On Bilateral Effort Contribution to IT Outsourcing

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Abstract

The success of an IT outsourcing project depends crucially on the close collaboration between both the outsourcing organization and the service provider. In this paper, we present a model to study the effort contribution from the two parties during the IT outsourcing process. The model incorporates two important and commonly observed features: 1) the true quality of the delivered project is unobservable, and 2) the outsourcing organization tends to downplay the quality of the project upon its delivery. The model is solved as a four-stage dynamic bilateral effort contribution game, and the results shed more lights on the interactions and dynamics between various parties during the IT outsourcing process.

1. Introduction

Information technology (IT) outsourcing occurs when an outsourcing organization enters into a contractual agreement with a service provider, who develops IT products or provides IT services for the outsourcing organization. Many types of IT products or services can be outsourced, such as software development and support, data centre operation, help desk services, network management, disaster recovery, and web hosting and application management. Rather than devoting budget, time, and energy to develop the IT products or services by themselves, outsourcing organizations feel they can potentially gain more benefits through outsourcing. Such benefits often include cost saving, focusing on core capabilities, maximizing internal IT resource, shortening development time, increasing knowledge transfer, and reducing investments risks, etc. Increasingly, managers realize that outsourcing is more than a simple purchase decision based upon economic or financial criteria; rather, it is a strategic decision that can create competitive advantages for an organization.

IT outsourcing is a very complex process, which involves legal, economic, managerial, and technological consideration. One of the major research streams in IT outsourcing is the management of partnerships so to reduce costs and maximize benefits (Oh and Gallivan 2004). In particularly, effective outsourcing needs to better understand the interactions and dynamics in the outsourcing process, and our study intends to contribute to this important literature.

2. Literature review

Outsourcing has gained increasing importance in the information systems (IS) research. For example, at corporate level, Lacity and Wilcocks (2001) provide outsourcing guidelines for practitioners, and Carmel and Agarwal (2002) use field study to identify four stages of corporate outsourcing maturity. However, these studies mainly focus on case studies or using empirical methods. A fact that is often overlooked in this literature is that, in essence, outsourcing is the process of contracting of products or service provision and subsequent implementations of the contracts. Therefore, to effectively manage the relationship between the parties involved in the outsourcing process, it is important to understand the interactions between the outsourcing organizations and the service providers. To this end, Whang (1992) analyzes a multi-phase software contracting process with prototyping and possible abandonment at each phase; Ngwenyama and Bryson (1999) use transaction cost theory to analyze the outsourcing decision. In this paper, we take a different approach based on the following facts that are very common in outsourcing practices:

1) In an outsourcing partnership, the quality of the delivered product or service not only depends on the effort contribution from the service provider, but also on that from the outsourcing organization. For example, in software development, the cooperation and efforts from both the outsourcing organization and the service provider are essential to better understand the underlying business processes and requirements so as to achieve success of the project.

2) Quite often, the effort contributions from both the outsourcing organization and the service provider are unobservable in IT outsourcing, and this is
exacerbated by the imperfect observation of the quality of the final project delivered.

3) Since the true quality of the delivered project is unobservable, the outsourcing organization has the tendency to degrade the quality of the project upon its delivery. To counter for this, it is a common practice for service provider to hire an auditor to audit the quality of the project if disagreement occurs.

In this paper, in light of the above features, we model the IT outsourcing process as a four-stage dynamic game. In the first stage, the outsourcing organization (principal) decides its level of effort contribution, and in the second stage, the service provider (agent) chooses its effort contribution accordingly. In the third stage the principal decides to what extent it should truthfully report the quality of the project upon its delivery, and in the last stage the agent decides if it needs to hire an auditor to audit the quality of the delivered project. We believe the richer contexts incorporated in the model can shed more light on the interactions among the parties involved during the outsourcing process.

