² <http://www.tpi.net/newsevents/news/releases/070319-UK.html>

on whether the vendor selection and contracting are a *sequential* process or rather a *simultaneous* process. In the former case the client splits the information collection and contracting into two sequential stages: the client selects a vendor based on the collected information and then enters into a contract with that vendor. The sequential process imposes fewer vendor and client commitments than does competitive bidding because the information provided by vendors does not constitute the contract terms. This method of outsourcing is mainly used for highly customized service—for example, R&D projects, customized software, and consulting services (Bajari et al. 2009, Bajari and Tadelis 2006, Wuyts and Geyskens 2005).

With the simultaneous process, however, the client performs vendor selection and contracting at the same time. So in this case the client, instead of collecting information about the vendors' capabilities, offers the vendors a menu of contracts with the aim of inducing information revelation. The client firm selects and enters into a contract with a vendor based on the individual choices made by each vendor. The procedure is similar to competitive bidding in that vendor selection and contracting occur simultaneously; however, an important difference is that here it's the client—not the vendor—that offers the contract.

Most existing research focuses on a single aspect of outsourcing: either better selection or efficient contracting. For instance, the competitive bidding process is usually studied as an auction game with the goal of designing an optimal “auction rule” to induce vendors' voluntary revelation of their true capabilities (Chen et al. 2005, 2008), yet the efficiency of the outsourcing contract remains unclear. In contrast, contract efficiency is usually studied in terms of a bilateral principal–agent problem of designing optimal contract terms (Hasija et al. 2008, Ren and Zhou 2008, Roels et al. 2010). However, these studies do not address the “how” and “why” of vendor selection.

A puzzle naturally arises when we consider vendor selection and contracting: Can a client get the best of both worlds? In other words, is it possible to achieve better selection *and* to maximize contracting efficiency? Assume that an outsourcing firm can achieve both. If a vendor truthfully reveals her private information, then what is there to prevent the client firm from exploiting this information and thereby de-incentivizing the vendor's honest representation of her capabilities?

To answer these questions, our study will analyze the performance of the different outsourcing mechanisms discussed previously with respect to the two key criteria: vendor selection and contract efficiency. We model the following scenario. A client seeks to select and sign a service outsourcing contract with one of two ex ante indistinguishable vendors who may or may not have client-specific capabilities (i.e., be a “match type” vendor). The client's own capability is significantly lower than that of the external specialized vendors, which implies that the client is unwilling to run the risk

of no vendor participation. Vendor efforts are assumed to be verifiable and their capabilities to be private information.

When each vendor offers a contract (competitive bidding), we show that the RFQ process yields good selection but inefficient contracting: the information rent for a match-type vendor remains positive. The reason is that, under competitive bidding, a match-type vendor need only marginally outbid a nonmatch type along a single dimension. In contrast, the RFP process yields both good selection and a reduced (but still positive) information rent, which corresponds to increased competition among vendors along two dimensions: price and choice of performance metric. So even though the RFP process dominates the RFQ process in terms of contract efficiency, competitive bidding cannot yield perfect contract efficiency. However, both the RFQ and RFP processes yield good vendor selection.

If instead it is the client who offers the contract, then we find that the *sequential* process enables the client to achieve perfect contract efficiency by imposing a performance-based menu; however, this process does not induce vendors' truth telling during selection and hence does not improve the odds of selecting a match-type vendor. In other words, under a sequential process the information collection step is superfluous because, in equilibrium, both vendors convey the same signal (of being match type). Therefore, the performance of this mechanism is similar to one in which the client randomly selects between the vendors and enters into a bilateral contract with the one that is chosen. After vendor selection, the contracting stage mirrors the bilateral principal-agent setting with a privately informed agent. We show that in this case the client can reduce the information rent to zero by offering the selected vendor a performance-based menu rather than a price-based menu. This is an interesting result because here the selection process does not alter the ex ante beliefs of the client and so, even though there is still information asymmetry, the client can reduce the information rent to zero. Alternatively, the client can improve his chance of making a good selection by organizing costly information collection (e.g., by hiring external consultants for this purpose). Such information collection is noisy, but it may improve the client's chances of making a good selection. The downside is that the client must incur a cost for collecting the information.

In contrast, a *simultaneous* process of selection and contracting can achieve good selection and efficient contracting both—although only in the special case of the initially nonselected vendor remaining available in case the selected vendor reneges from the partnership. If the nonselected vendor is no longer available for contracting, then the client is exposed to the threat to renege by the selected vendor. We show in this (more typical) case that the simultaneous selection and contracting process performs equivalently to the sequential process: it yields perfect contract efficiency but not good selection.

Our work has two important managerial and theoretical take-aways. First, under most of the vendor selection and contracting mechanisms observed in the service industry, the probability of selecting a match-type vendor cannot be simultaneously improved with contract efficiency. We show that under one scenario—namely, the simultaneous process whereby the client offers vendors a menu of contracts and then selects a vendor based on the vendors’ individual menu choices—perfect vendor selection and perfect contract efficiency may be achieved. However, this result depends on the restrictive assumption that, if the selected vendor reneges from the partnership, then the initially nonselected vendor is still available for contracting.

Second, we demonstrate the importance of using a performance-based menu in service outsourcing contracts. In the case of competitive bidding we show that, under the RFP process (where bids involve both price and choice of performance metric), less information rent is paid by the client. We also show that, if it’s the client who writes the contract, then a performance-based menu (unlike a price-based menu) reduces the information rent to zero.

2. Review of the Literature

Most of the literature treats vendor selection and contracting as two independent challenges and focuses only on one. Vendor selection is usually simplified in terms of an auction game (Chen et al. 2005, 2008, Wan and Beil 2009), and contracting is typically modeled as a bilateral principal–agent problem (Hasija et al. 2008, Ren and Zhou 2008, Roels et al. 2010).

With respect to vendor selection, a large body of literature focuses on designing an optimal selection mechanism to help managers render an accurate assessment of vendor capabilities and to improve their chances of selecting a “good” vendor (Chen et al. 2005, 2008). These studies mainly consider bidding on one dimension, such as price, and the insights gained concern the design of optimal auction rules. These studies do not examine the implications of performance measurement. Few other studies in this stream include an initial screening stage before competitive bidding, although possible screening instruments include a lump-sum fee charged to competing vendors (Snir and Hitt 2004) as well as a costly qualification involving a references check, financial audits, and on-site visits (Wan and Beil 2009). The aim of these particular studies is to generate results on either the optimal fees or the timing of qualification under a simple, price-based auction mechanism. Our study instead treats initial screening as an embedded implicit stage and addresses the task of vendor selection *after* initial screening.

Another body of literature is dedicated to bilateral contracting between the client and one vendor (Hasija et al. 2008, Ren and Zhou 2008, Roels et al. 2010, Yang et al. 2009). The main thrust

of these studies is to mitigate the contract inefficiencies due to asymmetric information between client and vendor (Hasija et al. 2008) or to the unobservability of the vendor’s actions (Aksin et al. 2008). In bilateral contracting models, the contract negotiation process is usually reduced to a single-stage game in which the client makes a take-it-or-leave-it offer to the selected vendor (Ren and Zhou 2008, Yang et al. 2009); implicit in this game is that the client reserves the decision power of contracting. Some works study the benefit of involving a second vendor. For example, Li and Debo (2009) model a two-period game in which the manufacturer has the option to select an additional vendor depending on the realization of demand. The client offers a contract to one vendor in the first period, and the second vendor is available only in the second period. This setting differs from that of our study, in which two vendors are *ex ante* similar from the perspective of the client, who must choose one of these vendors with the objective of maximizing his odds of making a good selection while minimizing payment of information rent.

This paper is related to studies on the application of performance measurement in designing incentives. Raith (2008) studies the choice of input- versus output-based performance measures as the vendor’s risk of income varies. Unlike that paper, which details when each measurement type should be used, we propose a menu that includes both input-based and output-based performance metrics. Surprisingly, our menu performs better than any other contract menu that is based on a single performance measure. Another study in the context of IT outsourcing empirically demonstrates how the performance metric should be congruent with project objectives—for instance, strategic market entry and cost reduction (Fitoussi and Gurbaxani 2010). Our study differs in that (i) the client’s only objective function is to maximize his expected payoff and (ii) we show theoretically how performance measurements can play different roles in both bilateral contracting and competitive bidding.

Our study is also closely connected with the mechanism design literature, where the client commits to a preannounced optimal contract before bidding (Cachon and Zhang 2006). In these complex optimal mechanisms, each vendor honestly reveals her type yet the information rent remains positive (Cachon and Zhang 2006). However, we show that imposing a simple performance-based menu enables the client to reduce the contracting information rent to zero.

A small body of economics literature compares auction and negotiation methods in the procurement of manufactured goods (Bulow and Klemperer 1996, Manelli and Vincent 1995). In these studies, the bidders are of different types and the contract is always won by the “highest type” bidder. Our study differs by allowing for the possibility that two bidders are of the same type; hence even a nonmatch-type bidder can win the contract. Note also that these studies consider

only linear contracts; in contrast, our study proposes a performance-based menu that can reduce the information rent earned by vendors.

3. Model Setup

We study the case where a service outsourcing firm—without sufficient in-house capability—chooses between two vendors. These two vendors are the only survivors of an initial qualification screening and are equally capable from the client’s perspective. As is typical in the industries of business and knowledge process outsourcing, the client first creates a detailed document about its particular service requirements and then invites “interest” from potential vendors. In these industries, the process is called a request for information (RFI). Each vendor assesses her capabilities in terms of the client’s specific needs and expresses interest by responding to the RFI. The client evaluates these responses and each vendor’s reputation in order to shrink the pool of potential vendors. This is the starting point of our paper, where the client must choose between the two remaining (but *ex ante* identical) vendors.

Previous studies in project management generally involve vendors with “strong expertise” or “industry reputation” and categorize each vendor’s capability as “high” or “low” (Ruckman 2005, Schiele 2006). This view of capability implicitly assumes the existence of an absolute dimension of capability that enables a vendor to perform better than others irrespective of the task’s nature. In a service context, however, it is typical for tasks to be highly customized and so client firms usually do not contact vendors without first screening their general capabilities. This procedure implies that the challenge in service outsourcing is often to identify not a dimension of “absolute” capability but rather those capabilities that are specific to the client’s needs and that cannot (normally) be identified simply by checking a vendor’s general track record. We refer to the client-specifically capable (resp., incapable) vendor as the *match-type* (resp., *nonmatch-type*) vendor. Let m and n denote, respectively, a vendor of match and nonmatch type.

We let each vendor’s client-specific capability be that vendor’s private information. For both the client and the vendors, however, it is common knowledge that each vendor is a match type with probability α , where $\alpha \in (0, 1)$. In other words, the client knows that both vendors could be match type (with probability α^2) or both could be nonmatch type (with probability $(1 - \alpha)^2$).

The client earns a concave reward function $R_i(\mu) \in \mathcal{R}$ with $i \in m, n$. Without loss of generality, the reward function $R_i(\cdot)$ may be considered as the difference between a revenue function and a disutility function; here μ is the vendor’s verifiable effort, which has a constant marginal cost c . Note that the same marginal cost of effort captures our notion that the vendors are potentially

horizontally differentiated in their client-specific capabilities; we view such capabilities as a type of organizational “sticky knowledge” that cannot be significantly improved via short-term investment (Leonard-Barton 1992). Instead we assume that a vendor with match capabilities is more likely to achieve a more successful service output than are vendors without such capabilities (Cui et al. 2011). The difference in vendor capabilities need not be restricted to a single attribute; it may be a vector of attributes. We assume that the client’s reward function is a mapping from the vector of vendor attributes to a scalar monetary value as a function of vendor efforts. Thus, $R_m(\mu) > R_n(\mu)$ for any μ . We also assume that the reward function $R_i(\cdot)$ yields a higher marginal reward for a match-type vendor’s effort; we denote this as $R'_m > R'_n$.

