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Contracting for IT Outsourcing with Asymmetric Information

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CONTRACTING FOR IT OUTSOURCING WITH ASYMMETRIC INFORMATION

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ABSTRACT

IT outsourcing allows a business to reduce the cost of IT service delivery and improve the quality of IT service by taking advantage of the service provider's economics of scale and technical expertise. However, the successful outsourcing of IT service is hampered by lack of guidance on how to design incentive contracts to encourage performance of the service provider, especially in the presence of information asymmetry and incentive divergence. In this article, we identify and characterize two asymmetric information factors: asymmetric effort information and asymmetric capability information. Depending on whether the service provider's effort information and capability information is symmetric or not, we consider three information scenarios and characterize optimal incentive contracts for each scenario. We also introduce the concept of information value to quantify the adverse effects of the two asymmetric information factors. The results provide theoretical support for designing incentive contracts that mitigate the adverse effects of asymmetric information, and recommend effective guidance for activities so as to reduce the degree of information asymmetry.

Keywords: IT outsourcing, contract design, information value, principal-agent model.

1 INTRODUCTION

IT service outsourcing refers to a company contract with external service provider for the provision of part or all of its information service needs rather than deliver them internally as was their practice [1] . With rapid development of information technology and economic globalization, IT outsourcing become a popular practice over the last two decades, it can reduce the cost of information systems service delivery by taking advantage of the service provider' economics of scale and specialization, and enhance service quality by using the technical expertise of the service provider, and improve business performance by better aligning IT strategy with business goals and allowing a focus on her core competency [2, 3]. Because of the advantages above-mentioned, companies have increasingly sourced many of their IT activities, the IT outsourcing market has seen rapid growth. The worldwide IT services market will reach $929 billion in 2016, with outsourcing contributing 60% of market growth in constant currency, the market will reach $1.1 trillion in 2020. However, the results of these outsourcing arrangements have been mixed [4, 5], while some firms have achieve their goals, other had various degrees of failure. A survey by Lacity and Willcocks find that 80% manangers report an unsatisfactory outcome with their outsourcing services [6]. Gupta argue that outsourcing may lead to uncertain level of IT service [7], and the service delivery may not have met the client firms' expectations [5, 8]. Many firms terminate contracts and decide to backsource an outsouced process, or search new service providers and write new contracts [9].

The successful outsourcing of IT services is hampered by lacking guidance on how to design IT outsourcing contracts to encourage and reward good performance of the service provider, especially in the presence of information asymmetry and incentive divergence [10, 11]. A frequent problem the client faces in service outsourcing is the fact that they lack perfect information about her service provider , the information asymmetry between the client and service provider may lead to loss of control and opportunistic behavior [5]. As a result, how to design effective contracts to mitigate the asymmetric information risk become important item to the success of IT outsourcing. In this article, we identify two factors that cause asymmetric information risk. First, the client firm may not contract on the effort spending on the IT outsourcing project, that is, the client firm may lack the information of the investment of the service provider. Second, the client may not know the service provider's capability information. Our objective is to characterize the adverse effects of each asymmetric information risk factor and to design contracts that maximize the client's profit by mitigating asymmetric information risk.

The first factor of asymmetric information risk is that the client and the service provider may not contract on effort, i.e., the investment to the project is unverifiable. First, the inputs of IT service outsourcing project are not freely verifiable, especially intangibility of the knowledge input, technology input, and human resources. Hence, firms cannot contract upon it. Second, it is difficult and costly for the client to monitor the action of the service provider and there may be some loss of control related to the direct supervision of the service provider, resulting in the client lacks information about the service provider's effort. Third, the firms cannot identify every possible contingency in advance. Thus, they cannot write a comprehensive contract that defines what to do in every possible contingency. The above three reasons result in the effort information asymmetry between the contracting parties. The second factor of asymmetric information risk is the service provider's private capability information. The service provider's capability information includes, for example, his R&D capability, technology capability, qualification, knowledge, experience, reputation, personnel quality and management capability [4]. The client may not know the service provider's capability because the capability components are difficult for outsiders to assess.

We introduce the concept of information value to measure the adverse effects of the above two asymmetric information risk factors. Information value arises as the difference between a decision maker's profit in the absence of information relative to what can be obtained in its presence . The information considered in this paper is classified into capability information and effort information. In the light of whether capability and effort information can be verified and contracted or not, there are four scenarios of information: (1) {symmetry, symmetry}: symmetric capability information and symmetric effort information, i.e., the client has the information about the service provider's effort and capability; (2) {symmetry, asymmetry}: symmetric capability information and asymmetric effort information, i.e., the client has the information about the service provider's capability but does not have the information about the service provider's effort; (3) {asymmetry, asymmetry}: asymmetric capability information and asymmetric effort information, i.e., the client does not have the information about the service provider's effort and capability; (4) {asymmetry, symmetry}: asymmetric capability information and symmetric effort information, i.e., the client has information about the service provider's effort but does not have the information about the service provider's capability. We also note that we will not study scenario (4)，i.e., asymmetric capability information but the effort is verifiable, in this scenario, the client can observe the effort level of the service provider, but due to unobservability of capability information, she is unable to choose the appropriate effort level to contract on, so the effort information is useless and this scenario does not yield additional insights and can be reduced to scenario (3). Therefore, in the following analysis, we will not study scenario (4) and we will only analyze performances of scenario (1), (2) and (3) respectively. Based on definition of value of information from Banker and Kauffman , the value of effort information is the client's payoff in scenario (1) minus her payoff in scenario in (2), and the value of capability information is the gap between the client's profit in scenario (2) and her profit in scenario (3).

In this article, in addition to identifying the asymmetric information risk factors, we quantify and compare their impact on the client's profits and IT service quality. We propose a moral hazard model under asymmetric effort information and an adverse model in the presence of asymmetric capability information. And we design contracts to mitigate their adverse effects and identify the key trade-offs between the value of information and the cost for the execution of information disclosure activities. We propose three respective contracts for the above-mentioned different information settings and analyze the impact of key parameters on the value of information. The results show that both the value of capability information and the value of effort information increase in the quality sensitivity and capability level, but with regard to the degree of risk aversion of the service provider and the uncertainty of quality, they show opposite effects, the value of capability information decreases in the degree of risk aversion and quality uncertainty while the value of effort information increases in them. Furthermore, we find that the ex ante belief about the service providers capability type has important influence on the value of cost information. The results of this paper provide theoretical support for designing outsourcing contracts under asymmetric information, and point out conditions under which the client should pay attention to the risk of information asymmetry and recommend effective guidance for making trade-off between the value of information and the cost of information disclosure activities.

The paper is organized as follows. We review the related literature in the next section. Section 3 presents the basic model, gives the first-best solution in symmetric information setting (scenario (1)), and relates the design of contracts under asymmetric information settings (scenarios (2) and (3)). We report the insights derived from numerical analysis in section 4. Finally, we provide concluding remarks and directions for further research.

2 LITERATURE REVIEW

Three streams of literature yield key insights regarding the contract design in IT outsourcing arrangements: transaction cost economics (TCE) perspective, principal-agent perspective and real options perspective. Each of these literature streams is reviewed as follows.