3. The model
First, we introduce the variables used in this study:

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitions</th>
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</thead>
<tbody>
<tr>
<td>( t )</td>
<td>Time line; ( t \in {0,1,2,3,4} )</td>
</tr>
<tr>
<td>( s )</td>
<td>Payment from the principal to the agent</td>
</tr>
<tr>
<td>( q )</td>
<td>The true quality of the project. ( q \in {0,1} ), where 0 is low and 1 is high.</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>The principal’s effort level for project development. ( a \in {0,1} ), where 0 is low and 1 is high.</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>The probability for the principal to exert high effort, i.e., ( \text{prob}(a = 1) )</td>
</tr>
<tr>
<td>( e )</td>
<td>The agent’s effort level for project development. ( e \in {0,1} ), where 0 is low and 1 is high.</td>
</tr>
<tr>
<td>( \mu )</td>
<td>The probability for the agent to exert high effort, i.e., ( \text{prob}(e = 1) )</td>
</tr>
<tr>
<td>( j )</td>
<td>The principal’s judgment of ( q ) upon delivery of the project. ( j \in {0,1} ), where 0 is of low quality and 1 is of high.</td>
</tr>
<tr>
<td>( \varepsilon )</td>
<td>Intentional project quality judgment bias by the principal when ( q = 1 )</td>
</tr>
<tr>
<td>( k )</td>
<td>The cost of auditing incurred by the agent when it decides to hire an auditor. ( k \leq s )</td>
</tr>
<tr>
<td>( l )</td>
<td>The auditing result. ( l \in {0,1} ), where 0 is that the project is judged to be of low quality and 1 of high quality.</td>
</tr>
</tbody>
</table>

The timing of this bilateral effort contribution game is as follows:

At \( t = 0 \), the principal offers a project development contract to the agent, in which a payment of \( s > 1 \) will be paid to the agent if the project is developed and also is judged to be of high quality by the principal upon its delivery. The agent will be paid 0 if the project is judged to be of low quality. However, \( q \) is unobservable. The agent decides to accept or reject the offer of the contract. If the agent rejects, both parties will get nothing; if it accepts, the project will be developed by the agent. The outside opportunity cost is normalized to 0.

At \( t = 1 \), the principal chooses to exert effort level \( a \in \{0,1\} \). The cost of effort is \( \phi = \phi(a) = c_{1}a^{2} \) where \( c_{1} > 0 \), and assume \( \text{prob}(a = 1) = \gamma \in \{0,1\} = \Omega \).

At \( t = 2 \), the agent can exert effort \( e \in \{0,1\} \) to develop the project with cost \( c = c(e) = c_{2}e^{2} \) where \( c_{2} > 0 \) Assume \( \text{prob}(e = 1) = \mu \in \Omega \), and \( \mu \) is independent of \( \gamma \). The final quality of the software project, \( q \), is determined jointly by the efforts of both the principal and the agent. Denote:

\[
\text{prob}(q = 1 | a = m, e = n) = p_{mn}, \text{ where } m, n \in \{0,1\}.
\]

Under most circumstance, the effort of the agent is the main determinant of \( q \), so \( 0 \leq p_{oo} < p_{10} < p_{11} < p_{1} \leq 1 \).

At \( t = 3 \), the agent delivers the project to the principal, who makes a judgment \( j \in \{0,1\} \) of \( q \). For example, the judgment could be based on the testing results of the delivered software or the performance of the delivered business process, etc. Assume \( \text{prob}(j = 0 | q = 1) = j_{a} + \varepsilon \), where \( \varepsilon \in [0, 1 - j_{a}] \), and \( \text{prob}(j = 1 | q = 0) = j_{b} \); \( j_{a} \) and \( j_{b} \) represent the truthful judgment of the quality, though not perfect, and \( \varepsilon \) represents an intentional bias of the judgment when \( q = 1 \), and it is at the discretion of the principal, i.e., the principal may intentionally degrade the quality of the project when it is of high quality.