Let $T_i \in \mathcal{R}^+$ be the transfer payment from client to vendor for providing the service. We assume that both vendors in the pool have a reservation value $V > 0$. Finally, we assume that each vendor earns an extra utility $\epsilon \rightarrow 0^+$ from this outsourcing partnership. This assumption ensures that each vendor strictly prefers the outsourcing partnership to her outside option as long as the partnership ensures that she earns her reservation value. It follows that with a vendor of type $i \in \{m, n\}$ and effort μ_i , the client’s expected payoff is $R_i(\mu_i) - T_i$; the vendor’s corresponding expected payoff is $T_i - c\mu_i$. Therefore, the expected payoff for the service supply chain (i.e., including both client and vendor) is $R_i(\mu_i) - c\mu_i$. The chain-optimal μ_i^* must satisfy the first-order condition $R'_i(\mu_i^*) = c$. We can see that $\mu_m^* > \mu_n^*$ because $R''_i \leq 0$ and $R'_m > R'_n$.

A client who is certain about the vendor’s capability can optimize his own expected payoff by offering a service level agreement (SLA) specifying the chain-optimal effort level μ_i^* and a minimal transfer payment term—provided the vendor’s expected payoff is not below her outside option V . If the vendor’s participation constraint is binding, then $T_i^* = V + c\mu_i^*$.

However, owing to asymmetric information about the vendors’ capabilities, the client is faced with two challenges: first, to select the vendor (if one exists) that has matched capabilities; second, to reduce the vendors’ expected rent that is earned on account of the information asymmetry.

4. Implications of Performance Measurement in Bilateral Contracting

Before analyzing the different vendor selection and contracting mechanisms, we present some results on the use of different performance metrics in bilateral contracting. These results will prove to be useful when we analyze different vendor selection and contracting mechanisms. In this section we ignore the vendor selection problem and assume that the client is faced with the challenge of designing a contract for a preselected vendor who has private information about her capabilities. In general, a principal who is unaware of an agent’s true type should offer a contract menu with

multiple transfer payment terms tailored to different types and let the vendor *self-select* the terms that fit her type. Such a bilateral contracting mechanism is often called a “screening process” (Bolton and Dewatripont 2005). In this section we compare two types of contract menus in services: price- and performance-based menus. The former involves just one performance metric but has different payment parameters tailored to different vendor types. The latter menu type includes at least two performance metrics and the payment parameters differ for each. The performance-based menu has been observed in some particular real-world operations—for example, in the management of an outsourced call center (Hasija et al. 2008)—but it has not been well studied in a broader service context.

In the service industry, there are two performance metrics commonly used to design transfer payments: an output-based measure, which we call *pay per success* (PPS); and an input-based measure, which we call *pay per project* (PPP). The output-based measure is widely considered to be a better indicator of performance when the principal is unaware of the agent’s specific knowledge and when such knowledge has value for the principal (Raith 2008). Under output-based measurement (PPS), the transfer payment made to the vendor is $T_i = \rho_i R_i(\mu_i)$, where the parameter ρ_i captures the share of revenues that are transferred to the vendor. In contrast, under input-based measurement (PPP) the vendor is paid for every project regardless of the outcome. It follows that in this case the transfer payment T_i is a fixed value chosen by the client. Since the vendor effort μ is verifiable, the client can ensure a desired effort level by devising an appropriate service level agreement that induces the vendor to exert that effort.

We shall start the analysis using the optimal price-based menu with PPS metric as a benchmark; then we show the optimal performance-based menu with both PPS and PPP metrics.

One might think that allowing for an additional performance metric (PPP) that does not depend on the vendor’s capability would make the client worse-off, but our analysis shows the opposite: a performance-based menu with two performance metrics leads to greater contract efficiency than does a price-based menu under a strictly PPS scheme.

The client’s contract design problem with the price-based menu is

$$\max_{\mu_i \geq 0, \rho_i \in [0,1]} \alpha R_m(\mu_m)(1 - \rho_m) + (1 - \alpha)R_n(\mu_n)(1 - \rho_n) \quad (1)$$

$$\text{s.t. } R_m(\mu_m)\rho_m - c\mu_m \geq R_m(\mu_n)\rho_n - c\mu_n, \quad (2)$$

$$R_n(\mu_n)\rho_n - c\mu_n \geq R_n(\mu_m)\rho_m - c\mu_m, \quad (3)$$

$$R_m(\mu_m)\rho_m - c\mu_m \geq V, \quad (4)$$

$$R_n(\mu_n)\rho_n - c\mu_n \geq V. \quad (5)$$

Here the inequalities (2) and (3) represent (respectively) the match-type and nonmatch-type vendors' incentive compatibility constraints while (4) and (5) represent their individual rationality constraints. This is a standard problem in mechanism design that is studied in principal-agent models under information asymmetry. One expected result of such a mechanism is that it yields a positive information rent for the match-type vendor. Given (2) and (5) and since $R_m(\cdot) > R_n(\cdot)$, we can see that $R_m(\mu_m)\rho_m - c\mu_m \geq R_m(\mu_n)\rho_n - c\mu_n > R_n(\mu_n)\rho_n - c\mu_n \geq V$. Hence the match-type vendor's individual rationality constraint is not "tight", so she will earn an information rent.

Next we show how the client can design a performance-based menu that incorporates both PPS and PPP performance metrics and thereby attain the first-best outcome (i.e., zero information rent) under bilateral contracting. The reason such a performance-based menu can attain this outcome is that it gives the client an extra degree of freedom: the choice of performance metric helps screen the vendors, and the payment terms under each metric can be set so that each vendor type faces a tight individual rationality constraint. The intuition is that a match-type vendor would not prefer a performance metric under which her relative advantage vis-à-vis the nonmatch-type vendor is reduced. In contrast, a nonmatch-type vendor would prefer to be paid in terms of a performance metric that allows her to compete with a match-type vendor. Given the inability of PPP to distinguish among different vendors' capabilities, the match-type vendor prefers PPS while the nonmatch type prefers PPP.

In order to extract the maximal benefit from both types, the client may set the payment parameters in a way that makes each type's individual rationality constraint binding. Observe that, with such parameters, the nonmatch-type vendor strictly prefers to be paid under PPP because payment under PPS would yield a payoff of less than V . The match-type vendor weakly prefers payment under PPS: even though payment under PPP would yield the same expected payoff (i.e., V), the weak preference can trivially be overcome by adding an extra $\xi \rightarrow 0^+$ payment to the PPS contract. Unlike the price-based menu—in which the client must pay some information rent to ensure that the match-type vendor's incentive compatibility constraint is satisfied—the performance menu renders the incentive compatibility constraint of both vendor types *automatically* binding under different performance measurements. The performance menu thus reduces to zero the information rent for both vendor types and also maximizes contract efficiency.

PROPOSITION 1. *Let μ_p and μ_s denote the respective SLAs under PPP and PPS performance measurement. With a performance menu that includes both PPP and PPS, the client obtains the first-best outcome (zero information rent) by offering the following terms under two types of performance metrics.*

- Under PPS: $\rho_s = \frac{c\mu_s + V}{R_m(\mu_s)}$, where $\mu_s = \mu_m^*$.
- Under PPP: $T_p = c\mu_p + V$, where $\mu_p = \mu_n^*$.

Here μ_i^* satisfies $R'_i(\mu_i^*) = c$.

By Proposition 1, a performance-based menu increases the client's expected payoff via (i) efficient contracting, which reduces the information rent to zero for both vendor types, and (ii) setting effort levels that maximize the service chain's payoff. Therefore, the bilateral service contract with a performance-based menu strictly dominates the one with a price-based menu. In the rest of this paper, We will use the insights gained from examining how a performance-based menu increases client flexibility (via a more efficient screening of vendors) as we examine the client's dual problem of vendor selection and contracting.

5. Vendor Selection and Contract Efficiency under Competitive Bidding

Section 4 showed how the performance-based menu improves contract efficiency when only a single service vendor is involved; the challenge of vendor selection is implicitly excluded. Here and in Section 6, we will jointly examine vendor selection and contract efficiency for the case of a client selecting (and signing a service contract with) one vendor from two candidates. In this section we focus on competitive bidding—which is commonly observed in practice—as the vendor selection and contracting mechanism. Under such a mechanism, the client first uses the RFI process to narrow down his choices and then asks for bids from the remaining acceptable vendors. We begin with the case in which the client invites price-based bids from the vendors. In practice, this mechanism for vendor selection and contracting is known as the request for quotation.

5.1. Request for Quotation

Under the RFQ process, the client invites price quotations from vendors with PPS as the performance metric. The client first announces the details of the service to be outsourced and the required SLA (μ_Q). The vendors submit their bids as PPS price quotations. The client updates his belief about the vendors and selects the vendor that maximizes his expected profit based on the updated belief and the vendor's bid. The selected vendor's bid automatically constitutes the terms of the outsourcing contract. Figure 1 illustrates the sequence of events.

We first describe the vendors' bidding equilibrium. Let $\rho_i \in [0, 1]$ denote the support of the symmetric strategy of an i -type vendor. We define x_{ρ_i, ρ_j} as one vendor's probability of winning the contract when she bids ρ_i and another vendor bids ρ_j , where $i, j \in \{m, n\}$. Recall that either (or neither) vendor in the pool may be a match-type vendor.

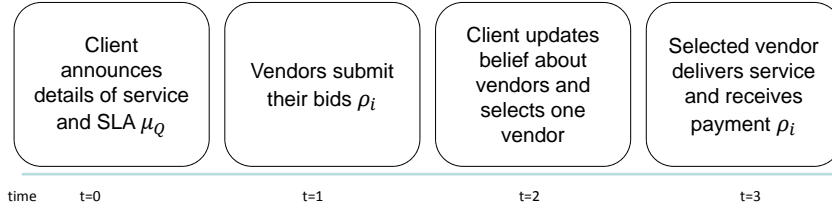


Figure 1 Sequence of Events in RFQ Process

Under this process, the selected vendor is paid as much as she bids. Vendors therefore have an incentive to bid high enough that the expected payoff from winning the contract exceeds their outside option—even if doing so runs the risk of losing the contract to another vendor. Hence a match-type vendor may want to bid just below the minimal bid that a nonmatch-type vendor can afford to make. But if the former plays a pure strategy (and so her bidding is anticipated), then her opponent (who could be a match-type vendor) might win the contract with a slightly lower bid. This means that match-type vendors must randomize their bids in order to keep other bidders guessing. The only optimal strategy for a nonmatch-type vendor is to bid the minimum (affordable) amount that maximizes her chances of being selected.

PROPOSITION 2. *In the RFQ process with an optimal SLA μ_Q , there is a unique symmetric equilibrium in which $\rho_n = \rho_n^* = \frac{c\mu_Q + V}{R_n(\mu_Q)}$ and ρ_m randomizes according to the continuous distribution $F(\rho)$ for $\rho \in [e, \frac{c\mu_Q + V}{R_n(\mu_Q)}]$, where $e = (1 - \alpha) \frac{c\mu_Q + V}{R_n(\mu_Q)} + \alpha \frac{c\mu_Q + V}{R_m(\mu_Q)}$. Also,*

$$F(\rho) = \frac{1}{\alpha} - \frac{1 - \alpha}{\alpha} \frac{(\frac{R_m(\mu_Q)}{R_n(\mu_Q)} - 1)(c\mu_Q + V)}{R_m(\mu_Q)\rho - c\mu_Q - V}.$$

In equilibrium, a nonmatch-type vendor plays a pure strategy by bidding $\rho_n = \frac{c\mu_Q + V}{R_n(\mu_Q)}$ while a match-type vendor plays a mixed strategy by bidding ρ_m randomized between e and $\frac{c\mu_Q + V}{R_n(\mu_Q)}$, where e is uniquely determined in such a way that, for a match-type vendor, the increased chance of winning the contract by lowering e is equal to the reduced expected payoff if she wins the contract. Since a match-type vendor's mixed strategy profile is continuously distributed, it follows that $\rho_m = \rho_n$ with a probability that approaches zero. Hence the bids of the two vendor types are perfectly separated by this process. Therefore, $x_{\rho_m, \rho_n} = 1$, $x_{\rho_n, \rho_m} = 0$, and $x_{\rho_i, \rho_i} = 1/2$ for $i \in m, n$. From the client's perspective, the chance of selecting a vendor with match capabilities increases from α to $(2\alpha - \alpha^2)$.³ However, a match-type vendor's information rent remains positive ($e > \frac{c\mu_Q + V}{R_m(\mu_Q)}$) whereas that of a selected nonmatch-type vendor approaches zero.