TCE addresses the assumption that market and, by extension, the contract are the most efficient mechanism to govern all transactions [12]. TCE argues that there are at least three major characteristic of transaction that determine the magnitude of transaction costs, including transaction-specific investments, uncertainty and complexity and reputation [13]. From the point of TCE the internal provision should be preferred when the transaction costs of securing a product or a service from external source are high. The IT outsourcing has received considerable attention from the transaction cost perspectives. Kern and Willcocks argue that the external sourcing of information services is characterized by high transaction costs . Specifically, these observers point to the difficulty of writing efficient contracts in the presence of considerable technological and business uncertainty [14]. Poppo and Zenger study the relationship between formal contract and relational exchange arrangements, argue that in the context of IT outsourcing that formal contracts and relational governance function as complements[15] . Grover et al. argue that while there is a positive relationship between outsourcing of less asset-specific transactions with success, outsourcing of more asset-specific interactions results in unsatisfactory outcomes . Kern and Willcocks identify seven categories of contractual issues that facilitate management control of outsourcing relationship, including service description and exchanges, service enforcement and monitoring, financial exchanges, financial control and monitoring, key vendor personnel, dispute resolution, and change control and management [14]. Gopal et al. study the determinants of contract choice, the determinants they consider are require uncertainty, projects size and potential resource shortages [10]. Kalnins and Mayer examine the impact of uncertainty, measurement issues and prior relationship on the contract structure [16]. Goo et al explore factors that influence the duration of IT contract, they conclude that while relationship-specific investments and the extent of substitution is positive related to IT contact duration, demand uncertainty and vendor opportunism leads to short contract duration [17]. The above researches based on transaction cost economics have generally provided helpful explanations in the trade-off between integration and nonintegration, that is, insourcing and outsourcing, but they lack the design and analysis of performance incentives in bilateral contracts, especially in the face of information asymmetry. Comparing to the above researches based on TCE, our research focus on designing and analyzing the incentive contracts for IT outsourcing in the presence of information asymmetry and characterizing the adverse effects of information asymmetry, so our research can better analyze the economic benefits of outsourcing and provide guidance in designing contracts for IT outsourcing with information asymmetry, and points out conditions under which the client should carry out activities to reduce the risk of information asymmetry.

In addition to researches based on transaction cost economics, another literature stream of contracts in IT outsourcing has primarily been studied through the viewpoints of principal-agent theory. Principal-agent theory focuses on contract design to mitigate incentive divergence between contracting parties. Elitzur and Wensley utilize a principal-agent approach to construct a moral hazard model, they focus on designing and analyzing contracts in the setting with asymmetric effort information, i.e., the effort expended by the service provider in providing the outsourced service is not freely verifiable [18]. Bryson and Ngwenyama develop an approach to analyzing outsourcing risks and structuring incentive contracts based on principal-agent theory [5]. The outsourcing risks considered are shirking and opportunistic bargaining, shirking results form asymmetric effort information, and opportunistic bargaining refers to a service provider's ability to demand higher than market prices. Ren and Zhou study contracting issues in an outsourcing supply chain, they propose different contracts depending on the observability and contractibility of the service provider's effort [19]. Dey et al present a contract-theoretic model considering information asymmetry and incentive divergence to analyzed how software outsourcing contracts can be designed. Depending on whether the effort spending on the software development can be verified and contracted or not, they design and analyze three types of contracts: fixed-price contract, time-and-materials contract and performance-based contract [20]. Roels and Karmarkar study contracting issues arising in collaborative services, such as IT outsourcing, they provide different contracts depending on whether the efforts are verifiable or not, they analyze fixed-fee contract when the vendor's efforts can not be contracted but the client's efforts are verifiable, and time-and-materials contract when the vendor's effort are verifiable but he client's efforts are not, and performance-based contract when both efforts are not verifiable [21]. Fitoussi and Gurbaxani examine the incentive contract design with multiple objectives in IT outsourcing, and in their model the efforts associated with the objectives cannot directly observed by the client [11]. Elitzur et al consider the information system outsourcing projects as a double hazard problem, in their model the success of the information system outsourcing projects depends on the efforts of both client and service provider, which are not freely verifiable and directly contractible [22]. The above researches main focus on the moral hazard due to the unobeservablity and uncontractibility of the service provider's effort, but in practical IT outsourcing, not only exists the moral hazard problem with asymmetric effort information, but also exists the adverse selection problem when the client can not acquire the service provider's private information such as capability information. In contrast to these prior studies, this paper presents a more comprehensive consideration of the asymmetric information factors involved in designing the contracts, not only the asymmetric effort leading to moral hazard problem, but also the asymmetric capability information leading to adverse selection problem is taken into account, and also we analyze the adverse effects of each asymmetric information risk factor. Through considering different information scenarios depending on whether the effort information and capability information is symmetric or not, we can provide more comprehensive advising for design outsourcing contracts under asymmetric information. Through quantifying and analyzing the adverse effects of information asymmetry, we can recommend effective policies for making trade-off between the value of information and the cost of information disclosure activities.

The third stream of literature on IT outsourcing contracts is from the perspective of real options, which examines contracting issues subject to irreversible outsourcing investment and uncertainty. Real options theory focuses on optimal investment decision making in the framework of irreversibility and uncertainty [23]. Jiang et al and Yao et al study the contract section and outsourcing timing in the presence of cost uncertainty [24, 25]. Two papers apply real option approach respectively analyze the impacts of demand uncertainty and souring flexibility on IT outsourcing contracts [26, 27]. These articles main concentrate on the contracting issues with uncertainty risk, however, they neglect the important risks of information asymmetry in IT outsourcing.

To summarize, the existing contracting researches based on transaction cost economics focus on the trade-off between insourcing and outsourcing, the researches based on principal-agent theory primarily concentrate on the moral hazard due to the asymmetric effort information, the researches based on real options theory only pay attention to the uncertainty in IT outsourcing. In this paper, we look at IT outsourcing as a problem that not only has asymmetric effort information coupled with moral hazard but also involves asymmetric capability information coupled with adverse selection. We quantify and compare the two asymmetric information factors' impact on the client's profits, and design contracts to mitigate their adverse effects.

3 BASIC MODEL

3.1 Model Components

3.1.1 Input and Output

Input is the service provider's effort, denoted by e. We assume the cost function of effort is $C(e)=\frac{1}{2}e^2$, i.e., the cost of providing effort level e. The quadratic form implies increasing marginal cost of effort level, division by 2 is for notational ease in subsequent analysis .

We use service quality to measure the output of service provider's work, denoted by q. We model service quality as a function of the vendor's capability θ and effort e and denotes as:

$$q = f(\theta, e) + \varepsilon,$$

where $\frac{\partial f}{\partial \theta}>0$, $\frac{\partial f}{\partial e}>0$, $\frac{\partial^2 f}{\partial \theta \partial e}\geq 0$. $\frac{\partial f}{\partial \theta}>0$ and $\frac{\partial f}{\partial e}>0$ imply the service quality increases with the service provider's effort and capability. $\frac{\partial^2 f}{\partial \theta \partial e}\geq 0$ implies that the effect of efforts on quality improvement is stronger if the service provider's capability is higher. ε is the uncertainty associated with service quality. We model ε as a normally distributed random variable with zero mean and variance σ^2. For ease of mathematical treatment, we simplify $f(\theta,e)=\theta e$, so we can get $q=\theta e+\varepsilon$.The utility of service to the client increases with the service quality level, the expected utility of the client can be expressed as

$$V = \mu q = \mu(\theta e + \varepsilon),$$

where μ is the client's sensitivity to service quality. μ represents the client's valuation of service quality and is closely related to the importance, functionalities and complexity of the service[20], the higher value of μ implies the service quality is more important for the client.