At \( t = 4 \), if \( j = 1 \), the principal pays the agent in the amount of \( s \). If \( j = 0 \) and the agent accepts it, then no payment to the agent; alternatively, the agent can consider hiring an auditor at its own cost to audit the quality of the delivered project. Let \( l \in \{0,1\} \) denotes the auditing result. Further let \( \text{prob}(l = 0 | q = 1) = l_{a} \), and \( \text{prob}(l = 1 | q = 0) = l_{b} \). Moreover, \( 0 \leq l_{a} < 1/2 \)
and 0 ≤ l < 1/2 , so that the auditing is helpful and informative. If audit results in l = 1, then s is paid to the agent, and in addition the principal has to compensate the agent the cost of auditing, k; if l = 0, s is not paid to the agent. Finally, the utility of the delivered project to the principal is defined as V(q) = vq, and v > s.

4. Analysis of the model

Formally this is a four-stage dynamic game of perfect and complete information, and all information is common knowledge to both parties. In the first stage, the principal decides on its probability to exert effort (γ), and in the second stage the agent chooses its probability of exerting effort (μ). In the third stage the principal decides on how truthfully to report the quality of the project. In the following, we solve this game in the spirit of backward induction.

At t = 4, given the effort levels of the principal and the agent, γ and μ , the probability that the project is of high quality is as follows:

\[
\text{prob}(q = 1) = \sum_{m=0}^1 \sum_{n=0}^1 p_m p(γ = m) p(μ = n) = p_{00}γ(1−μ) + p_{01}(1−γ)μ + p_{10}(1−γ)(1−μ)
\]  

(1)

and the probability that the project is of low quality is \(\text{prob}(q = 0) = 1−\tilde{q}\).

An important property of this probability is:

\[
\frac{\partial \tilde{q}}{\partial γ} = p_{10}μ - p_{00}μ + p_{01}(1−μ) - p_{00}(1−μ) > 0
\]

\[
\frac{\partial \tilde{q}}{\partial μ} = p_{10}γ - p_{00}γ + p_{01}(1−γ) - p_{00}(1−γ) > 0
\]

i.e., the probability that project quality is high increases with the efforts of both the principal and the agent.

In addition, given the principal’s judgments \(j_0\), \(j_1\), and bias \(ε\), we can derive the probability that the project is of high quality given the principal judges it as low using Bayes’s Theorem:

\[
\text{prob}(q = 1 | j = 0) = \frac{(j_0 + ε)\tilde{q}}{(1−j_1)−(1−j_0)−j_1−ε)\tilde{q}} = \tilde{q}
\]  

(2)

If the agent decides to hire an auditor when the principal judges the quality as low, the probability that the auditor can reverse the principal’s judgment is given by:

\[
\text{prob}(l = 1 | j = 0) = (1−l_0)\tilde{q} + l_1(1−\tilde{q})
\]

(3)

\[l_1 = (1−l_0)\tilde{q} + l_1(1−\tilde{q}) = \tilde{I}
\]

So upon the principal’s declaration that the project is of low quality, the agent will hire an auditor iff: \((s + k)\tilde{I} ≥ k\).

Substitute in \(\tilde{q}\) and \(\tilde{I}\) as in (2) and (3), we have the following:

\[(s + k)[l_1 + \frac{(1−l_0)−l_1(j_0+ε)\tilde{q}}{(1−j_0)−(1−j_0)−j_1−ε)\tilde{q}}] ≥ k \]  

(4)

The left-hand side is the possible gain of hiring an auditor and right-hand is the cost, so the agent has to consider this trade-off before making its decision.

There’re several interesting observations about inequality (4):

• It is more likely to hold if \(s ≫ k\). This corresponds to the situation where the cost of hiring an auditor is very low compared with the potential loss of the payment.

• It is more likely to hold as \(\tilde{q}\) increases, i.e., when the agent knows that efforts have been made to develop the project.

• It is more likely to hold if \(l_0 \to 0\) and \(l_1 \to \frac{1}{2}\). This corresponds to possible collusion between the agent and the auditor, so the auditor is inclined to judge the quality of the project as high even it is low, but would never miss it when the quality is high.

• It is less likely to hold if \(l_0 \to \frac{1}{2}\) and \(l_1 \to 0\). This corresponds to possible collusion between the principal and the auditor, so the principal never misses it when the quality is low, while the auditing result is hardly informative when the quality is high.