With probability $(1 - \alpha)^2$, both vendors are of nonmatch type and bid ρ_n^* . The client's expected payoff in this case is $R_n(\mu_Q) - \rho_n^* R_n(\mu_Q)$. With probability $2\alpha - 2\alpha^2$ there is exactly

³ It is easy to check that $2\alpha - \alpha^2 \geq \alpha$ because $\alpha \in [0, 1]$.

one match-type vendor in the pool, and the matched vendor always wins the contract. The client's expected payoff in this case is therefore $\int_e^{\rho_n^*} [R_m(\mu_Q) - \rho R_m(\mu_Q)] f(\rho) d\rho = R_m(\mu_Q) - R_m(\mu_Q) E[\rho]$. With probability α^2 , both vendors are of match type and each bids $\rho_m \in [e, \frac{c\mu_Q + V}{R_n(\mu_Q)}]$; the matched vendor with the lower bid wins the contract. In this case, the client's expected payoff is $2 \int_e^{\rho_n^*} \{ \int_e^\rho [R_m(\mu_Q) - y R_m(\mu_Q)] f(y) dy \} f(\rho) d\rho = 2 \int_e^{\rho_n^*} (\int_y^{\rho_n^*} f(\rho) d\rho) [R_m(\mu_Q) - y R_m(\mu_Q)] f(y) dy = 2 \int_e^{\rho_n^*} (1 - F(y)) [R_m(\mu_Q) - y R_m(\mu_Q)] f(y) dy$.

In sum, the client's expected payoff is

$$E[u_c^Q] = (1 - \alpha)^2 [R_n(\mu_Q) - c\mu_Q - V] + (2\alpha - 2\alpha^2) [R_m(\mu_Q) - R_m(\mu_Q) E[\rho]] + 2\alpha^2 \int_e^{\rho_n^*} (1 - F(\rho)) [R_m(\mu_Q) - \rho R_m(\mu_Q)] f(\rho) d\rho.$$

Define $\Pi_i(\mu_j) = R_i(\mu_j) - c\mu_j - V$ and $\Delta(\cdot) = \frac{R_m(\cdot)}{R_n(\cdot)}$ for $i \in \{m, n\}$. Simplification then yields $E[u_c] = (1 - \alpha)^2 \Pi_n(\mu_Q) + (2\alpha - \alpha^2) \Pi_m(\mu_Q) - 2\alpha(1 - \alpha)(\Delta(\mu_Q) - 1)(c\mu_Q + V)$. Therefore, the optimal RFQ will entail an SLA μ_Q that maximizes the previously displayed equality.

COROLLARY 1. *In the RFQ process, the optimal SLA μ_Q is characterized by*

$$\mu_Q = \arg \max_{\mu \geq 0} (1 - \alpha)^2 \Pi_n(\mu) + (2\alpha - \alpha^2) \Pi_m(\mu) - 2\alpha(1 - \alpha)(\Delta(\mu) - 1)(c\mu + V).$$

In this equation, the first and second terms on the right-hand side capture, respectively, the payoff when the client selects a nonmatch-type vendor (when both vendors are of nonmatch type) and when he selects a match-type vendor (when at least one vendor is of match type). The last term, $2\alpha(1 - \alpha)(\Delta(\mu_Q) - 1)(c\mu_Q + V)$, is always nonnegative because $\alpha \leq 1$ and $\Delta(\mu_Q) > 1$; it captures the expected information rent that the client must pay when selecting a match-type vendor. This rent is nonlinear with respect to α : when α is either 0 or 1, the expected rent approaches zero. In other words, there is no additional cost of selection when the client is certain about the vendors' true capabilities. The information rent increases with $\Delta(\mu_Q)$, which implies that a larger gap in performance between the two types also increases the cost of selecting a match-type vendor (i.e., it increases the expected information rent).

5.2. Request for Proposal

The RFP is another common process used in service outsourcing, and it usually allows the vendors to submit a proposal that addresses not only payment terms but also performance metrics. The client uses the vendors' bids to update his belief about vendor capabilities and then chooses the proposal that yields the highest expected payoff given his updated belief. Compared with RFQ, RFP gives the client and the vendors more flexibility: vendor bids may include, in addition to the

price, a favorable performance metric; and the client may design an outsourcing plan with multiple SLAs tailored to different measures of performance. Nonetheless, the benefits (and drawbacks) of the RFP process have not been well studied in the literature.

In practice, a number of performance measures could be used to design a RFP. Yet for our purposes of deriving simple and clear managerial insights, we focus on a simplified RFP process in which the client invites bids from vendors who may choose to be paid in terms of either a PPS or a PPP metric. Our insights from Section 4 suggest that such a process—in using both input- and output-based measures of performance—will yield the client more profit because of the added flexibility.⁴

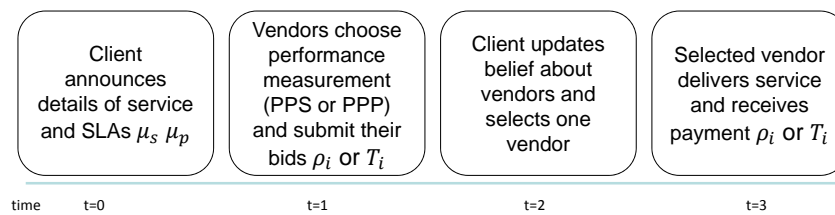


Figure 2 Sequence of Events in RFP Process

Under the optimal RFP process, we can show that a nonmatch-type (resp., match-type) vendor strictly prefers bidding with a PPP (resp., PPS) metric. The intuition here is in line with our discussion in Section 4. Under the PPS measure, a nonmatch-type vendor faces more competition from a match-type vendor because this output-based metric ensures that the most capable vendor is paid the most. Moreover, the client can set the SLAs to reflect his preference for a nonmatch-type vendor who chooses the PPP measure over a nonmatch-type vendor who chooses the PPS measure (for the same effective transfer payment). These two factors ensure that a nonmatch-type vendor will strictly prefer the PPP metric. A match-type vendor will strictly prefer the PPS measure because the PPP measure is indifferent to vendor type and hence offers her no advantage. In fact, the PPP metric is a disadvantage for a match-type vendor: she cannot distinguish herself under this measure from a nonmatch-type competitor, which reduces her odds of winning the contract but yields no compensating upside potential. This is why a match-type vendor strictly prefers the PPS metric. Much as in the RFQ process, in this case a match-type vendor will play a mixed strategy to keep other potential match-type vendors guessing about her bid and thereby maximize her own chance of winning. However, the match-type vendor’s bidding strategy is more restricted

⁴ We can show that the client’s expected payoff from this process is equivalent to that from a general RFP process involving choices of payment terms and performance measures along multiple dimensions—as when, for instance, a vendor’s bid can feature a combination of PPS and PPP terms.

here than in the RFQ process: the added choice in performance measurement implies that a match-type vendor must bid below the minimum affordable bid of a nonmatch-type vendor under both performance measures; given that the PPP performance metric thus gives nonmatch-type vendors an extra edge that is not available under the RFQ process, in this case the bid of a match-type vendor is lower in equilibrium. Therefore, the expected information rent that a match-type vendor can extract by winning the contract is lower under the RFP than under the RFQ process, although it remains positive. Define $\rho_i \in [0, 1]$ and $T_i \in [0, \infty)$ as the respective bids by a vendor of type $i \in m, n$ under PPS and PPP.

PROPOSITION 3. *In the optimal RFP outsourcing process, the client will set the SLAs $\{\mu_s, \mu_p\}$ such that there is a unique symmetric equilibrium in which (i) a nonmatch-type vendor always bids a pure-strategy, PPP proposal with $T_n = T_n^* = (c\mu_p + V)$ and (ii) a match vendor always chooses PPS and randomizes her bid ρ_m in the support $[\hat{e}, \rho^*]$ with cumulative distribution function (c.d.f.) $F(\cdot)$. Here $\hat{e} = (1 - \alpha)\rho^* + \frac{\alpha(c\mu_s + V)}{R_m(\mu_s)}$ for $\rho^* = \min\{\frac{c\mu_s + V}{R_n(\mu_s)}, \hat{\rho}\}$, where $\hat{\rho} = \frac{c\mu_s + V + \Lambda(\mu_s, \mu_p)}{R_m(\mu_s)}$, and $\Lambda(\mu_1, \mu_2) \doteq (R_m(\mu_1) - c\mu_1) - (R_n(\mu_2) - c\mu_2)$. The c.d.f. $F(\cdot)$ is*

$$F(\rho) = \frac{1}{\alpha} - \frac{1 - \alpha}{\alpha} \frac{R_m(\mu_s)\rho^* - c\mu_s - V}{R_m(\mu_s)\rho - c\mu_s - V},$$

and the SLAs are set such that

$$\begin{aligned} \mu_p &= \mu_n^*, \\ \mu_s &= \arg \max_{\mu \geq 0, \mu \neq \mu_n^*} (2\alpha - \alpha^2)[R_m(\mu) - c\mu - V] - 2\alpha(1 - \alpha) \min\{(\Delta(\mu) - 1)(c\mu + V), \Lambda(\mu, \mu_n^*)\}. \end{aligned}$$

PROPOSITION 4. *The optimal RFP yields a strictly greater expected payoff for the client than does the optimal RFQ.*

In equilibrium, a nonmatch vendor always receives zero rent because $T_n^* = (c\mu_p + V)$ under PPP. The upper bound of a match-type vendor's proposed payment term ρ^* should be the lesser of two values: $\frac{c\mu_s + V}{R_n(\mu_s)}$, or the lowest bid that a nonmatch-type vendor can afford under PPS; and $\hat{\rho}$, a payment term yielding the same expected payoff for the client from choosing a match-type vendor under PPS as that from choosing a nonmatch-type vendor under PPP. A match-type vendor's information rent is therefore less than in a RFQ because of the tougher competition induced by a bidding process in which the client asks vendors to indicate a preferred performance measure in their bids. Nevertheless, the information rent earned by a match-type vendor in this case is still nonzero. As shown in the proof of Proposition 4 (see the Appendix), $\Lambda(\mu_s, \mu_n^*) > 0$; this implies that $\rho^* > \frac{c\mu_s + V}{R_m(\mu_s)}$ and $\hat{e} = (1 - \alpha)\rho^* + \frac{\alpha(c\mu_s + V)}{R_m(\mu_s)} > \frac{c\mu_s + V}{R_m(\mu_s)}$. Since a match-type vendor's bid is in the interval

$[\hat{e}, \rho^*]$, it follows that vendors of this type earn a positive information rent. In sum, competitive bidding yields good selection for the client but does not yield perfect contract efficiency. The RFP process dominates the RFQ process because the former lowers the information rent earned by a match-type vendor, but that rent remains positive.

6. Vendor Selection and Contract Efficiency When the Client Chooses the Contract Terms

In this section we study the equilibria that arise when contract terms are chosen by the client. In the economics literature this arrangement is modeled in a principal–agent framework, where the principal (client) offers the agent (vendor) a set (menu) of take-it-or-leave-it contracts. Our problem is more complex because the client faces the dual problem of vendor selection and contracting.

6.1. Sequential Outsourcing Process

Our analysis begins with the sequential process, in which selecting the vendor and then signing a contract with that vendor occur in two consecutive stages. At the start of the sequential process, the client either lets each vendor self-report or actively collects information regarding the vendors' capabilities. Then the client selects one vendor and offers her a contract (terms and performance measures) based on the information reported or collected up front. Unlike competitive bidding, in which the selected vendor's bid automatically constitutes the payment terms, the sequential process allows the client to impose his preferred contract terms. At the same time, it involves the additional challenge (and cost) of gathering information about the vendors.

In selecting among vendors based on their own reports, the client commits to a simple selection rule: a vendor claiming to be of match type is strictly preferred to one claiming to be of nonmatch type. If the two vendors claim similar capabilities (e.g., if each claims to be a match-type vendor) then the client chooses one randomly. After selection, the vendor is offered a contract (menu) that is based on information revealed during the previous stage. The vendor then decides whether to accept the contract and, if so, chooses the terms from the offered menu. Once the contract terms are accepted, the vendor delivers the service and the payment is transferred; otherwise, the client continues to use his in-house expertise and the vendor pursues her outside option V . Figure 3 illustrates the sequence of events that characterize the sequential contracting process.