3.1.2 Contract Type

Generally, there are two classes of outsourcing contracts, fixed fee and incentive [5, 20]. In a simple fixed fee contract, a predetermined price is paid to the service provider and he is responsible for all the risk of cost overruns, in practice however, the service provider can engage in opportunistic bargaining, that is he may pressure the client to pay the overruns if he is the unique service provider and there is no option of switching [5]. Another type of fixed fee arrangement is a time and materials contract, also known as cost plus contract, requires the client to pay the service provider the cost of efforts plus a profit. The above two types of fixed fee contract require the effort spending on the IT outsourcing project are freely verifiable, that is, the effort information is symmetric so the client can pay the fixed fee according to the cost of effort. However, in reality the client usually lacks information about the effort of the service provider [20], what is more, the output of service may influence by outside uncertainty that beyond the service provider's control [11, 20], so the service provider's effort can not be inferred from the output, so adoption of fixed fee contract may lead to poor performance. The second type, incentive contracts, attempts to share risks and rewards between the client and the service provider. In this type of contracts, the payoff to the service provider is tied to the performance of the IT service, generally they specify incentives for various levels of performance.

In the presence of information asymmetry, we consider incentive contracts so as to provide effective incentives to the service provider. In these contracts, the client agrees to pay the service provider a portion of the agreed upon fixed price ensuring the participation of the service provider and additional incentive payments for various levels of performance so as to induce the service provider to perform at higher levels (exert more efforts). Following Holmstrom and Migrom's model , We consider an incentive contract from where the payment from the client to the service provider is expressed as

$$W(q) = \varpi + \beta q ,$$

where ϖ is the fixed part of the payment, β is the incentive payment per level of performance, $\beta \in [0, \mu]$.

We assume the service provider is risk averse and his utility function is $U(x) = -e^{-rx}$ [28], where $r > 0$ is the service provider's coefficient of absolute risk aversion and $x = W(q) - C(e)$ is the service provider's net payoff—the realized compensation minus the cost. The client is risk neutral and so seeks to maximize the expected value of profit, $\pi_c = V - W$.

Given the contract $W(q) = \varpi + \beta q$, the service provider's problem is

$$\max_e - e^{-r[\varpi + \beta\theta e - \frac{1}{2}e^2]} \int_{-\infty}^{\infty} e^{-r\beta\varepsilon} \phi(\varepsilon) d\varepsilon ,$$

where $\phi(\varepsilon)$ denotes the normal density function. The service provider's certainty equivalent is

$$CE(\varpi, \beta) = \varpi + \beta\theta e - \frac{1}{2}e^2 - \frac{1}{2} r\beta^2\sigma^2 .$$

For notational convenience, we replace $CE(\varpi, \beta)$ by π_s in the subsequent sections, i.e., $\pi_S = CE(\varpi, \beta)$.

3.1.3 Description of Contracting Game

We model the contracting process as a Stackelberg game, in which the client offers a contract to the service provider and the service provider makes the choice of effort level. The timing of the game is modeled as follows: (1) the client offers the contract $W(q)$; (2) the service provider accepts the contract if its certainty equivalent profit π_s is larger than his reservation utility, denoted by $\pi_R \geq 0$, or rejects the contract otherwise; (3) After the service provider has accepted the contract, he chooses the appropriated effort level e; (4) events beyond the service provider's control ε occur; (5) the effort e and the noise term ε determine the output q; (6) the project is completed, the quality of service q is realized and released to the client; (7) the service provider receives the monetary payment specified by the contract; see Figure 1.

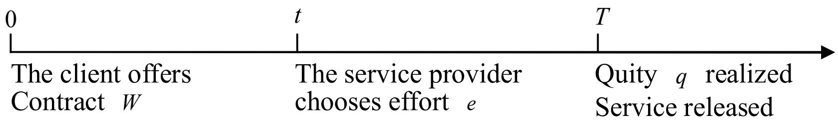

Figure 1. Timing of the model

3.2 First-best contract under symmetric information

As a benchmark, consider the first-best solution, as if both the effort information and capability information is symmetric between the client and the service provider (that is, scenario (1)). In this situation, the client is able to choose the service provider's effort so as to maximize her profit. The client's contracting problem is

P1

$$\max_{\varpi,\beta,e} \pi_C = (\mu - \beta)\theta e - \varpi \tag{1}$$

$$s.t.\quad \pi_S = \varpi + \beta\theta e - \frac{1}{2}e^2 - \frac{1}{2}r\beta^2\sigma^2 \geq \pi_R . \tag{2}$$

The constraint assures that the service provider's expected profit is no less than his reservation profit π_R. Solving program 1, we can obtain the following proposition 1.

PROPOSITION 1. The first-best results under symmetric effort and capability information are as follows: (a) The optimal Contract $W^{FB} = (\varpi^{FB}, \beta^{FB})$ where $\varpi^{FB} = \pi_R + \frac{1}{2}\mu^2\theta^2$, $\beta^{FB} = 0$; (b) the optimal effort level $e^{FB} = \mu\theta$; (c) The service provider's expected profit $\pi_S^{FB} = \pi_R$. The client's expected profit $\pi_C^{FB} = \frac{1}{2}\mu^2\theta^2 - \pi_R$, increasing in θ and μ.

The proofs of this and all the subsequent propositions and lemmas are given in Appendix.

Proposition 1 characterizes the optimal contract terms and shows that when both the effort information and capability information are symmetric, the results are the same as integrated firm, i.e., equal to the results of solving $\max_e \{\mu\theta e - \frac{1}{2}e^2\}$. The channel does not lose efficiency due to outsourcing. The client is effectively the only decision maker. Hence, she can squeeze out all channel profits and leave the service provider with just enough profit to ensure his participation. We use the results under symmetric information as benchmarks for the rest of the paper.

3.3 Optimal choice of contract under asymmetric information

We now turn our attention to the optimal choice of contract when the capability information θ and effort information e can not be always verifiable and contractible. Scenario (2) and (3) must be considered. When the service provider's effort level can not be contracted on, the problem reduces to a standard principal-agent model. The transfer payment W can only be a function of what is contractible, namely the performance q. Given the contract payment $W(q) = \varpi + \beta q$, the service provider's problem is to maximize $\varpi + \beta\theta e - \frac{1}{2}e^2 - \frac{1}{2}r\beta^2\sigma^2$. When $\beta = 0$, this problem equals to maximize $\varpi - \frac{1}{2}e^2$, it is easy to see the optimal effort level of the service provider is $e=0$, which does not meet the client's objective, so in the asymmetric information context, the scope of β is $(0,\mu]$. $\beta=0$ implies the client will not provide the contract payment and the service provider get reservation utility π_R from the outside opportunity.

3.3.1 Symmetric Capability Information and Asymmetric Effort Information

We now examine the contract performance under symmetric capability information but asymmetric effort information, that is, the client has information about the service provider's capability but lacks information about the service provider's effort spending on the IT outsourcing project. The client chooses the contract that maximizes her expected profit, subject to the service provider's participation constraint (4), ensuring that the service provider obtains a certainty equivalent profit at least no less than its reservation utility, and the incentive compatibility constraint (5), which defines the noncooperative Nash game of effort choice. According, the service provider's problem can be formulated as follows:

P2

$$\max_{\varpi,\beta} \pi_C = (\mu-\beta)\theta e - \varpi \tag{3}$$

$$s.t.\quad \pi_S = \varpi + \beta\theta e - \frac{1}{2}e^2 - \frac{1}{2}r\beta^2\sigma^2 \geq \pi_R \tag{4}$$

$$e^* = \arg\max\{\pi_S = \varpi + \beta\theta e - \frac{1}{2}e^2 - \frac{1}{2}r\beta^2\sigma^2\}. \tag{5}$$

We denote the equilibrium contract solution as (ϖ^*,β^*) and the service provider's best response as e^*. The equilibrium contract, the service provider's strategy and their respective expected utility are derived as follows:

PROPOSITION 2. Suppose that the capability information is symmetric, but the effort level information is asymmetric, the contract $W^*=(\varpi^*,\beta^*)$ and service provider's choice of effort e^* constitute a Nash equilibrium, where ϖ^*, β^* and e^* are given by $\varpi^* = \pi_R - \frac{\mu^2\theta^4(\theta^2 - r\sigma^2)}{2(\theta^2+r\sigma^2)^2}$; $\beta^* = \frac{\mu\theta^2}{\theta^2+r\sigma^2}$, increasing in μ and θ but decreasing in r and σ^2; $e^* = \frac{\mu\theta^3}{\theta^2+r\sigma^2}$, increasing in θ and μ but decreasing in r and σ^2. The client's optimal profit is such that $\pi_c^* = \frac{\mu^2\theta^4}{2(\theta^2+r\sigma^2)} - \pi_R$, increasing in θ and μ but decreasing in r and σ^2. The service provider's optimal utility $\pi_S^* = \pi_R$.