• Most importantly, it is more likely to hold if \(ε \to 1−j_0\). This corresponds to the situation when the principal’s bias of the quality is very high, and the agent finds it more beneficial to have a second opinion.

Obviously, the decision to hire an auditor or not depends on \(ε\), i.e., how truthfully the principal reports the quality of the project. In other words, \(ε\) is the response function by the principal at \(t = 3\). We’ll see this more clearly from the following analysis.

From (4), we have:

\[
ε\tilde{q}(s−sl_0−kl_0) ≥ (k−sl_0−kl_0)(1−j_0)(1−\tilde{q}) + j_0\tilde{q}(kl_0−s+sl_0)
\]
Then it follows that \( \frac{s}{k} \geq 1 > \frac{l_0}{1 - l_o} \) or \( s - s l_o - k l_o > 0 \), and then (4) becomes:

\[
e \geq \frac{(k - s l_o - k l_o)(1 - j_o)(1 - \overline{q})}{q(s - s l_o - k l_o)} - j_o = \overline{E} \quad (5)
\]

So, the agent will hire an auditor iff \( E \geq \overline{E} \); otherwise it will not hire an auditor. Intuitively, the agent will be more inclined to find an auditor if its loss \( s \) or judgment bias \( \varepsilon \) are high. The marginal value is \( \overline{E} = \overline{E} \), and the agent will be indifferent to the two alternatives. It is important to note that \( \overline{E} \) is a function of \( \overline{q} \), which is further a function of \( \gamma \) and \( \mu \).

At \( t = 3 \), the principal will decide its best response function \( E^* \), i.e., how truthfully it should judge the quality of the delivered project when it is of high quality, given any \( \gamma \), \( \mu \), and the agent’s best response function as to hire an auditor or not as in (5). There are three cases.

First, assuming \( 0 \leq E \leq 1 - j_o \) or \( \mu \in A_1 \subseteq \Omega \) for any given \( \gamma \) (see appendix for derivation of \( A_1 \)). It is noted that by intentionally degrading the quality when it is high, the principal might save the cost that should have been paid to the agent. Denote the saving of this payment as \( \zeta_1 = ES \). From (5), the principal knows that if it chooses any \( E \leq \overline{E} \), then the agent will not hire an auditor, and as a result the principal will optimally choose \( E^* = \overline{E} \) to maximize \( \zeta_1 \), so that \( \zeta_1^* = \overline{E}S \).

On the other hand, if the principal chooses any \( 1 - j_o \geq E \geq \overline{E} \), then the agent will hire an auditor for sure if principal announces the quality of the project as low. Although the principal may still gain a benefit of \( ES \) from degrading the quality of the project, but at the same time it faces the possibility of being caught by the auditor, so it chooses \( E \) to maximize:

\[
\zeta_2 = ES - (s + k)\hat{j} = ES - l_1(s + k) - \frac{(1 - l_o - l_1)(j_o + \varepsilon)q(s + k)}{(1 - j_o) - (1 - j_o - j_i - \varepsilon)q}
\]

Since \( \frac{\partial \zeta_2}{\partial E} = S - \frac{(1 - l_o - l_1)(s + k)(1 - j_o)(1 - \overline{q})}{[(1 - j_o) - (1 - j_o - j_i - \varepsilon)q]^2} \), and \( \frac{\partial^2 \zeta_2}{\partial E^2} > 0 \), so \( \zeta_2(E) \) is a convex function, and the optimal solution has to be at the two extreme points, or \( E^* \in \{\overline{E}, 1 - j_o\} \), which leads to \( \zeta_2^* \). Define \( \text{arg max}(f(x), g(y)) \) as the arguments \( x \in X \) and \( y \in Y \) that gives \( \text{max}(f(x'), g(y')) \), where \( x' \in \text{arg max } f(x) \) and \( y' \in \text{arg max } g(y) \), then when \( 0 \leq \overline{E} \leq 1 - j_o \), we have:

\[
E^* \in \text{arg max}(\zeta_1, \zeta_2^*)
\]