As shown previously, the performance-based menu strictly dominates the price-based menu in terms of reducing the vendor's information rent. The optimal performance-based menu is one that enables the client to achieve perfect contract efficiency. Therefore, we next focus on describing the vendors' self-revelation strategy given that an optimal performance-based menu is offered.

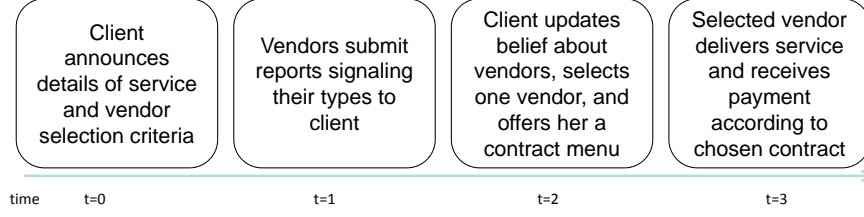


Figure 3 Sequence of Events in Sequential Process

We use d_m (resp., d_n) to denote the realization of a potentially mixed strategy for the match-type (resp., nonmatch-type) vendor, where $d_i \in [0, 1]$ is interpreted as the probability with which an i -type vendor will report being of match type. We set $d_i = 1$ (resp., $d_i = 0$) for a vendor who claims to be of match type (resp., nonmatch-type). Based on the reports submitted by the vendors, the client updates his belief about the vendors, selects one vendor (indexed by “1”), and offers her a contract. At $t = 2$, the client is faced with a contract design problem similar to the case in Section 4 but with an updated belief (β_1) about the selected vendor’s type. The updated belief about the type of the nonselected vendor (indexed by “2”) is thus β_2 . Formally, the client’s problem at $t = 2$ is to design an optimal contract menu $\{\rho_s, \mu_s\}$ and $\{T_p, \mu_p\}$ such that

$$\max_{\mu_s, \mu_p \geq 0, \rho_s \in [0, 1], T_p \geq 0} \beta_1 [R_m(\mu_s)(1 - \rho_s)] + (1 - \beta_1) [R_n(\mu_p) - T_p] \quad (6)$$

$$\text{s.t. } R_m(\mu_s)\rho_s - c\mu_s \geq T_p - c\mu_p, \quad (7)$$

$$T_p - c\mu_p \geq R_n(\mu_s)\rho_s - c\mu_s, \quad (8)$$

$$R_m(\mu_s)\rho_s - c\mu_s \geq V, \quad (9)$$

$$T_p - c\mu_p \geq V. \quad (10)$$

As shown in Proposition 1, this problem yields the first-best outcome for the client when we set $\rho_s = \frac{c\mu_m^* + V}{R_m(\mu_m^*)}$, $\mu_s = \mu_m^*$, $T_p = c\mu_n^* + V$, and $\mu_p = \mu_n^*$. Note that no other contract menu will improve the client’s profit because this menu yields the first-best outcome for the client. Such a menu leaves the participation constraint tight for both vendor types. Since the vendors are assumed to earn an extra utility $\epsilon \rightarrow 0^+$ from winning the contract, at $t = 1$ both vendor types will submit reports that maximize their odds of being selected. The following proposition presents the equilibrium outcome.

PROPOSITION 5. *In the sequential process with a performance menu that includes both PPP and PPS, we have the following unique perfect Bayesian equilibria (PBE) in which $d_m = 1$ and $d_n = 1$.*

- Under PPS: $\rho_s = \frac{c\mu_m^* + V}{R_m(\mu_m^*)}$ and $\mu_s = \mu_m^*$, where $R'_m(\mu_m^*) = c$.
- Under PPP: $T_p = c\mu_p + V$ and $\mu_p = \mu_n^*$, where $R'_n(\mu_n^*) = c$.

The client’s updated belief remains unchanged, $\beta_1 = \beta_2 = \alpha$.

In equilibrium, a nonmatch-type vendor who claims to be a match-type vendor strictly increases her odds of being selected—a result she prefers to the outside option. Of course, a truly match-type vendor also increases her selection odds by claiming to be a match-type vendor. Suppose that, after selection, the client imposes a price-based menu; then the strategy of claiming to be of match type protects a match-type vendor’s information privacy and earns her an information rent. Under a performance-based menu, however, no information rent is earned by either vendor type. Yet reducing the information rent to zero does not improve the client’s odds of selecting the best vendor, so the problem boils down to the single-stage contracting problem described in Section 4. Here the information collection stage is *redundant* because, in equilibrium, all vendors claim to be of match type. Therefore, this case is equivalent to the one in which the client randomly selects one vendor and then contracts with that vendor using the optimal performance-based menu. Although the client’s chances of making a good selection are not improved under these circumstances, we know (from the foregoing analysis) that they yield zero information rent and hence attain perfect contract *efficiency*. The client’s expected profit in this case is $\alpha[R(\mu_m^*) - c\mu_m^* - V] + (1 - \alpha)[R_n(\mu_n^*) - c\mu_n^* - V]$.

Alternatively, a client can hire external consultants or organize costly field visits to collect information on each vendor’s true type. Suppose that each field visit results in a signal from the vendor; that signal may be positive or negative and depends on the vendor’s true type. The probability of generating a positive signal is p_m for a vendor of match type and p_n for one of nonmatch type, where $0 < p_n < p_m < 1$. After N field visits, the vendor generating the most number of positive signals is selected. However, the client incurs a collection cost ν for each field visit.

It immediately follows that collecting vendor information as just described entails that the client selects a match-type vendor with a probability that is strictly greater than α for any $N \geq 1$.⁵ Therefore, better results are obtained by collecting information than by randomly choosing between two vendors if each one has probability α of being a match-type vendor. In fact, collecting information can improve the odds of selecting a match type vendor to nearly $1 - (1 - \alpha)^2 = 2\alpha - \alpha^2$ (perfect selection) if N is sufficiently large (for finite N , however, the probability will remain strictly less than $2\alpha - \alpha^2$). Yet with large N the collection cost $N\nu$ becomes too high for the client to afford. We conclude that a costly process of information collection can improve vendor selection but that, owing to the cost associated with collecting information, there remains an unresolved tension between vendor selection and contract efficiency. We shall not attempt to solve for the

⁵ We can easily show this by induction; the proof may be sketched as follows. When $N = 1$, we can show that $\Pr(\text{selecting match}) = \alpha^2 + \alpha(1 - \alpha)(1 + p_m - p_n) > \alpha^2 + \alpha(1 - \alpha) = \alpha$. Likewise, if we assume that $\Pr(\text{selecting match}) > \alpha$ for N rounds of inspection then the result will hold for $N + 1$ rounds as well.

client’s “optimal” information collection process, in which the client evaluates the trade-off between information collection costs and improved vendor selection. Instead, our aim here is simply to show that, although a performance-based menu reduces the information rent to zero, the sequential outsourcing process cannot simultaneously yield perfect selection and perfect contract efficiency.

6.2. Simultaneous Outsourcing Process

In a simultaneous outsourcing process, the client first designs and commits to a contract menu (screening contracts). The vendors communicate their choice of contract to the client. Based on the choices made by the vendors, the client updates his belief about them and selects the vendor that in expectation will yield the highest payoff; then the contract terms are imposed on the selected vendor. The distinguishing feature of this process is that the tasks of vendor selection and contracting are both performed at the same time—that is, when the client announces the service contract. In this section we study the simultaneous outsourcing process, whose sequence of events is shown in Figure 6.

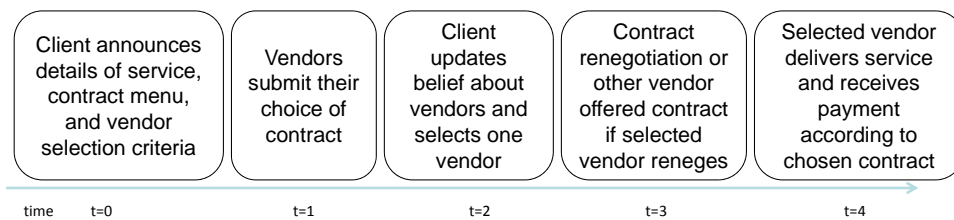


Figure 4 Sequence of Events in Simultaneous Process

In the following analysis, we refer to the vendor who is initially selected as the “first” vendor and refer to the alternate vendor as the “second” one.

6.2.1. The Equilibrium When the Second Vendor Is Unavailable If the First Vendor Reneges In the process outsourcing industry, vendor selection and contracting is a long and tedious endeavor. It may take client firms many months to finalize such an outsourcing relationship—in fact, from 9 to 18 months (according to the managers of client firms that we interviewed). Moreover, in real life the second vendor’s availability is seldom guaranteed. For example, most offshore call centers and IT developers serve multiple clients at the same time. The availability of vendors, especially those with strong capabilities, is usually on a short cycle owing to service vendors’ relatively fixed staffing levels (Hasiija et al. 2008) and to the length of time needed for contract negotiations (Fitoussi and Gurbaxani 2010). Hence the client may become locked in with the initially selected vendor and may not actually have the option of employing the second vendor

should the first one renege on the offered contract. We have assumed in this study that the client lacks the internal capacity to perform the needed service and so strictly prefers an outside vendor, even if that vendor is of nonmatch type.

To capture this scenario, we assume that selecting a vendor (based on her contract choice) renders the other vendor unavailable for contracting. This means that, if the offered contract does not satisfy the first vendor's individual rationality constraint, then she can credibly renegotiate with the client to alter the contract terms. To maintain comparability between this case and our other cases, we assume that the vendor has no extra bargaining power and that renegotiation will not occur *unless* the offered contract yields a profit below her reservation utility (the renegotiated contract would ensure that she earns her reservation utility). In light of this assumption, it is straightforward to see that both match- and nonmatch-type vendors will select the contract that is tailored to the match-type vendor, since doing so maximizes the chances of being selected. If the selected vendor is truly of match type, then the contract will be implemented because its terms will satisfy her individual rationality constraint. However, if the selected vendor is of nonmatch type then she will renegotiate the contract terms so that her participation constraint is satisfied. The client must accept the new terms offered by the nonmatch type vendor because using this vendor is preferable to employing his poor in-house capabilities (model assumption). So it follows that in this case, too, the client will be unable to attain perfect selection—though he will continue to attain perfect contract efficiency because the information rent remains zero. In equilibrium, this case leads to the same client outcome as in Section 6.1. Our next proposition formally states the equilibrium of this case.

PROPOSITION 6. *Prior to selecting a vendor, the client announces the following performance-based menu.*

- Under PPS: $\rho_s = \frac{c\mu_s + V}{R_m(\mu_s)}$ and $\mu_s = \mu_m^*$, where $R'_m(\mu_m^*) = c$.
- Under PPP: $T_p = c\mu_p + V$ and $\mu_p = \mu_n^*$, where $R'_n(\mu_n^*) = c$.

The client announces that he will give priority to vendors that select the PPS contract. The respective vendor strategies are $d_m = 1$ and $d_n = 1$, where d_i is the probability with which the i -type vendor chooses the PPS contract. If the selected vendor is a nonmatch type, then both she and the client mutually benefit by signing the PPP contract through renegotiation. If the selected vendor is a match type then there is no renegotiation and the PPS contract is implemented.

6.2.2. The Equilibrium When the Second Vendor Is Available If the First Vendor Reneges When the second vendor is always available to be selected, the first vendor can no longer credibly renegotiate the client's contract terms. This occurs when the market for the vendors' service is not highly competitive and/or when contract finalization is relatively simple and timely. In that case, if the selected vendor seeks to renegotiate then the client can reject the renegotiation and easily switch to the second vendor; in equilibrium, the second vendor is of match type with probability α while the vendor seeking renegotiation is surely of nonmatch type. It follows that, given the performance-based menu announced by the client, a match-type (nonmatch-type) vendor will choose PPS (PPP) terms, hence each vendor will reveal her true type. If a nonmatch-type vendor initially selects the PPS contract, then implementing its terms will reduce her expected payoff to a level below her reservation utility V . Because this vendor cannot credibly renegotiate the offered contract, she must forgo any contractual relationship with the client. Similarly, if a match-type vendor initially selects the PPP contract, then her chance of winning the contract is reduced and so she becomes strictly worse-off. As a result, in this case the vendor strategies for match and nonmatch type are completely different and the client can therefore achieve good selection. Analogously to our preceding analysis in Section 4, the client also achieves efficient contracting with any type of vendor. In short, the tension between good selection and efficient contracting completely disappears in this scenario.