The proposition characterizes the optimal contract terms, the resulting effort level and profits. Which shows that with high quality sensitivity, high capability, low degree of risk aversion and uncertainty, the client is prone to provide more incentive for the service provider and as a result get higher IT service quality and more profit. In summary, a high capability increases the client's profit, however, with high degree of risk aversion and quality uncertainty, the client's profit will decrease. And more importantly, the proposition enables us to quantify the impact of the service provider's capability. Note that in practice the service provider can improve his capability by investing in new technologies and recruiting IT experts. The proposition can be used to quantify how such activities impact resulting profit when the capability of service provider is known to both parties.

Comparing the results under symmetric capability information and asymmetric effort information with those under symmetric information, we have the following result:

PROPOSITION 3. In the setting with symmetric capability information and asymmetric effort information, the service provider would invest lower effort compared to the first-best solution, resulting in a lower service quality and the client's expected profit.

Proposition 3 suggests that in the setting with symmetric capability information and asymmetric effort information, the service provider does not have an incentive to provide effort at the first-best level.

PROPOSITION 4. The value of effort information can be calculated as

$$\kappa_e = \pi_C^{FB} - \pi_C^* = \frac{r\mu^2\theta^2\sigma^2}{2(\theta^2 + r\sigma^2)} \tag{6}$$

The effort information value κ_e increases in μ, θ, r and σ^2.

Proposition 3 and 4 characterize the effects of the first asymmetric information risk factor (asymmetric effort information). Specially, proposition 4 quantifies the adverse effects of the first asymmetric information risk factor, i.e., the value of effort information. In some cases, to minimize the adverse effects of asymmetric effort information, the client firms may contract on effort through costly monitoring and supervising, or may invest in monitoring and coordinating mechanisms. Generally, the client can setup an organizational unit to coordinate the interactions between its end-users and the service provider and to supervise the service provider's action[5]. This unit may be costly depending the size and complexity of the outsourcing service. Also, the client firms can introduce hierarchical governance structure to reduce opportunistic behavior by the service provider [29]. When the client firm wants to take the above activities to mitigate the adverse effects of the asymmetric effort information, she should make the trade-off between the cost of these activities and the value of effort information. The value of effort information κ_e provides an upper bound of such activities. Furthermore, the comparative static analysis of κ_e gives conditions under which the client should pay attention to the risk of asymmetric effort information, with high importance of quality, high capability of the service provider, high risk aversion of the service provider and high uncertainty of quality, it is worth carrying out such activities, but with low importance of quality, low capability of the service provider, low degree of risk aversion and uncertainty, the client is better off not carrying out such activities.

3.3.2 Asymmetric Capability Information and Asymmetric Effort information

In this subsection, we address a setting in which both the capability information and effort information is not symmetric. Here, in addition to the asymmetric effort information, we consider the inefficiency due to private capability information. Assume a service provider that can be of two types: a high-capability service provider with capability θ_H and a low-capability service provider with capability θ_L, where $\theta_H > \theta_L$. In this scenario, the service providers know which type they belong to, but the client lacks the information, she merely knows the proportion of low-capability type in the outsourcing market is p and high-capability type is $1-p$, i.e., the belief is such that the service provider has low-capability with probability p and high-capability with $1-p$.

In order to facilitate the analysis, we define a new function. Substituting Equation (B3) (see the Appendix B) into Equation (4), we write the service provider's profit as functions of the contract parameters, i.e., $\pi_s = \varpi + f(\beta,\theta)$, where $f(\beta,\theta) = \frac{1}{2}\beta^2\theta^2 - \frac{1}{2}r\beta^2\sigma^2$, $\beta \in (0,\mu]$. When $\beta = 0$, according to the above analysis, in asymmetric information setting, the client would refuse to do business with the service provider, thus $\varpi = 0$, $f(0,\theta) = \pi_R$. From the above analysis, we get

$$f(\beta,\theta) = \begin{cases} \pi_R & \text{if } \beta = 0 \\ \frac{1}{2}\beta^2\theta^2 - \frac{1}{2}r\beta^2\sigma^2 & \text{if } 0 < \beta \le 1 \end{cases} \tag{7}$$

The following lemma establishes an important property of $f(\beta,b)$ that we will use in the analysis.

LEMMA 1. The function $f(\beta,\theta)$ has increasing differences in θ, that is $f(\beta_2,\theta) - f(\beta_1,\theta)$ is increasing in θ for $0 < \beta_1 < \beta_2 \le \mu$. Thus, a high-capability service provider values an increase in the per-unit incentive payment more than a low-capability service provider does.

Before offering a contract, the client can ask the service provider to report his capability and next she can offer the contract characterized in the previous section. However, if the client asks for the service provider's capability information report, the service provider may misreport his private information and uses his information advantage to get extra profit except the reservation profit. Hence, the client needs to design a truth-telling mechanism to credibly obtain the service provider's private capability information while maximizing her profit. According to the revelation principle [39], through designing the optimal menu of contracts $\{(\varpi_L,\beta_L),(\varpi_H,\beta_H)\}$, the client can reveal the true type of the service provider. The client solves the following problem

P3

$$\max_{\{(\varpi_H,\beta_H),(\varpi_L,\beta_L)\}} E[\pi_c] = p[(\mu-\beta_L)\theta_L e_L - \varpi_L] + (1-p)[(\mu-\beta_H)\theta_H e_H - \varpi_H] \tag{8}$$

$$s.t. \quad \pi_{S_{HH}}^{**} = f(\beta_H,\theta_H) + \varpi_H \ge f(0,\theta_H) = \pi_R \tag{9}$$

$$\pi_{S_{LL}}^{**} = f(\beta_L, \theta_L) + \varpi_L \geq f(0, \theta_L) = \pi_R \tag{10}$$

$$\pi_{S_{HH}}^{**} = f(\beta_H, \theta_H) + \varpi_H \geq \pi_{S_{HL}}^{**} = f(\beta_L, \theta_H) + \varpi_L \tag{11}$$

$$\pi_{S_{LL}}^{**} = f(\beta_L, \theta_L) + \varpi_L \geq \pi_{S_{LH}}^{**} = f(\beta_H, \theta_L) + \varpi_H . \tag{12}$$

The individual rationality constraints (9) and (10) ensure that both service provider types participate in transaction. The incentive compatibility constraints (11) and (12) ensure that service provider chooses the contract intended for his type.

The proposition below presents the client's optimal contracts menu and the resulting optimal profits and efforts in the setting of asymmetric capability information.