The question is when \( \overline{E} \) or \( 1 - j_o \) can be the optimal choice by the principal. It follows that as \( \zeta_2(\overline{E}) < \zeta_1(\overline{E}) \), so \( E^* \neq \overline{E} \), and \( E^* = \overline{E} = \overline{E} \) iff \( \zeta_1(\overline{E}) \geq \zeta_2^*(1 - j_o) \), or \( \overline{E}S \geq (1 - j_o)s - l_1(s + k) \); plug in (3), (5) and \( \zeta_2^* = 1 - j_o \), we have that \( E^* = \overline{E} \) iff:

\[
\frac{(k - s l_o - k l_o)(1 - j_o)(1 - \overline{q})}{q(s - s l_o - k l_o)} - j_o = S
\]

\[
\leq (1 - j_o)S - \frac{(1 - l_o - l_1)q(s + k)}{1 - j_o + j_i q}(s + k)
\]

or \( \mu \in B = [l_1, b_{l_1}] \subseteq A_1 \), where \( 0 \leq b_{l_1} \leq b_{l_1} \leq 1 \) (see appendix for derivation of \( B \)). Otherwise \( E^* = 1 - j_o \).

The result in (6) has some practical implications:

- If \( \mu \in B \), then \( E^* = \overline{E} \) as given in (5), which implies that:
  - The principal is more like to degrade project quality when \( \hat{j}_o \) and \( \hat{j}_1 \) are small. Intuitively, when the judgment of the principal is almost perfect, it can afford more bias without increasing the agent’s tendency to ask for auditing.
  - The principal is more likely to degrade project quality when \( \overline{q} \) is small. When low quality is more likely to occur, the principal would not miss the opportunity to take advantage of this.
• If \( \mu \in \bar{B} = \{b_1, b_2\} = A_1 - B \), then \( \epsilon^* = 1 - j_0 \), and, based on function \( \zeta_2 \), the principal will degrade project quality to the maximum possibility.

The second case is when \( \bar{q} < 0 \) or \( \mu \in A_2 \), then (5) is always satisfied, and the agent would always hire an auditor, so \( \epsilon^* \in \text{arg max} (\zeta_2) \), where \( \zeta_2 \) is given above. Since \( \zeta_2 \) is convex, it follows \( \epsilon^* \in (0, 1 - j_0) \).

If \( \epsilon^* = 0 \), then
\[
\zeta_2 = -\ell(s + k) - \frac{(1 - \ell - l_j)j_0q(s + k)}{(1 - j_0) - (1 - \ell - j_0)q}.
\]

If \( \epsilon^* = 1 - j_0 \), then
\[
\zeta_2 = (1 - j_0)s - l_0(s + k) - \frac{(1 - l_0 - l_j)q(s + k)}{1 + j_0q}.
\]

So the principal will choose \( \epsilon^* = 0 \) iff:
\[
s(1 - j_0) + \frac{(1 - l_0 - l_j)j_0q(s + k)}{(1 - j_0) - (1 - \ell - j_0)q} \leq \frac{(1 - l_0 - l_j)q(s + k)}{1 + j_0q}.
\]

Otherwise \( \epsilon^* = 1 - j_0 \). The above inequality reveals that, in this case, the principal will be less like to degrade the project quality if \( s \) is small, \( j_0 \) is large (the principal is more confident about its own judgment when quality is high), or \( l_0 \) and \( l_j \) are small (when auditing result tends to be more informative).

In the third case when \( \bar{q} > 1 - j_0 \), or \( \mu \in A_3 = \{a_{33}, a_{34}\} \), then (5) never holds, and the agent will never hire an auditor. Such scenarios include that \( q \) is extremely low or \( l_0 \) is large. In this case, \( \epsilon^* \in \text{arg max} (\zeta_1) \), which gives \( \epsilon^* = 1 - j_0 \): the principal will degrade the project to the maximum possibility. The three cases analyzed above constitute \( \epsilon^* \), the best response function by the principal, regarding the choice of \( \mu \) by the agent in stage 2. Taken together, the principal’s best response at this stage takes on one of the three values, i.e., \( \epsilon^* \in \{0, \bar{q}, 1 - j_0\} \). Also note that we have \( B \cup \bar{B} \cup A_1 \cup A_2 \cup A_3 = A_1 \cup A_2 \cup A_3 = \Omega \).