PROPOSITION 7. *Prior to selecting a vendor, the client announces the following performance-based menu.*

- Under PPS: $\rho_s = \frac{c\mu_s + V}{R_m(\mu_s)}$ and $\mu_s = \mu_m^*$, where $R'_m(\mu_m^*) = c$.
- Under PPP: $T_p = c\mu_p + V$ and $\mu_p = \mu_n^*$, where $R'_n(\mu_n^*) = c$.

The client announces that he will give priority to vendors that select the PPS contract. The respective vendor strategies are $d_m = 1$ and $d_n = 0$, where d_i is the probability with which the i -type vendor chooses the PPS contract.

7. Numerical Illustration of the Tension between Vendor Selection and Contract Efficiency

So far we have demonstrated that the client can achieve both perfect vendor selection and efficient contracting only if he can contract with either vendor at any time (e.g., whenever one vendor reneges). Given that option, the client can design performance-based screening contracts along with a selection rule that favors vendors who select the PPS performance contract, thereby attaining both perfect selection and contract efficiency. We have shown that, absent this flexibility, if the

second vendor is no longer available then the client cannot attain both perfect selection and contract efficiency. In such cases, if the contract terms are determined by the client (resp., the vendors) then the client can attain contract efficiency (resp., perfect selection). The client must then decide which is more important: vendor selection or contract efficiency. The answer to this question will naturally depend on the context.

In fact, answering this question is beyond the scope of our paper and requires a separate study. That being said, we shall present an illustrative example with the aim of providing some intuition about the trade-off between vendor selection and contract efficiency. We conjecture that contract efficiency will be favored in industries for which the average vendor quality is high and the service outsourced is more specialized or customized. In such industries, the a priori odds of good vendor selection are favorable yet the information rent can be high (owing to the service's specialized nature); hence contract efficiency will dominate good selection. Conversely, in industries for which the odds of good selection are unfavorable (because the vendor pool is of low average quality) or the potential information rent is low (owing to less customized nature of the service), we conjecture that good vendor selection will dominate contract efficiency.

To illustrate these conjectures, we use a numerical example to compare the optimal RFP process (Proposition 3) with the optimal sequential outsourcing process (Proposition 5). Because the optimal RFQ process will always perform worse than the optimal RFP process, we will not consider the former. Similarly, simultaneous selection and contracting matches the performance of the optimal sequential process (Proposition 6). Since the simultaneous process presented in Section 6.2.2 completely resolves the tension between vendor selection and contract efficiency, it is not considered in our numerical illustration. We consider a simple $M/M/1$ queuing system for our illustration. The vendor's effort is the service rate μ . We define a service success rate function $f_i(\mu)$ that is decreasing in μ , where $i \in \{m, n\}$. Our model thus captures the speed-quality trade-off typical of service systems. The client earns revenue $r_0 \in \mathcal{R}^+$ per successful service request and incurs a waiting cost $w \in \mathcal{R}^+$ per unit time for each pending service request. Thus the client's reward function is $R_i(\mu) = r_0 \lambda f_i(\mu) - \frac{w\lambda}{(\mu-\lambda)^+}$. We further assume a linear project success rate function $f_i(\mu) = 1 - \mu\beta_i$, where β_i (which is always positive and such that $1 - \mu\beta$ is nonnegative) denotes the capability of a vendor. Observe that f_i is decreasing in β_i , which means that a higher β_i value signifies a lesser capability. Throughout the numerical example, we fix $\beta_m = 0.01$ and vary the value of β_n within the range $\beta_m < \beta_n < 0.7$. Varying β_n gives us a parsimonious way of capturing the specialized or customized nature of a service: the higher the β_n , the more specialized the nature of that service.

We also vary α , which allows us to capture the a priori probability of selecting a match-type vendor. As for the other parameters, we set $r_0 = 100$, $V = 12$, $\lambda = 1$, $w = 1$, and $c = 1$. Given these values, we numerically solve for the optimal RFP and sequential outsourcing process and then compute the client's expected payoffs as a function of the varying α and β_n . Figure 5 presents a two-dimensional comparison between the client's expected payoff in the optimal sequential process under a performance-based menu and the payoff in the optimal RFP. The bubbles represent the difference between the two process,⁶ and the bubble size is proportional to the absolute value of those differences; white and gray denote (respectively) negative and positive values. The x -axis represents the average capability of the vendor pool while the y -axis represents the capability of a nonmatch-type vendor.

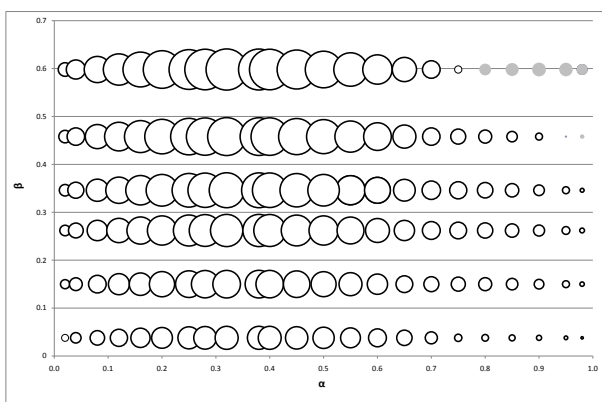


Figure 5 Difference in Expected Payoffs from Optimal Sequential Process and Optimal RFP

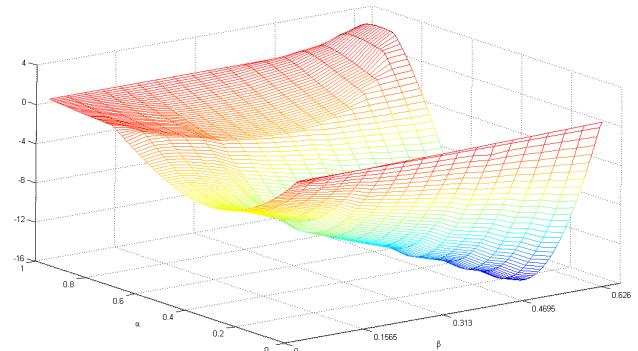


Figure 6 Detailed Comparison between Optimal Sequential Process and Optimal RFP

Figure 5 confirms that RFP dominates the sequential process under most feasible conditions. This finding is consistent with industry practice, where competitive bidding is more commonly used than any sequential process (Bajari and Tadelis 2006). Note that RFP achieves its greatest relative advantage over the sequential process when β_n is high and α is at a medium level. This observation is intuitive because, under those conditions, the vendor's information rent is maximized (α is close to 0.5) and the potential gain from better selection is maximized ($\beta_n \gg 0.01$). These two factors make RFP more favorable to the client than the sequential process in this scenario than otherwise.

We remark that there are some cases in which the sequential process can yield a higher expected payoff than RFP. In particular, the former begins to dominate when both α and β_n take high values. Higher α implies that the client has a better chance of finding a match-type vendor and so is less in need of better selection; this gives the client relatively more incentive to pursue contract

⁶ In other words, the expected payoff under the optimal sequential process *minus* that under the optimal RFP.

efficiency. At the same time, higher β_n implies a greater performance gap between match- and nonmatch-type vendors, which leads to a higher selection cost in terms of information rent. The combination of these two forces drives the dominance of a sequential process over RFP. In short, the importance of contract efficiency (as when the client decides the contract) overrides the benefit from better selection (as when the vendors decide the contract) if (i) the average capability of the vendor pool is sufficiently high and (ii) the performance gap between match and nonmatch types is sufficiently large. These observations are consistent with our previous conjectures.

Figure 6 presents a three-dimensional comparison by plotting the difference in the client’s expected payoff under two processes. It confirms our intuition that (in the vertical direction) the payoff difference curve becomes positive only in the upper left-hand corner—an area where both α and β_n have high values. Observe also that both the peak and the valley of a payoff difference curve occur when β_n is at its maximum feasible value. In other words, as the performance gap between match and nonmatch vendors increases, the particular outsourcing process chosen becomes especially important.

8. Conclusions and Implications

The selection of a partner with proper capabilities and the efficiency of a contract with that partner are key, interrelated challenges in the outsourcing of such business processes as procurement, service, and R&D. By studying the different outsourcing processes (e.g., RFQ, RFP, sequential and simultaneous processes) observed in the service industry, this paper bridges these two challenges and highlights that—in most practical service scenarios—there is a fundamental yet often overlooked trade-off between vendor selection and contract efficiency: better odds of selecting a good vendor cannot be achieved with a perfectly efficient outsourcing contract. Both perfect selection and efficient contracts can be achieved only if the client has a flexible option of contracting with a previously nonselected vendor should the selected vendor renege. In all other cases, the client faces the trade-off between vendor selection and contract efficiency.

We demonstrate in particular that if the contract terms are determined by the vendors (via a competitive bidding process) then the client is able to achieve perfect selection but poor contract efficiency, whereas perfect contract efficiency but poor selection results when the client determines the contract terms. Our numerical illustration suggests that, when average vendor capability and the performance gap between capability types are *both* sufficiently high, contract efficiency begins to dominate vendor selection. This result intuitively explains why, in practice, the sequential vendor selection and contracting process is often observed in situations where the outsourced product or service is highly customized and the vendors are “generally” capable (Bajari and Tadelis 2006).

Our study also highlights the implications of performance measurements. In a bilateral contract, a performance-based menu with two performance metric options (PPS and PPP) enables the client to obtain greater contract efficiency and a higher expected payoff than does a price-based menu with PPS only. Perfect efficiency is achieved by ensuring that the match-type vendor's incentive compatibility constraint is binding. Under competitive bidding, performance measures reduce the information rent of a match-type vendor by intensifying the competition among vendors. This effect leads to a higher expected payoff for the client under RFP than under RFQ. These results enrich the emerging literature on performance measurement in contract design (Fitoussi and Gurbaxani 2010, Raith 2008).

The analysis presented here is stylized and simplified. For instance, vendors may exhibit different levels of “match” (rather than being only of two extreme types), and the vendor pool may include more than two vendors. However, we believe that including more types and vendors would increase the technical complexity without yielding commensurate insight. Note also that, in practice, the client may decide some terms and allow the vendors to decide other terms. Our study offers a starting point from which to explore the firm's outsourcing activity as an interlinked, multistage *process*. Finally, our findings ground the hypothesis for future empirical research—including not only the application of outsourcing processes but also the conditions under which each process is chosen.

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Appendix A: Proofs of Propositions

Proof of Proposition 1. Given the terms of the contract, showing that the client obtains the first-best outcome requires showing that match-type vendors prefer a PPS contract and that nonmatch-type vendors prefer a PPP contract. If that is true, then the individual rationality constraint of each vendor type will be tight. By way of contradiction, we assume that the nonmatch-type vendor prefers a PPS contract. In that case, $\frac{c\mu_m^*+V}{R_m(\mu_m^*)}R_n(\mu_m^*) - c\mu_m^* \geq V$. Since $R_m(\cdot) > R_n(\cdot)$, it follows that $\frac{c\mu_m^*+V}{R_m(\mu_m^*)}R_n(\mu_m^*) - c\mu_m^* < c\mu_m^* + V - c\mu_m^* = V$. Hence the nonmatch-type vendor actually does prefer the PPP contract. For the match-type vendor, her expected profit under a PPP contract is $c\mu_n^* + V - c\mu_n^* = V$ and under a PPS contract is $\frac{c\mu_m^*+V}{R_m(\mu_m^*)}R_m(\mu_m^*) - c\mu_m^* = V$. The match-type vendor is consequently indifferent between the two contract types. In this case, it is standard to assume that a match-type vendor will choose so as to increase overall contract efficiency (i.e., will choose the PPS contract). This assumption is not restrictive, and it can be ensured trivially by adding a payment $\xi \rightarrow 0^+$ linked to the PPS contract. Therefore, the performance-based menu yields the first-best outcome for the client.

Proof of Proposition 2. The RFQ process is similar to standard first-price auctions with two player types. The unique equilibrium strategy played in such auctions is a pure strategy played by “low” type players and a mixed strategy played by “high” type players (Tirole 1991, p. 225). Without loss of generality, we focus on one specific vendor from the pool. We call this vendor i the “focal” vendor; vendor j is the other vendor.