PROPOSITION 5. Suppose that neither the capability information nor the effort information is symmetric, the high-capability service provider optimally chooses the contract $W_H^{**} = (\varpi_H^{**}, \beta_H^{**})$, where the incentive payment is not distorted (that is, $\beta_H^{**} = \beta_H^{*}$). The low-capability service provider optimally chooses the contract $W_L^{**} = (\varpi_L^{**}, \beta_L^{**})$, where the incentive payment is distorted downward (that is, $\beta_L^{**} < \beta_L^{*}$). The contract parameters satisfy

$$\varpi_H^{**} = \pi_R - \frac{\mu^2\theta_H^4(\theta_H^2 - r\sigma^2)}{2(\theta_H^2 + r\sigma^2)^2} + \frac{\mu^2\theta_L^4(\theta_H^2 - \theta_L{}^2)}{2(\theta_L^2 + r\sigma^2 + T)^2};\ \varpi_L^{**} = \pi_R - \frac{\mu^2\theta_L^4(\theta_L^2 - r\sigma^2)}{2(\theta_L^2 + r\sigma^2 + T)^2};$$

$$\beta_H^{**} = \frac{\mu\theta_H^2}{\theta_H^2 + r\sigma^2};\quad \beta_L^{**} = \frac{\mu\theta_L^2}{\theta_L^2 + r\sigma^2 + T},$$

where $T = ((1-p)/p)(\theta_H^2 - \theta_L^2)$. The service provider's optimal effort e_L^{**} and e_H^{**} are $e_L^{**} = \frac{\mu\theta_L^3}{\theta_L^2 + r\sigma^2 + T}$; $e_H^{**} = \frac{\mu\theta_H^3}{\theta_H^2 + r\sigma^2}$. The client's optimal profit is $\pi_{C_L}^{**} = \frac{\mu^2\theta_L^4(\theta_L^2 + r\sigma^2 + 2T)}{2(\theta_L^2 + r\sigma^2 + T)^2} - \pi_R$; $\pi_{C_H}^{**} = \frac{\mu^2\theta_H^4}{2(\theta_H^2 + r\sigma^2)} - \frac{\mu^2\theta_L^4(\theta_H^2 - \theta_L{}^2)}{2(\theta_L^2 + r\sigma^2 + T)^2} - \pi_R$. Where $\pi_{C_i}^{**}$ denotes the client's optimal profit when the service provider is type i. The service provider's optimal equivalent profit is

$$\pi_{S_L}^{**} = \pi_R;\quad \pi_{S_H}^{**} = \pi_R + \frac{\mu^2\theta_L^4(\theta_H{}^2 - \theta_L{}^2)}{2(\theta_L^2 + r\sigma^2 + T)^2}.$$

Where $\pi_{S_i}^{**}$ denotes the service provider's optimal equivalent profit when his type is i.

Proposition 5 suggests that with the contracts menu $\{(\varpi_H^{**}, \beta_H^{**}), (\varpi_L^{**}, \beta_L^{**})\}$, the client is able to identify the service provider's type. The next proposition further characterizes the behavior of the optimal effort level and contract parameters under the contract menu $\{W_H^{**}, W_L^{**}\}$.

PROPOSITION 6. (a) Both e_L^{**} and e_H^{**} are increasing with μ and their respective capability level θ_H and θ_L but decreasing with r, σ^2; (b) Both β_L^{**} and β_H^{**} are decreasing with r, σ^2 but increasing with μ and their respective capability θ_H and θ_L, furthermore, β_L^{**} is decreasing with capability gap between low-capability parameter and high-capability parameter, where the capability gap $x = \theta_H - \theta_L$; (c) $\partial\beta_H^{**} / \partial p = 0$, $\partial\beta_L^{**} / \partial p > 0$. The client's ex ante belief of service provider's type would have no impact on the high-capability type service provider's optimal incentive payment, but would influence the low-capability type service provider's optimal incentive payment. The more accurate the client's judgement of low-capability type is (that is, the higher p), the larger the incentive payment to the low-capability type becomes, i.e., the larger the proportion of low-capability type in the market, the less distortion; (d) $\beta_H^{**} - \beta_L^{**} \geq 0$, $\partial\Delta\beta_{HL}^{**} / \partial x > 0$, where $\Delta\beta_{HL}^{**} = \beta_H^{**} - \beta_L^{**}$. The high-capability type service provider's incentive payment is higher than the low-capability type service provider's, and moreover, the incentive payment gap between the low-capability type provider's and the high-capability's increases in the capability gap.

Comparing the results in the setting of asymmetric capability information and asymmetric effort information with those in the setting of symmetric capability information and asymmetric effort information, we have the following proposition:

PROPOSITION 7. (a) The high-capability service provider would invest the same effort but the low-capability service provider would invest lower effort, resulting in a lower expected service quality; (2) The equivalent profit of low-capability type service provider would keep the same, but the expected profit of the client would be lower. The high-capability service provider would obtain an information rent in addition to reservation utility.

Proposition 7 characterizes the effects of private capability information. When the service provider belongs to high-capability type, the only difference from the symmetric capability information situation results is the information rent that the service provider obtains. In order to distinguish the different capability type service provider, the client distorts the low-capability service provider incentive payment β_L^{**} downward, which results in a lower effort level and service quality and a reduction in the client's expected profit.

PROPOSITON 8. Comparing the client's payoff in the presence of capability information with that in the absence of capability information, the value of capability information can be stated as

$$\kappa_c = E[\pi_C^*] - E[\pi_C^{**}] = \frac{p\mu^2\theta_L^4 T^2}{2(\theta_L^2 + r\sigma^2)(\theta_L^2 + r\sigma^2 + T)^2} + \frac{(1-p)\mu^2\theta_L^4(\theta_H^2 - \theta_L{}^2)}{2(\theta_L^2 + r\sigma^2 + T)^2} \tag{13}$$

Consistent with κ_e, κ_c increases in μ, but on the contrary, κ_c decreases in r and σ^2 while κ_e increases in r and σ^2. Moreover, κ_c is increasing with the capability gap x.

The above proposition quantifies the effect of the second asymmetric information risk factor on the client's profit. In some cases, the client may acquiring the service provider's capability information through writing a comprehensive request for information (RFI) or contract that includes detain information of the service provider's capability information, such as whether the service provide get CMM (Capability Maturity Model) or CMMI (Capability Maturity Model Integration) certification, and which CMM or CMMI level have they achieved. Also the client can obtain the service provider's private information through a auditing the service provider by hiring internal or external experts. If the client prepares to carry out such activities, it should ensure the cost of such activities is lower than the value of capability information. Furthermore, the value of capability information points out condition under which the client should pay attention to the asymmetric capability information, with high importance of quality, low risk aversion of the service provider, low uncertainty of quality and large difference between the low-capability type service provider's capability and the high-capability type service provider's capability, such information disclosure activities deserve to be carried out.

4 NUMERICAL ANALYSIS OF INFORMATION VALUE

Next, we compare the effects of the two asymmetric information risk factors, that is, we compare the value of effort information, with the value of information on the service provider's capability. Through numerical analysis we want to figure out which of the two asymmetric information risk factors affects the system more, and when does one asymmetric information risk factor play a important role than the other, and when should the client pay more attention to these asymmetric information risk factors.

In this section, we analysis the relation between the relevant parameters and the value of information described in proposition 4 and proposition 8. Further, we show the impact of five key parameters on the value of information, including (1) and the quality sensitivity parameter, μ, (2) the capability level of high-capability service provider, θ_H, (3) the risk aversion measurement parameter, r, (4) the uncertainty measurement parameter of quality, σ^2, (5) the client's ex ante belief, p. First, we purposely select a set of baseline parameters: $\mu = 1$, $r = 0.1$, $\sigma^2 = 0.2$, $\theta_H = 2\theta_L$, $\theta_H = 0.5$, $p = 0.5$, $\pi_R = 0$. Then for each scenario, we vary one parameter at a time over a wide range of value and calculate two statistics—the value of effort information κ_e and the value of capability information κ_c, resulting in Figures 2-6.