At \( t = 2 \), the agent will optimally choose \( \mu \), given any \( \lambda \in \Omega \) in the first stage, and the principal’s best response function \( \epsilon^* \) in the third stage of the game, and the agent’s decision as to hire an auditor or not in the last stage.

For all \( \epsilon \in [0, 1 - j_0] \), the probability the principal will declare that the project is of low quality upon its delivery is given by:
\[
\begin{align*}
\text{prob}(j = 0) &= \text{prob}(j = 0 \mid q = 1) \text{prob}(q = 1) \\
+ \text{prob}(j = 0 \mid q = 0) \text{prob}(q = 0) \quad (8)
\end{align*}
\]
\[
= \epsilon(\mu)q(\mu) - (1 - j_0 - j_1)q(\mu) + 1 - j_1 = \bar{j}
\]

As mentioned earlier, there exists four possibilities (in the three cases) regarding choice of \( \mu \) or \( \mu(\gamma) \).

First for \( \forall \mu \in B \), \( \epsilon^* (\mu) = \epsilon^* (\mu) = \epsilon^* (\mu) \) and the agent will not hire an auditor if \( j = 0 \). So the payoff function to the agent is:
\[
\psi_i = s(1 - \bar{j}) - \mu c = s(1 - \bar{j}) - \mu c_2
\]

The first term is the payment to the agent if the principal judges the quality as high and the second is the effort of the agent for developing the project. Substituting (8) and (5) into \( \psi_i \), we have:
\[
\psi_i = s\bar{q}(1 - j_0) - \frac{(k - s)l - kl_0(1 - j_0)(1 - \bar{q})}{s - s - kl_0} + sj_0 - \mu c_2
\]

Plugging in (2),
\[
\frac{\partial \psi_i}{\partial \mu} = \frac{s(1 - j_0)(s - s - kl_0) + (k - s)l - kl_0)(1 - j_0)}{s - s - kl_0} \quad (9)
\]

Clearly, the sign of \( \omega_i (\gamma) \) depends on \( \gamma \). If \( \omega_i (\gamma) > 0 \), then \( \mu^* (b) = b \); if \( \omega_i (\gamma) < 0 \), then \( \mu^* (b) = b_0 \); if \( \omega_i (\gamma) = 0 \), then \( \mu^* (b) \) for \( \forall b \in B \), i.e., the agent will have a mixed strategy.

Second, if \( \mu \in \bar{B} \), then \( \epsilon^* (\mu) = \epsilon^* (\mu) = 1 - j_0 \), and the agent will hire an auditor for sure if \( j = 0 \), so the payoff function to the agent will be:
\[
\psi_i = s(1 - j_0) + \bar{j}(k + s)l - k - \mu c_2
\]

The first and the third term are the same as in (9). The second term is the payment the agent gets if the auditor can reverse the judgment. From (2), (3) and (8), we have:
\[ \bar{\gamma} = 1 - j_i + j_i \bar{q} > 0, \quad \text{and} \quad \bar{l} = l_i + \frac{(1 - l_0 - l_i \bar{q})}{1 - j_i + j_i \bar{q}} , \]

Substitute \( \bar{\gamma} \) and \( \bar{l} \) into \( \psi_2 \), we have:

\[ \psi_2 = s - \mu c_2 - (k + s)(1 - j_i + j_i \bar{q}) + (k + s)[l_i(1 - j_i + j_i \bar{q}) + (1 - l_0 - l_i \bar{q})] \]

Using (2), it follows:

\[ \frac{\partial \psi_2}{\partial \mu} = (k + s)[l_i(1 - j_i - 1 - l_0)] \]

\[ [p_{1i} \gamma - p_{0i} \gamma + p_{00}(1 - \gamma) - p_{00}(1 - \gamma)] - c_2 < 0 \]

So, \( \mu^*_2 = \bar{b}_i \).