The expected payoff for focal vendor of type i is $E_{\rho_j}[x_{\rho_i, \rho_j}(\rho_i R_i(\mu_Q) - c\mu_Q) + (1 - x_{\rho_i, \rho_j})V]$, where $i, j \in \{m, n\}$. By the client’s selection rule, we have $x_{\rho_i, \rho_j} = 1$ if $(1 - \rho_i)R_i(\mu_Q) > (1 - \rho_j)R_j(\mu_Q)$, $x_{\rho_i, \rho_j} = 1/2$ if $(1 - \rho_i)R_i(\mu_Q) = (1 - \rho_j)R_j(\mu_Q)$, and $x_{\rho_i, \rho_j} = 0$ if $(1 - \rho_i)R_i(\mu_Q) < (1 - \rho_j)R_j(\mu_Q)$.

For a focal nonmatch-type vendor, the expected payoff from playing the pure strategy $\rho_n = \rho_n^* = \frac{c\mu_Q+V}{R_n(\mu_Q)}$ is equal to $x_{\rho_n^*, \rho_j}(V + \epsilon) + (1 - x_{\rho_n^*, \rho_j})V = V + x_{\rho_n^*, \rho_j}\epsilon$, where $\epsilon \rightarrow 0^+$ captures the vendors’ preference for winning the contract over an equal payoff from an outside option.

First, note that this vendor will not deviate from the prescribed strategy by bidding $\rho_n < \rho_n^*$. The reason is that, because $x_{\rho_n, \rho_j} \leq 1$ and $\rho_n R_n(\mu_Q) - c\mu_Q < V$, her expected payoff in that case would become $x_{\rho_n, \rho_j}(\rho_n R_n(\mu_Q) - c\mu_Q) + (1 - x_{\rho_n, \rho_j})V < V$ and this would make her strictly worse-off. Second, if she deviates by playing any strategy $\rho_n > \rho_n^*$, then $x_{\rho_n, \rho_j} = 0$ and her expected payoff is V . Thus she is again strictly worse-off.

Next we determine the strategy played by a focal match-type vendor. It is easy to see that a match-type vendor will not choose $\rho_m > \frac{c\mu_Q+V}{R_n(\mu_Q)}$, since doing so would prevent her from winning the contract. Therefore, a match-type vendor’s bid is bounded by $\frac{c\mu_Q+V}{R_n(\mu_Q)}$. Let us assume that the match-type vendor plays a mixed strategy according to a continuous distribution $G(\rho)$ for $\rho \in [\theta, \frac{c\mu_Q+V}{R_n(\mu_Q)}]$. For such a strategy to be optimal for the match-type vendor, it must be that the distribution of her bid leaves her indifferent between the extra profit she can earn by increasing her bid and the increased odds of selection by reducing her bid. Formally, it must be that $\forall \rho \in [\theta, \frac{c\mu_Q+V}{R_n(\mu_Q)}]$, $[R_m(\mu_Q)\rho - c\mu_Q](1 - G(\rho)\alpha) + V\alpha G(\rho) = \text{constant}$ (see Tirole 1991,

p. 225). Since $G(\frac{c\mu_Q+V}{R_n(\mu_Q)}) = 1$, it follows that $G(\rho)$ is defined by $[R_m(\mu_Q)\rho - c\mu_Q](1 - G(\rho)\alpha) + V\alpha G(\rho) = [R_m(\mu_Q)\frac{c\mu_Q+V}{R_n(\mu_Q)} - c\mu_Q](1 - \alpha) + V\alpha$. Simplification then yields

$$G(\rho) = \frac{1}{\alpha} - \frac{1 - \alpha}{\alpha} \frac{(\frac{R_m(\mu_Q)}{R_n(\mu_Q)} - 1)(c\mu_Q + V)}{R_m(\mu_Q)\rho - c\mu_Q - V}.$$

Therefore, $G(\rho) = F(\rho)$ (as stated in the proposition) and is also unique. To define θ , we use the property that $G(\theta) = 0$. Thus, $\theta = (1 - \alpha)\frac{c\mu_Q+V}{R_n(\mu_Q)} + \alpha\frac{c\mu_Q+V}{R_m(\mu_Q)} = e$. Hence the match-type player plays according to the mixed strategy described in the proposition. The expected utility of a match-type vendor is $[R_m(\mu_Q)\frac{c\mu_Q+V}{R_n(\mu_Q)} - c\mu_Q](1 - \alpha) + V\alpha$. Next we will show that there is no pure strategy equilibrium for match-type vendors. If a match-type vendor plays a pure strategy with $\rho_m = \tilde{\rho}_m > \frac{c\mu_Q+V}{R_m(\mu_Q)}$, then another match-type vendor is better off by bidding $\tilde{\rho}_m - \eta$, where $\eta \rightarrow 0^+$, because $(1 - \frac{\alpha}{2})[R_m(\mu_Q)\tilde{\rho}_m - c\mu_Q + \epsilon] + \frac{\alpha}{2}V < R_m(\mu_Q)(\tilde{\rho}_m - \eta) - c\mu_Q + \epsilon$ for small enough η . If a match-type vendor plays a pure strategy with $\rho_m = \frac{c\mu_Q+V}{R_m(\mu_Q)}$, then another match-type vendor is better-off by bidding $\frac{c\mu_Q+V}{R_n(\mu_Q)} - \eta$, where $\eta \rightarrow 0^+$, because $(1 - \alpha)[R_m(\mu_Q)(\frac{c\mu_Q+V}{R_n(\mu_Q)} - \eta) - c\mu_Q + \epsilon] + \alpha V > V + \epsilon$ for small enough η . Finally, note that $\rho_m < \frac{c\mu_Q+V}{R_m(\mu_Q)}$ will not be an equilibrium because such a bid does not satisfy the participation constraint of match-type vendors.

Proof of Corollary 1. We know that $E[u_c] = (1 - \alpha)^2[R_n(\mu_Q) - c\mu_Q - V] + (2\alpha - 2\alpha^2)[R_m(\mu_Q) - R_m(\mu_Q)E[\rho]] + 2\alpha^2 \int_e^{\rho_n^*} (1 - F(\rho))[R_m(\mu_Q) - \rho R_m(\mu_Q)]f(\rho)d\rho$. Furthermore,

$$\begin{aligned} 2\alpha^2 \int_e^{\rho_n^*} (1 - F(\rho))[R_m(\mu_Q) - \rho R_m(\mu_Q)]f(\rho) d\rho \\ = \alpha^2 R_m(\mu_Q) - 2\alpha^2 R_m(\mu_Q)E[\rho] + 2\alpha^2 \int_e^{\rho_n^*} R_m(\mu_Q)\rho F(\rho)f(\rho) d\rho. \end{aligned}$$

Next, we calculate $E[\rho]$. Let $k = \frac{1-\alpha}{\alpha}(\Delta(\mu_Q) - 1)(c\mu_Q + V)$ and let $a = R_m(\mu_Q)$ and $b = c\mu_Q + V$. Then

$$E[\rho] = \int_e^{\rho_n^*} \rho f(\rho)d\rho = ka \int_e^{\rho_n^*} \frac{\rho}{(a\rho - b)^2} d\rho = ka \times \frac{1}{a^2} [\ln(a\rho - b) + \frac{b}{b - a\rho}] \Big|_e^{\rho_n^*} = \frac{k}{a} [\ln(a\rho - b) + \frac{b}{b - a\rho}] \Big|_e^{\rho_n^*};$$

also, $a\rho_n^* - b = R_m(\mu_Q)\frac{c\mu_Q+V}{R_n(\mu_Q)} - c\mu_Q - V = (\Delta(\mu_Q) - 1)(c\mu_Q + V)$ and $ae - b = \alpha(c\mu_Q + V) + \Delta(\mu_Q)(1 - \alpha)(c\mu_Q + V) - (c\mu_Q + V) = [\alpha + \Delta(\mu_Q)(1 - \alpha) - 1](c\mu_Q + V)$. Therefore, $E[\rho] = \frac{c\mu_Q+V}{R_m(\mu_Q)} [1 - \frac{1-\alpha}{\alpha}(\Delta(\mu_Q) - 1)\ln(1 - \alpha)]$ and

$$\begin{aligned} \int_e^{\rho_n^*} \rho F(\rho)f(\rho)d\rho &= \frac{1-\alpha}{\alpha} ab(\Delta - 1) \int_e^{\rho_n^*} (\frac{1}{\alpha} - \frac{k}{a\rho - b}) \frac{r}{(a\rho - b)^2} d\rho \\ &= \frac{1-\alpha}{\alpha} ab(\Delta(\mu_Q) - 1) \Big|_{\frac{bk\alpha}{(b-a\rho)^2} + \frac{2(b-k\alpha)}{b-a\rho} + 2\ln(a\rho - b)} \Big|_e^{\rho_n^*} \\ &= \frac{b}{2a} - \frac{(1-\alpha)(\Delta(\mu_Q) - 1)b}{a\alpha} [1 + \frac{\ln(1-\alpha)}{\alpha}]. \end{aligned}$$

We can now simplify the client's expected payoff under price-based bidding as follows:

$$E[u_c] = (1 - \alpha)^2[R_n(\mu_Q) - c\mu_Q - V] + (2\alpha - \alpha^2)[R_m(\mu_Q) - c\mu_Q - V] - 2\alpha(1 - \alpha)(\Delta(\mu_Q) - 1)(c\mu_Q + V). \quad (11)$$

Since μ_Q is the optimal SLA, it follows that

$$\mu_Q = \arg \max_{\mu \geq 0} (1 - \alpha)^2 \Pi_n(\mu) + (2\alpha - \alpha^2) \Pi_m(\mu) - 2\alpha(1 - \alpha)(\Delta(\mu) - 1)(c\mu + V). \quad (12)$$

Proof of Proposition 3. We consider the case where $\alpha \in (0, 1)$. The boundary cases of $\alpha = 0$ and $\alpha = 1$ are trivial because they exclude the possibility of asymmetric information. In this game, a vendor's bidding strategy depends on the client's target (optimal) SLAs, which in turn take the vendor's possible bidding strategies into account. In order to break the circularity of equilibria, we look at three (jointly exhaustive) cases of target SLAs and describe the unique equilibrium in each case.

Case One: Client sets SLAs μ_s and μ_p such that $\Pi_n(\mu_p) > \Pi_n(\mu_s)$.

We start with the optimality of the nonmatch-type vendor's strategy. Clearly, under the PPP performance measure the nonmatch-type vendor cannot bid a T above T_n^* : for any bid of $T > T_n^*$, she will lose the contract to another nonmatch-type vendor whose bid is T_n^* . Therefore, the nonmatch-type vendor will bid T_n^* under the PPP performance measure. Similarly, under PPS the nonmatch-type vendor bids $\rho_n = \frac{c\mu_s + V}{R_n(\mu_s)}$.

Hence the nonmatch-type vendor's expected profit under PPP is $E[u_n^{\text{PPP}}] = \Pr(\text{win contract})_{\text{PPP}}(c\mu_p + V - c\mu_p + \epsilon) + \Pr(\text{not win})_{\text{PPP}}V = \Pr(\text{win contract})_{\text{PPP}}(V + \epsilon) + \Pr(\text{not win})_{\text{PPP}}V$. Similarly, under PPS the nonmatch-type vendor's expected profit is $E[u_n^{\text{PPS}}] = \Pr(\text{win contract})_{\text{PPS}}(R_n(\mu_s)\frac{c\mu_s + V}{R_n(\mu_s)} - c\mu_s + \epsilon) + \Pr(\text{not win})_{\text{PPS}}V = \Pr(\text{win contract})_{\text{PPS}}(V + \epsilon) + \Pr(\text{not win})_{\text{PPS}}V$.

However, $\Pr(\text{win contract})_{\text{PPP}} > \Pr(\text{win contract})_{\text{PPS}}$. To see this, note that the client chooses the vendor proposal that maximizes his expected payoff. With a nonmatch-type vendor, the client's expected profit is either $E[u_c^{\text{PPP}}] = R_n(\mu_p) - c\mu_p - V$ or $E[u_c^{\text{PPS}}] = R_n(\mu_s) - c\mu_s - V$. Recall that μ_s and μ_p are such that $\Pi_n^p > \Pi_n^s$. This means that, for the focal vendor, $\Pr(\text{win contract})_{\text{PPP}} = 1 - \alpha$ and $\Pr(\text{win contract})_{\text{PPS}} = 0$. Therefore, the nonmatch-type vendor will choose to bid T_p^* under the PPP performance measure. We shall show that nonmatch-type vendors always lose to match-type vendors, so this strategy is optimal for them because it maximizes their chances of being selected.