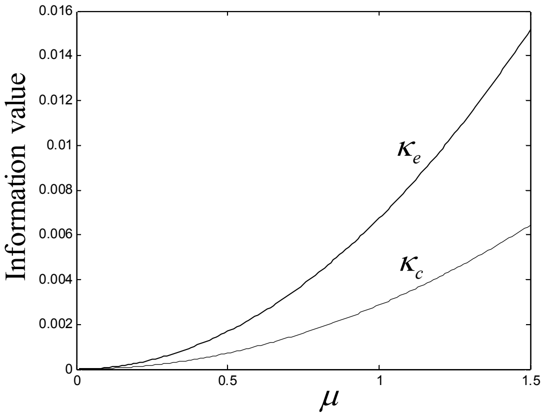

Figure 2. The impact of μ on κ_e and κ_c .

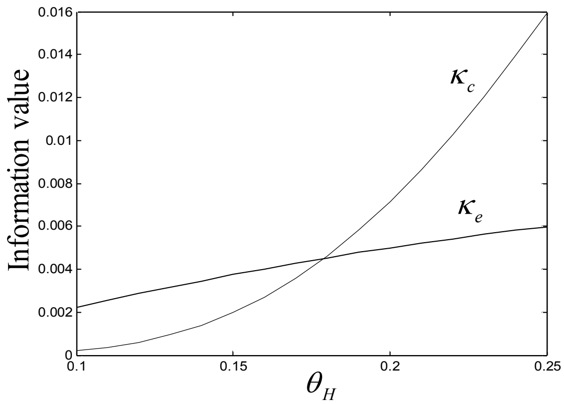

Figure 3. The impact of θ_H on κ_e and κ_c

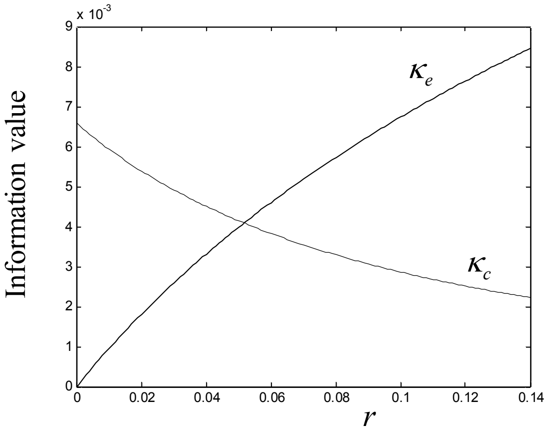

Figure 4. The impact of r on κ_e and κ_c

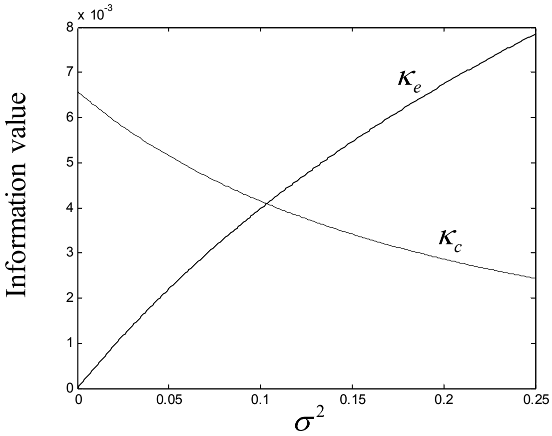

Figure 5. The impact of σ^2 on κ_e and κ_c

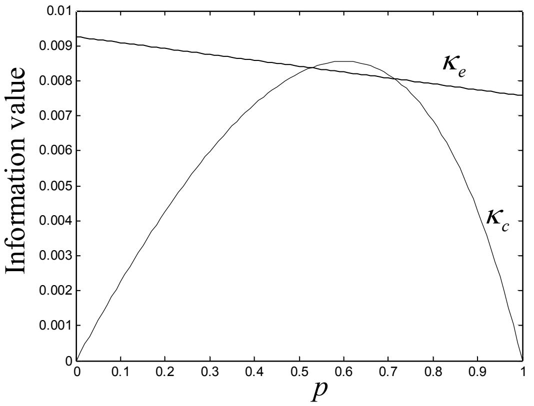

Figure 6. The impact of p on κ_e and κ_c

Figure 2 and figure 3 illustrate the comparisons as functions of μ and θ_H, respectively. We observe that both the value of capability information and the value of effort information increase in μ and θ_H, a high importance of quality and a high capability level generally lead to high value of information on effort and capability, i.e., high adverse effects of the two asymmetric information risk factors, which shows that when the IT service quality is important for the client and the capability of the service provider is high, the client can consider taking measures to reduce the degree of information asymmetry, such as build an organization unit to collect the service provider's capability information and monitor the actions of service provider. Figure 4 and figure 5 illustrate the comparisons as functions of r and σ^2. We observe that while the value of effort information is increasing with r and σ^2, the value of capability information is decreasing with them. The first factor of asymmetric information risk (the asymmetric effort information) is significantly more important than the second factor (private capability information) when the degree of risk aversion of the service provider and the uncertainty of quality is high, and the second factor of asymmetric information risk is more pronounced when the degree of risk aversion and quality uncertainty is low. These findings suggest that with low degree of risk aversion and quality uncertainty, the client ought to sign an expensive comprehensive contract containing detailed capability information of the service provider but unnecessary to strictly monitor the action of the service provider. Figure 6 illustrates that κ_e is monotonically decreasing in p, that is, as the proportion of low-capability type service provider increase, the value of effort information is decreasing, which indicates that when most service providers are belonging to high-capability type, the client can invest in monitoring mechanism to get the service provider's effort information. Note that the impact of p on the value of capability information κ_c is inconsistent with the result of κ_e, κ_c is concave in p, and its maximum value is obtained when p near 0.5, which is the maximum uncertainty level of the client's judgment. As the client's judgment of service provider becomes more and more accurate, that is, p is closer to 0 or 1, the value of capability information decreases. In the extreme, when $p = 0$ or $p = 1$ (this means that the client know clear what the type of the service provider is, i.e., for the client, there is no uncertainty of capability type), the value of κ_c reduces to zero. The above analysis indicates that when the portion of the two types of service provider in the outsourcing market is almost the same, the client suffers large loss due to asymmetric capability information, but when most service providers belong to one type, not knowing the service provider's capability information does not cause a large reduction in the client's profit.

5 CONCLUSIONS

The client firm may lack the information about the service provider's private capability and the effort exerting on the IT outsourcing service project. Depending on the verifiability and contractibility of the service provider's effort and capability information, we consider three information scenarios and analyze contracts for each scenario. Specially, a moral hazard model under asymmetric effort information and an adverse selection model under asymmetric quality cost information are proposed, and we characterize the optimal contracts that mitigate the asymmetric information risk. Also, we quantify and compare the two asymmetric information risk factors' impact the client's expected profits, i.e., the value of effort information and the value of capability information. Our research results offer the following managerial insights:

First, our results provide useful insights on incentive contract design in different information settings. When both effort information and capability information are symmetric, the client firm only need to provide the fixed payment to the service provider because she can make the decision of effort choice for the service provider. When the effort information is asymmetric, she can not make the decision of effort choice for the service provider, due to the opportunism behavior of the service provider, she should provide a incentive payment to induce the service provider to exert effort, also she need to make the trade-off between incentive and insurance, because of the quality uncertainty risk, she need to pay an insurance for the service provider, that is, the fixed payment. When the capability information is asymmetric, compared to the symmetric capability information, for screening the types of the service providers, the client provides information rent for the high-capability service provider, to reduce this rent, the client distorts the low-capability service provider per-unit incentive payment. With regard to the fixed part of the payment, we can see in the scenario where both the effort information and capability information are symmetric, the service provider's fixed payment are constituted by her reservation profit and compensatory for her effort, but in the scenario where the effort information is asymmetric (scenario 2), because the service provider shares risk of uncertainty, the client provides risk compensation for him. Under asymmetric capability information, in order to ensuring the service provider chooses the different contract, the client adds information rents in the fixed part of payment.

Second, our results point out conditions under which the client should pay attention to the risk of information asymmetry and provide effective guidance for making the trade-off between the information value and cost of acquiring information. We find that both the value of capability information and effort information increases in the quality sensitivity and the capability level, but with regard to the degree of risk aversion of the service provider and the uncertainty of quality, they show contrary results, the value of capability information decreases in the degree of risk aversion and uncertainty of quality while the value of effort information increases in them. Furthermore, we find that the ex ante belief about the service provider's cost type has important influence on the value of capability information. In summary, with high capability of service provider, high importance of the IT service quality, high risk aversion of the service provider and high uncertainty, the adverse effects of asymmetric effort information are high, the client can take measures to obtain effort information, such as investing in monitoring and coordinating mechanisms and introducing hierarchical governance structure. With high capability of service provider, high importance of the IT service quality, high uncertainty of the judgment related to the service provider's type, but low degree of risk aversion and quality uncertainty, the adverse effects of asymmetric of capability information are high, the client can take actions to acquire the service provider's private capability information, such as writing comprehensive request for information (RFI), term sheet and request for proposal (RFP), and carrying out in-depth investigations of the service providers' capability information including business experience, management capability and technical capability, and auditing the service provider by internal or external experts.

If the cost of activities reducing the adverse effects of the two asymmetric information factors is extremely large, the client can consider building strategic partnership with his service provider. A strategic partnership contains provisions for sharing risks and rewards associated with outsourcing, and aliens goals of the client and the service provider (Klepper and Jones, 1998), hence under strategic partnership the service provider would like to sharing information and the adverse effects of asymmetric information can be mitigated even can be eliminated. Saunder et al. (1997) agrues that partnership arrangements are more successful than pure supplier relationships. However, viewing a relationship as a partnership can be dangerous because it may lead to a loose contract, in part because the client thinks of the outsourcing vendor as a partner when in fact he is not.

Consequently, the possibility for "opportunistic behavior" by the vendor exists (Lacity and Hirschheim, 1993). So there needs to be a careful consideration before utilize the partnership. And the results of our research can contribute to helping the client in deciding whether to build strategic partnership by comparing the value of information and potential risk of strategic partnership. Future research could analyze the contracting dynamics arising in the environment of repeated games between the client firm and the service provider, and consider the new foundation for the theory of incentive contracts, such as relational contracts. Another one is to study the impact of the service providers' growing power. To model this change, one may analyze a relationship in which the service provider offer the contract. Finally, empirical investigation of the asymmetric information risk factors discussed in this article is also a promising research.

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APPENDIX A Proof of Proposition 1

Noting that the reservation constraint, Constraint (2), must bind, we can substitute it into the objective function, giving us an unconstrained optimization problem:

$$\max_{\beta,e} \pi_c = \mu\theta e - \frac{1}{2}e^2 - \frac{1}{2}r\beta^2\sigma^2 - \pi_R . \tag{A1}$$

Equation (A1) indicates that we have transformed our problem into a joint expected profit maximization problem. The first-order condition for (A1) is $\partial\pi_c / \partial e = \mu\theta - e$ and the second-order condition for (A1) is $\partial^2\pi_c / \partial e^2 = -1 < 0$. Therefore, the objective function is concave in e and the first-best effort level is $e^{FB} = \mu\theta$. Because $\partial\pi_c / \partial\beta = -r\beta\sigma^2 < 0$, the optimal solution of incentive payment is $\beta^{FB} = 0$. Substitute e^{FB} and β^{FB} into Equations (A1) and (2), we find ϖ^{FB}, π_S^{FB} and π_C^{FB}.

APPENDIX B Proof of Proposition 2

Using standard backward induction, we first examine the service provider's problem in Equation (5). The first-order condition for the problem is

$$\frac{\partial\pi_s}{\partial e} = \beta\theta - e = 0. \tag{B1}$$

The second-order condition for the problem is

$$\frac{\partial^2\pi_S}{\partial e^2} = -1 < 0. \tag{B2}$$

Therefore, the objective function in Equation (5) is concave. From Equation (B1), we get

$$e^* = \beta\theta. \tag{B3}$$

Next, we examine the client firm's problem in Equation (3). Clearly, the participation constraint condition for the service provider must be binding because the client firm can choose the lowest possible fixed payment to maximize π_C. Thus,

$$\varpi = \frac{1}{2}e^2 - \beta\theta e + \frac{1}{2}r\beta^2\sigma^2 + \pi_R ,$$

which, after substitution, simplifies the client firm's problem to

$$\max_{\beta} \pi_c = \mu\theta e - \frac{1}{2}e^2 - \frac{1}{2}r\beta^2\sigma^2 - \pi_R .$$

Because the client firm can anticipate the service provider's strategy in designing the optimal contract, we substitute e^* from Equation (B3) into the client's problem and derive the first-order derivative as

$$\frac{d\pi_C}{d\beta} = \mu\theta^2 - (\theta^2 + r\sigma^2)\beta .$$

The second derivative of the client's objective function is

$$\frac{d\pi_C^2}{d\beta^2} = -(\theta^2 + r\sigma^2) < 0\,.$$

Thus, the client's objective function is concave, solving $d\pi_C / d\beta = 0$, we get the unique following solution

$$\beta^* = \frac{\mu\theta^2}{\theta^2 + r\sigma^2} \tag{B4}$$

Finally, after substitution, we get

$$\varpi^* = \pi_R - \frac{\mu^2\theta^4(\theta^2 - r\sigma^2)}{2(\theta^2 + r\sigma^2)^2},\ \ \pi_S^* = \pi_R,\ \ \pi_c^* = \frac{\mu^2\theta^4}{2(\theta^2 + r\sigma^2)} - \pi_R\,.$$

APPENDIX C Proof of Proposition 3

$$\frac{\mu\theta^3}{\theta^2 + r\sigma^2} < \mu\theta\,,$$

it's thus clear that $e^* < e^{FB}$, and the expected quality in this setting with symmetric capability information and asymmetric effort information is lower when compared to the first-best quality.

APPENDIX D Proof of Proposition 4

The proof follows from substituting π_C^{FB} from proposition 1 and π_C^* from proposition 2. From Equation (6), it is easily to prove that $\partial\kappa_e / \partial\mu > 0$, $\partial\kappa_e / \partial\theta > 0$, $\partial\kappa_e / \partial r > 0$ and $\partial\kappa_e / \partial\sigma^2 > 0$.