Under PPP, the match-type vendor cannot distinguish herself from the nonmatch-type vendor; hence it is trivial to check that her bid is $T_m^* = c\mu_p + V$ with expected payoff $E[u_m^p] = V$. Under PPS, the match-type vendor can distinguish herself from the nonmatch-type vendor. We will describe the match-type vendor's bidding strategy under the PPS performance measure and then demonstrate that it yields her a higher expected profit than does the PPP performance measure.

We start by showing that $\rho_m \leq \rho^* = \min\{\frac{c\mu_s + V}{R_n(\mu_s)}, \hat{\rho}\}$. Observe that $\hat{\rho}$ yields the same expected payoff for the client when he chooses a match-type vendor under PPS with $\rho_m = \hat{\rho}$ as when he selects a nonmatch-type vendor with $T_n^* = c\mu_p + V$ under PPP. To see this, note that $R_n(\mu_p) - c\mu_p - V = R_m(\mu_s) - \hat{\rho}R_m(\mu_s)$ for $\hat{\rho} = \frac{c\mu_s + V + \Lambda(\mu_s, \mu_p)}{R_m(\mu_s)}$. Clearly, ρ_m should not exceed $\hat{\rho}$, for otherwise the nonmatch-type vendor could outbid the match-type vendor by proposing $T_n^* = c\mu_p + V$ with PPP. Similarly, ρ_m should not exceed $\frac{c\mu_s + V}{R_n(\mu_s)}$; otherwise, the nonmatch-type vendor could outbid the match-type vendor by proposing $\rho_n = \frac{c\mu_s + V}{R_n(\mu_s)}$ under PPS. As explained in the text analysis of Proposition 2, a mixed strategy played by the match-type vendor strictly dominates a pure strategy. The lower bound \hat{e} of ρ_m must solve the equality $(1 - \alpha)[R_m(\mu_s)\rho^* - c\mu_s] + \alpha V = R_m(\mu_s)\hat{e} - c\mu_s$, from which it follows that $\hat{e} = (1 - \alpha)\rho^* + \frac{\alpha(c\mu_s + V)}{R_m(\mu_s)}$. We now address two subcases as follows.

(i) *The SLAs are such that $\Lambda(\mu_s, \mu_p) \geq 0$.* We remark that this case has a nonempty feasible set (e.g., $\{\mu_m^*, \mu_n^*\}$). Hence the expected profit of the match-type vendor under this bidding strategy is $E[u_m^{\text{PPS}}] =$

$(1 - \alpha)[R_m(\mu_s)\rho^* - c\mu_s + \epsilon] + \alpha V > V = E[u_m^{\text{PPP}}]$, where $\epsilon \rightarrow 0^+$ represents the arbitrarily low additional utility of winning the contract. Thus the match-type vendor strictly prefers the bidding strategy under the PPS performance measure. We next compute the c.d.f. of the mixed bidding strategy employed by the match-type vendor. This vendor draws her bids from a distribution $F(\rho)$ such that she is left indifferent in expectation; that is, $(1 - \alpha)[R_m(\mu_s)\rho^* - c\mu_s] + \alpha V = (1 - \alpha F(\rho))(R_m(\mu_s)\rho - c\mu_s) + \alpha F(\rho)V$. Consequently, $F(\rho) = \frac{1}{\alpha} - \frac{1-\alpha}{\alpha} \frac{[R_m(\mu_s)\rho^* - c\mu_s - V]}{R_m(\mu_s)\rho - c\mu_s - V}$. We now derive an expression for the client's expected profit in this case. Following steps similar to those in the proof of Corollary 1, we see that his expected profit here is

$$\begin{aligned} E[u_c^1] &= (1 - \alpha)^2[R_n(\mu_p) - c\mu_p - V] + (2\alpha - \alpha^2)[R_m(\mu_s) - c\mu_s - V] - 2\alpha(1 - \alpha)[R_m(\mu_s)\rho^* - c\mu_s - V] \quad (13) \\ &= (1 - \alpha)^2\Pi_n(\mu_p) + (2\alpha - \alpha^2)\Pi_m(\mu_s) - 2\alpha(1 - \alpha)[R_m(\mu_s)\rho^* - c\mu_s - V]. \quad (14) \end{aligned}$$

After we apply some algebra, this equality can be rewritten as

$$E[u_c^1] = (1 - \alpha)^2\Pi_n(\mu_p) + (2\alpha - \alpha^2)\Pi_m(\mu_s) - 2(\alpha - \alpha^2) \min\{(\Delta(\mu_s) - 1)(c\mu_s + V), \Lambda(\mu_s, \mu_p)\}. \quad (15)$$

From our definitions of $\Lambda(\mu_s, \mu_p)$ and μ_n^* it is clear that $E[u_c^1]$ is maximized at $\mu_p = \mu_n^*$. In this case, then, the client will choose μ_s such that

$$\mu_s = \arg \max_{\mu \geq 0, \mu \neq \mu_n^*} (2\alpha - \alpha^2)[R_m(\mu) - c\mu - V] - 2\alpha(1 - \alpha) \min\{(\Delta(\mu) - 1)(c\mu + V), \Lambda(\mu, \mu_n^*)\}. \quad (16)$$

We must check to ensure that, under such SLAs, neither condition of this case is violated; that is, we must have $\Pi_n(\mu_p) > \Pi_n(\mu_s)$ and $\Lambda(\mu_s, \mu_n^*) \geq 0$. The first condition is satisfied because $\mu_s \neq \mu_n^*$. To check the second condition we assume that $\Lambda(\mu_s, \mu_n^*) \leq 0$, which implies that $\mu_s \neq \mu_n^*$. Therefore,

$$\begin{aligned} E[u_c^1] &= \alpha^2\Pi_m(\mu_s) + (1 - \alpha^2)\Pi_n(\mu_n^*) \\ &< \alpha^2\Pi_m(\mu_n^*) + (1 - \alpha^2)\Pi_n(\mu_n^*) \\ &\leq (1 - \alpha)^2\Pi_n(\mu_n^*) + (2\alpha - \alpha^2)\Pi_m(\mu_n^*) - 2(\alpha - \alpha^2) \min\{(\Delta(\mu_n^*) - 1)(c\mu_n^* + V), \Lambda(\mu_n^*, \mu_n^*)\} \\ &< (1 - \alpha)^2\Pi_n(\mu_n^*) + (2\alpha - \alpha^2)\Pi_m(\mu_s) - 2(\alpha - \alpha^2) \min\{(\Delta(\mu_s) - 1)(c\mu_s + V), \Lambda(\mu_s, \mu_n^*)\}. \end{aligned}$$

We have thus obtained a contradiction, so μ_s as defined by equation (16) is such that $\Lambda(\mu_s, \mu_n^*) > 0$.

(ii) *The SLAs are such that $\Lambda(\mu_s, \mu_p) < 0$.* We show that the client will not prefer to choose SLAs that satisfy the conditions of this subcase. Here we are led to a pooling equilibrium in which both match- and nonmatch-type vendors choose the PPP contract and bid $T_n = T_m = c\mu_p + V$. To see this, observe that (as before) the nonmatch-type vendor's bid will reflect her tight participation constraint. Moreover, the nonmatch-type vendor prefers the PPP contract because, under the PPS contract, the match-type vendor is certain to outbid her; in the PPP contract, however, the match-type vendor has no type advantage. Even so, the match-type vendor is also better-off choosing the PPP contract because she will certainly lose the bid by choosing the PPS contract. As a consequence, these conditions lead to the pooling outcome. Let $\mu_p = \tilde{\mu}$ be the optimal SLA choice for the client in this subcase. Then the client's expected profit is

$$\begin{aligned} E[\tilde{u}_c^1] &= (1 - \alpha)^2\Pi_n(\tilde{\mu}) + (2\alpha - \alpha^2)\Pi_m(\tilde{\mu}) - \alpha(1 - \alpha)\Lambda(\tilde{\mu}, \tilde{\mu}) \\ &= (1 - \alpha)\Pi_n(\tilde{\mu}) + \alpha\Pi_m(\tilde{\mu}). \end{aligned}$$

It is easy to check that $\mu_n^* < \tilde{\mu} < \mu_m^*$. Let $\bar{\mu}$ be such that

$$R_m(\bar{\mu})\left(1 - \frac{c\bar{\mu} + V}{R_n(\bar{\mu})}\right) = R_m(\tilde{\mu}) - c\tilde{\mu} - V. \quad (17)$$

Note that $\bar{\mu} > \tilde{\mu}$ because $R_m(\bar{\mu}) - c\bar{\mu} - V > R_m(\bar{\mu})\left(1 - \frac{c\bar{\mu} + V}{R_n(\bar{\mu})}\right) = R_m(\tilde{\mu}) - c\tilde{\mu} - V > R_n(\tilde{\mu}) - c\tilde{\mu} - V$. Therefore, $R_n(\tilde{\mu}) - c\tilde{\mu} - V > R_n(\bar{\mu}) - c\bar{\mu} - V$. Hence $\bar{\mu}$ and $\tilde{\mu}$ are feasible SLAs for this subcase, so

$$E[u_c^1] > (1 - \alpha)^2 \Pi_n(\tilde{\mu}) + (2\alpha - \alpha^2) \Pi_m(\bar{\mu}) - 2\alpha(1 - \alpha)(\Delta(\bar{\mu}) - 1)(c\bar{\mu} + V).$$

Substituting terms from equation (17) into this inequality yields

$$\begin{aligned} E[u_c^1] &> (1 - \alpha)^2 \Pi_n(\tilde{\mu}) + \alpha^2 \Pi_m(\bar{\mu}) + 2\alpha(1 - \alpha) \Pi_m(\tilde{\mu}) \\ &> (1 - \alpha)^2 \Pi_n(\tilde{\mu}) + (2\alpha - \alpha^2) \Pi_m(\tilde{\mu}). \end{aligned}$$

It follows that $E[u_c^1] - E[\tilde{u}_c^1] > (\alpha - \alpha^2)(R_m(\tilde{\mu}) - R_n(\tilde{\mu})) > 0$, so this subcase can be ruled out.

Case Two: Client sets SLAs such that $\Pi_n(\mu_p) < \Pi_m(\mu_s)$.