APPENDIX E Proof of Lemma1

From Equation (7), we have

$$\partial(f(\beta_2,\theta) - f(\beta_1,\theta)) / \partial\theta = \theta(\beta_2^2 - \beta_1^2) > 0\,, \text{ for } 0 < \beta_1 < \beta_2 \le \mu\,.$$

APPENDIX F Proof of Proposition 5

Noting that lemma 1 implies $f(\beta_L^*,\theta_H) - f(0,\theta_H) > f(\beta_L^*,\theta_L) - f(0,\theta_L)$. Adding ϖ_L^* to both sides, we get

$$f(\beta_L^*,\theta_H) - f(0,\theta_H) + \varpi_L^* > f(\beta_L^*,\theta_L) - f(0,\theta_L) + \varpi_L^*. \tag{F1}$$

According to Equation (11) and Equation (F1), we have

$$f(\beta_H^{**},\theta_H) + \varpi_H^{**} - f(0,\theta_H) \ge f(\beta_L^{**},\theta_H) + \varpi_L^{**} - f(0,\theta_H) > f(\beta_L^{**},\theta_L) + \varpi_L^{**} - f(0,\theta_L) \ge 0,$$

thus, Constraint (9) is redundant. Constraint (10) is binding at optimality, otherwise, decreasing both ϖ_H and ϖ_L by the same amount would increase the client's expected profit while not affecting Constraints (9), (11) and (12). Constraint (11) is binding, otherwise, decreasing ϖ_H by a small amount would increase the client's expected profit while preserving Constraint (11), and not affecting Constraint (10) and (9). From binding Constraints (10) and (11), we get

$$\varpi_L^{**} = \pi_R - f(\beta_L^{**}, \theta_L), \tag{F2}$$

$$\varpi_H^{**} = \pi_R - f(\beta_H^{**}, \theta_H) + f(\beta_L^{**}, \theta_H) - f(\beta_L^{**}, \theta_L). \tag{F3}$$

Substituting Equations (F2) and (F3), the Constraint(12) becomes

$$f(\beta_H^{**}, \theta_H) - f(\beta_L^{**}, \theta_H) \geq f(\beta_H^{**}, \theta_L) - f(\beta_L^{**}, \theta_L). \tag{F4}$$

According to lemma 1, this constraint is satisfied. Thus, Constraint (12) is redundant at optimality. Substitute Equations (F2) and (F3) into Equation (8), the service provider's objective becomes

$$\begin{aligned} \max_{\beta_H, \beta_L} E[\pi_c] = {} & (1-p)[(\mu - \beta_H)\theta_H e_H + f(\beta_H, \theta_H)] + p[(\mu - \beta_L)\theta_L e_L + f(\beta_L, \theta_L)] \\ & -(1-p)[f(\beta_L, \theta_H) - f(\beta_L, \theta_L)] - \pi_R. \end{aligned} \tag{F5}$$

Because the client firm can anticipate the service provider's effort level, we substitute $e_H = \mu\beta_H\theta_H$ and $e_L = \mu\beta_L\theta_L$ into Equation (F5) and derive the first-order derivatives as

$$\frac{\partial E[\pi_C]}{\partial \beta_H} = (1-p)[\mu\theta_H^2 - \beta_H(\theta_H^2 + r\sigma^2)],$$

$$\frac{\partial E[\pi_C]}{\partial \beta_L} = p[\mu\theta_L^2 - \beta_L(\theta_L^2 + r\sigma^2)] - (1-p)\beta_L(\theta_H^2 - \theta_L^2).$$

The second-order derivatives are:

$$\frac{\partial E^2[\pi_C]}{\partial \beta_H^2} = -(1-p)(\theta_H^2 + r\sigma^2) < 0,$$

$$\frac{\partial E^2[\pi_C]}{\partial \beta_L^2} = -p(\theta_L^2 + r\sigma^2) - (1-p)(\theta_H^2 - \theta_L^2) < 0.$$

Therefore, the optimal solution is unique, solving $\partial E[\pi_c] / \partial \beta_L = 0$ and $\partial E[\pi_c] / \partial \beta_H = 0$, we get

$$\beta_H^{**} = \frac{\mu\theta_H^2}{\theta_H^2 + r\sigma^2}, \tag{F6}$$

$$\beta_L^{**} = \frac{\mu\theta_L^2}{\theta_L^2 + r\sigma^2 + T}. \tag{F7}$$

Where $T = ((1-p)/p)(\theta_H^2 - \theta_L^2)$

Compared β_H^{**} and β_L^{**} to β_H^* and β_L^*, we can easily see that $\beta_H^{**} = \beta_H^*$ and $\beta_L^{**} < \beta_L^*$. Then we substitute β_H^{**} and β_L^{**} into Equations (F2) and (F3), the solution of ϖ_L^{**} and ϖ_H^{**} can be obtained. We then substitute β_H^{**} and β_L^{**} into $e_H = \beta_H \theta_H$ and $e_L = \beta_L \theta_L$, e_H^{**} and e_L^{**} can be obtained. $\pi_{S_H}^{**}$ follows from Equations (7), (F3) and (F6). $\pi_{S_L}^{**}$ follows from Equations (7) and (F2).

Finally we substitute β_L^{**}, β_H^{**}, e_L^{**}, e_H^{**}, Equations (F2) and (F3) into $\pi_{C_H} = (\mu - \beta_H)\theta_H e_H - \varpi_H$ and $\pi_{C_L} = (\mu - \beta_L)\theta_L e_L - \varpi_L$, then $\pi_{C_H}^{**}$ and $\pi_{C_L}^{**}$ can be obtained.

APPENDIX G Proof of Proposition 6

From proposition 4, the proof of this proposition is straightforward and thus can be omitted.

APPENDIX H Proof of Proposition 7

Comparing the results in this setting with the symmetric capability information and asymmetric effort information results, it is clear to see that

$$e_L^{**} < e_L^*, \ e_H^{**} = e_H^* . \tag{H1}$$

$$\pi_{C_L}^{**} < \pi_{C_L}^*, \ \pi_{S_L}^{**} = \pi_R = \pi_{S_L}^* . \tag{H2}$$

$$\pi_{C_H}^{**} = \pi_{C_H}^* - \Delta R, \ \pi_{S_H}^{**} = \pi_{S_H}^* + \Delta R . \tag{H3}$$

Where ΔR denotes information rent of high-capability service provider, the value of ΔR is given by

$$\Delta R = \pi_{S_H}^{**} - \pi_{S_H}^* = \frac{\mu^2 \theta_L^4 (\theta_H{}^2 - \theta_L{}^2)}{2(\theta_L^2 + r\sigma^2 + T)^2} . \tag{H4}$$

Appendix I Proof of Proposition 8

The value of information of service provider's capability arises as the difference between the client's expected payoff under symmetric and asymmetric capability information scenarios, i.e., the difference between the client's expected payoff in scenario (2) and scenario (3). Let $\pi_{C_L}^*$ and $\pi_{C_H}^*$ denote the client's profit in the setting of symmetric capability information and asymmetric effort information, with a low-capability and high-capability service provider, respectively. From proposition 2, $E[\pi_C^*]$ is given by

$$E[\pi_C^*] = \frac{\mu^2}{2}[\frac{p\theta_L^4}{\theta_L^2 + r\sigma^2} + \frac{(1-p)\theta_H^4}{\theta_H^2 + r\sigma^2}] - \pi_R . \tag{I1}$$

From proposition 5, $E[\pi_C^{**}]$ becomes

$$E[\pi_C^{**}] = \frac{p\mu^2\theta_L^4(\theta_L^2 + r\sigma^2 + 2T)}{2(\theta_L^2 + r\sigma^2 + T)^2} + (1-p)(\frac{\mu^2\theta_H^4}{2(\theta_H^2 + r\sigma^2)} - \frac{\mu^2\theta_L^4(\theta_H^2 - \theta_L{}^2)}{2(\theta_L^2 + r\sigma^2 + T)^2}) . \tag{I2}$$

From Equations (I1) and (I2), we obtain the value of capability information as

$$\kappa_c = E[\pi_C^*] - E[\pi_C^{**}] = \frac{p\mu^2\theta_L^4 T^2}{2(\theta_L^2 + r\sigma^2)(\theta_L^2 + r\sigma^2 + T)^2} + \frac{(1-p)\mu^2\theta_L^4(\theta_H^2 - \theta_L{}^2)}{2(\theta_L^2 + r\sigma^2 + T)^2} . \tag{I3}$$

From Equation (I3), we can easily prove that $\partial\kappa_c / \partial\mu > 0$, $\partial\kappa_c / \partial r < 0$, $\partial\kappa_c / \partial\sigma^2 < 0$ and $\partial\kappa_c / \partial x > 0$.