To avoid confusing the notation, we denote the SLAs in Case Two by $\tilde{\mu}_s$ and $\tilde{\mu}_p$ for the PPS and PPP performance measures, respectively. As before, the nonmatch-type vendor's bidding strategy will be to ensure that her participation constraint is tight, since bidding any higher will guarantee than another nonmatch-type will win the contract by marginally underbidding. Because $\Pi_n(\mu_p) < \Pi_m(\mu_s)$, in this case the client prefers a nonmatch-type vendor who chooses the PPS performance metric and bids $\rho_n = \frac{c\tilde{\mu}_s + V}{R_n(\tilde{\mu}_s)}$ over a nonmatch-type vendor who chooses PPP and bids $T_n = c\tilde{\mu}_p + V$. As with Case One, in equilibrium the match-type vendor will not choose PPP because doing so neutralizes the advantage she gains by being of match type. It trivially follows that, in this case, there is one unique equilibrium in which both vendor types propose to be paid via PPS. This means that the PPP metric is redundant here and so the resulting equilibrium will be identical to the one presented in Proposition 3. Thus, by Corollary 1 it is optimal for the client to set $\tilde{\mu}_s = \mu_Q$. The client's expected profit is then

$$E[u_c^2] = (1 - \alpha)^2 \Pi_n(\mu_Q) + (2\alpha - \alpha^2) \Pi_m(\mu_Q) - 2\alpha(1 - \alpha)(\Delta(\mu_Q) - 1)(c\mu_Q + V).$$

Next we show that $E[u_c^1] > E[u_c^2]$. From equations (15) and (16) it follows that

$$\begin{aligned} E[u_c^1] &= (1 - \alpha)^2 \Pi_n(\mu_n^*) + (2\alpha - \alpha^2) \Pi_m(\mu_s) - 2\alpha(1 - \alpha) \min\{(\Delta(\mu_s) - 1)(c\mu_s + V), \Lambda(\mu_s, \mu_n^*)\} \\ &\geq (1 - \alpha)^2 \Pi_n(\mu_n^*) + (2\alpha - \alpha^2) \Pi_m(\mu_Q) - 2\alpha(1 - \alpha) \min\{(\Delta(\mu_Q) - 1)(c\mu_Q + V), \Lambda(\mu_Q, \mu_n^*)\} \\ &\geq (1 - \alpha)^2 \Pi_n(\mu_n^*) + (2\alpha - \alpha^2) \Pi_m(\mu_Q) - 2\alpha(1 - \alpha)(\Delta(\mu_Q) - 1)(c\mu_Q + V). \end{aligned}$$

If $\mu_Q \neq \mu_n^*$, then

$$\begin{aligned} E[u_c^1] &> (1 - \alpha)^2 \Pi_n(\mu_Q) + (2\alpha - \alpha^2) \Pi_m(\mu_Q) - 2\alpha(1 - \alpha)(\Delta(\mu_Q) - 1)(c\mu_Q + V) \\ &= E[u_c^2]; \end{aligned}$$

if $\mu_Q = \mu_n^*$, then by equations (15) and (16) we have

$$E[u_c^1] = (1 - \alpha)^2 \Pi_n(\mu_n^*) + (2\alpha - \alpha^2) \Pi_m(\mu_s) - 2\alpha(1 - \alpha) \min\{(\Delta(\mu_s) - 1)(c\mu_s + V), \Lambda(\mu_s, \mu_n^*)\}$$

$$\begin{aligned}
&> (1 - \alpha)^2 \Pi_n(\mu_Q) + (2\alpha - \alpha^2) \Pi_m(\mu_Q) - 2\alpha(1 - \alpha) \min\{(\Delta(\mu_Q) - 1)(c\mu_Q + V), \Lambda(\mu_Q, \mu_Q)\} \\
&> (1 - \alpha)^2 \Pi_n(\mu_Q) + (2\alpha - \alpha^2) \Pi_m(\mu_Q) - 2\alpha(1 - \alpha)(\Delta(\mu_Q) - 1)(c\mu_Q + V) \\
&= E[u_c^2].
\end{aligned}$$

Case Three: Client sets SLAs such that $\Pi_n(\mu_p) = \Pi_n(\mu_s)$.

We shall differentiate the notation in this case by using $\hat{\mu}_s$ and $\hat{\mu}_p$ to denote the SLAs with PPS and PPP performance measures, respectively. Once again, the nonmatch-type vendor's bidding strategy is to ensure that her participation constraint is tight and thereby to prevent another nonmatch-type from winning the contract by marginally underbidding. In this case, the client is indifferent between a nonmatch-type vendor who chooses the PPP performance metric and one who chooses PPS. So here the nonmatch-type vendor bids $T_n = c\hat{\mu}_p + V$ under PPP or bids $\rho_n = \frac{c\hat{\mu}_s + V}{R_n(\hat{\mu}_s)}$ under PPS.

Under PPP, the match-type vendor cannot distinguish herself from the nonmatch-type vendor; hence it is trivial to check that her bid is $T_m = c\mu_p + V$ with expected payoff $E[u_m^{\text{PPP}}] = V$. Under PPS, the match-type vendor can distinguish herself from the nonmatch-type vendor. We will describe the match-type vendor's bidding strategy under the PPS performance measure and then demonstrate that it yields her a higher expected profit than does the PPP performance measure. We begin by showing that the match-type vendor's bid under PPS is $\rho_m \leq \min\{\frac{c\hat{\mu}_s + V}{R_m(\hat{\mu}_s)}, \bar{\rho}\}$, where $\bar{\rho}$ yields the same expected payoff for the client from choosing a match-type vendor with $\rho_m = \bar{\rho}$ under PPS as from choosing a nonmatch-type vendor with $T_n = c\hat{\mu}_p + V$ under PPP or from choosing a nonmatch-type vendor with $\rho_n = \frac{c\hat{\mu}_s + V}{R_n(\hat{\mu}_s)}$ under PPS. Therefore, $\bar{\rho} = \frac{c\hat{\mu}_s + V + R_m(\hat{\mu}_s) - R_n(\hat{\mu}_s)}{R_m(\hat{\mu}_s)}$. Observe that $R_n(\hat{\mu}_s) - c\mu_s - V = R_m(\hat{\mu}_s) - \bar{\rho}R_m(\hat{\mu}_s)$ for this value of $\bar{\rho}$. It is easy to see that $\frac{c\hat{\mu}_s + V}{R_n(\hat{\mu}_s)} < \bar{\rho}$. Much as with our analysis in Proposition 2 and in the foregoing cases, the mixed strategy played by the match-type vendor strictly dominates a pure strategy. The lower bound \bar{e} of ρ_m must solve the equality $(1 - \alpha)[R_m(\hat{\mu}_s)\frac{c\hat{\mu}_s + V}{R_n(\hat{\mu}_s)} - c\hat{\mu}_s] + \alpha V = R_m(\hat{\mu}_s)\bar{e} - c\hat{\mu}_s$, from which it follows that $\bar{e} = (1 - \alpha)\frac{c\hat{\mu}_s + V}{R_n(\hat{\mu}_s)} + \frac{\alpha(c\hat{\mu}_s + V)}{R_m(\hat{\mu}_s)}$. Therefore, the expected profit of the match-type vendor under this bidding strategy is $E[u_m^{\text{PPS}}] = (1 - \alpha)[R_m(\hat{\mu}_s)\frac{c\hat{\mu}_s + V}{R_n(\hat{\mu}_s)} - c\hat{\mu}_s] + \alpha V > V = E[u_m^{\text{PPP}}]$. Thus the match-type vendor strictly prefers the bidding strategy under PPS.

We next compute the c.d.f. of the mixed bidding strategy employed by the match-type vendor. This vendor draws her bids from a distribution $F(\rho)$ such that she is left indifferent in expectation; that is, $(1 - \alpha)[R_m(\hat{\mu}_s)\frac{c\hat{\mu}_s + V}{R_n(\hat{\mu}_s)} - c\hat{\mu}_s] + \alpha V = (1 - \alpha F(\rho))(R_m(\hat{\mu}_s)\rho - c\hat{\mu}_s) + \alpha F(\rho)V$, which implies

$$F(\rho) = \frac{1}{\alpha} - \frac{1 - \alpha}{\alpha} \frac{[R_m(\hat{\mu}_s)\frac{c\hat{\mu}_s + V}{R_n(\hat{\mu}_s)} - c\hat{\mu}_s - V]}{R_m(\hat{\mu}_s)\rho - c\hat{\mu}_s - V}.$$

We can now derive the expression for the client's expected profit in this case. Following steps similar to those in the proof of Corollary 1, we see that the client's expected profit here is

$$\begin{aligned}
E[u_c^3] &= (1 - \alpha)^2 \Pi_n(\hat{\mu}_p) + (2\alpha - \alpha^2) \Pi_m(\hat{\mu}_s) - 2\alpha(1 - \alpha)[R_m(\hat{\mu}_s)\frac{c\hat{\mu}_s + V}{R_n(\hat{\mu}_s)} - c\hat{\mu}_s - V] \\
&= (1 - \alpha)^2 \Pi_n(\hat{\mu}_s) + (2\alpha - \alpha^2) \Pi_m(\hat{\mu}_s) - 2\alpha(1 - \alpha)(\Delta(\hat{\mu}_s) - 1)(c\hat{\mu}_s + V).
\end{aligned}$$

It follows from this equation and Corollary 1 that $\hat{\mu}_s = \mu_Q$. We thus conclude that $E[u_c^3] = E[u_c^2] < E[u_c^1]$, which completes the proof.

Proof of Proposition 4. The proof of this proposition follows directly from the discussion in Case Two.

Proof of Proposition 5. Given the equilibrium, each vendor of type i has 50% probability of winning the contract. Since the optimal performance-based menu leaves the individual rationality constraint of both vendor types tight, it follows that the expected payoff for each vendor is V . We assume that the vendors strictly prefer to win the contract (i.e., that they value the earnings V from the relationship more highly than the outside option); hence, to complete this proof we need only show that the vendors cannot improve their chances of being selected by deviating from the equilibrium.

We start by demonstrating that there is no profitable deviation for either type of vendor. If a match-type vendor deviates by playing any mixed strategy with realization $d_m < 1$ (given the hypothesized strategy played by the other vendor), then her probability of winning the contract is

$$\begin{aligned} \Pr(\text{win}) &= \Pr(\text{win} \mid \text{other vendor is nonmatch}) \Pr(\text{other vendor is nonmatch}) \\ &\quad + \Pr(\text{win} \mid \text{other vendor is match}) \Pr(\text{other vendor is match}) \\ &= \frac{1-\alpha}{2} d_m + \frac{\alpha}{2} d_m = \frac{d_m}{2} < \frac{1}{2}. \end{aligned}$$

Deviating therefore leaves a match-type vendor strictly worse-off. Similarly, we can see that a nonmatch-type vendor's likelihood of being selected is $\frac{d_n}{2}$ if she plays any mixed strategy with realization $d_n < 1$. Hence a nonmatch-type vendor also strictly prefers claiming to be of match type. The client's updated belief about each vendor's type is $\beta_1 = \beta_2 = \alpha$ according to Bayes' rule.

Proof of Proposition 6. Given the equilibrium, each vendor of type i has 50% probability of winning the contract. As in the proof of Proposition 5, if a match-type vendor deviates by playing any mixed strategy with realization $d_m < 1$ (given the hypothesized strategy played by the other vendor), then the probability of her winning the contract is $\frac{d_m}{2} < \frac{1}{2}$. Deviating thus leaves the match-type vendor strictly worse-off (in terms of her likelihood of being selected). Note that, once selected, the match-type vendor has nothing to gain from renegotiation: she stands to earn V under either a PPS or a PPP contract. Similarly, we can see that the nonmatch-type vendor's chances of being selected are $\frac{d_n}{2}$ if she plays any mixed strategy with realization $d_n < 1$. Therefore, a nonmatch-type vendor also strictly prefers claiming to be of match type. Although the PPS contract does not satisfy her individual rationality constraint, this vendor knows that she can credibly induce the client to employ instead a PPP contract (else face possible renegeing). The nonmatch-type vendor is thus assured of earning her reservation utility, and this strategy maximizes her chances of winning the contract.

Proof of Proposition 7. Here the client will always choose the initially nonselected vendor if the first vendor threatens to renege. The reason is that only a nonmatch-type vendor would threaten to renege on a PPS contract and seek to have the client change it to a PPP contract. Because vendors always earn V , their strategy will simply be to maximize their probability of entering into a contractual relationship with the client. Given this hypothesized strategy, the probability of winning the contract is $1 - \frac{\alpha}{2}$ for a match-type vendor and $\frac{1-\alpha}{2}$ for a nonmatch-type vendor. We next show that there is no profitable deviation for either

vendor type. If a match-type vendor deviates by playing any strategy with realization $d_m \in [0, 1)$ (given the hypothesized strategy played by the other vendor), then her chances of winning the contract are given by

$$\begin{aligned}\Pr(\text{win}) &= \Pr(\text{win} \mid \text{other vendor is nonmatch}) \Pr(\text{other vendor is nonmatch}) \\ &\quad + \Pr(\text{win} \mid \text{other vendor is match}) \Pr(\text{other vendor is match}) \\ &= (1 - \alpha)d_m + \frac{\alpha}{2}d_m = d_m\left(1 - \frac{\alpha}{2}\right) < 1 - \frac{\alpha}{2}.\end{aligned}$$

Hence deviating leaves the match-type vendor strictly worse-off. If a nonmatch-type vendor is initially selected after choosing the PPS contract, then she will definitely renege and not continue the contractual relationship. Therefore, if a nonmatch-type vendor deviates from the equilibrium by choosing $d_n > 0$, then her odds of winning the contract are $(1 - \alpha)\frac{1-d_n}{2} < \frac{1-\alpha}{2}$. As a result, such a deviation leaves the nonmatch-type vendor strictly worse-off.

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