Third, if \( \mu \in A_1 \), then \( \epsilon^*_2 \) is given by (7) and the agent would always hire an auditor if \( j = 0 \).

If \( \epsilon^*_2 = 1 - j_0 \), then the payoff function \( \psi_{31} = \psi_2 \).

If \( \epsilon^*_2 = 0 \), then \( \bar{\gamma} = 1 - j_i - (1 - j_0 - j_i \bar{q}) \), and

\[ \bar{l} = l_i + \frac{(1 - l_0 - l_i j_i \bar{q})}{1 - j_i - (1 - j_0 - j_i \bar{q})} . \]

Again, similar to \( \psi_2 \), the payoff function is:

\[ \psi_{32} = s(1 - \bar{\gamma}) + \bar{l}[(k + s)\bar{l} - k] - \mu c_2 = s_j(1 - j_0 - j_i \bar{q}) + [1 - j_i - (1 - j_0 - j_i \bar{q})] \]

\[ \{k + s[l_i + \frac{(1 - l_0 - l_i) j_i \bar{q}}{(1 - j_i) - (1 - j_0 - j_i \bar{q})}] - k\} - \mu c_2 \]

So, \( \mu^*_2 \in \arg \max (\psi_{31}, \psi_{32}) \) and

\[ \psi_3 = \max(\psi_{31}, \psi_{32}) \quad (11) \]

Last, if \( \mu \in A_1 \), then \( \epsilon^*_2 = 1 - j_0 \), and

\[ \bar{\gamma} = 1 - j_i + j_i \bar{q} \], and the agent would never hire an auditor if \( j = 0 \). Then similar to \( \psi_2 \),

\[ \psi_4 = s(1 - \bar{\gamma}) - \mu = s_j - s \bar{q} - \mu c_2 \quad (12) \]

Using (2), \( \frac{\partial \psi_4}{\partial \mu} = -s_j \frac{\partial \bar{q}}{\partial \mu} - c_2 < 0 \), \( \mu^*_4 = a_{3L} \),

the lower bound of \( A_4 \).

At this stage, given any \( \gamma \), the best response function of the agent is given together by \( \mu^*_i (\gamma) \) and

\[ i \in \{1, 2, 3, 4\} \] , In addition, we can obtain \( C_1 \), \( C_2 \), \( C_3 \) and \( C_4 \), the supports of \( \gamma \) so that \( \mu^*_i (\gamma) \) are within in domains \( B_i, \bar{B}_i, A_i \), and \( A_2 \) correspondingly. This is necessary since the corresponding domain within which \( \mu^*_i (\gamma) \) falls determines the best response function the principal takes in the third stage of the game, i.e., \( \epsilon^*_i (\mu) \). Again, \( C_i \cup C_i \cup C_i \cup C_i = \Omega \).

At \( t = 1 \), the principal will choose \( \gamma \) to maximize its payoff. From above, the support of \( \gamma \) is \( \Omega \). There are four cases here:

In the first case, for any \( \gamma \in C_1 \), the equilibrium path following the principal’s choice are \( \mu^*_i \in \{b_i, b_i, b_i, B\} \) depending on \( a_i(\gamma) \) as in (9-2), \( \epsilon^*_1 = \bar{E} \), and the agent will not hire an auditor if \( j = 0 \). At the same time, given (1) and the principal’s utility function \( V(q) \), the payoff function for the principal is:

\[ \pi_1 = \bar{q}[(1 - j_0 - \bar{E})(v - s) + (j_0 + \bar{E})v] - (1 - \bar{q}) j_s - \gamma c_1 \quad (13) \]

The first term is the gain when quality is high, and second term is the principal’s loss due to inaccurate judgment when quality is low. The last term is the cost of effort: when \( a = 1 \), \( \phi(a) = c_i a_0^2 = c_i \). Note the first term has two parts, which represent the gain when the principal judges the quality as high or low.

In the second case, for any \( \gamma \in C_1 \), the equilibrium path is \( \mu^*_2 = \bar{b}_L \), \( \epsilon^*_2 = 1 - j_0 \), and the agent will hire an auditor if \( j = 0 \); then the payoff function for the principal is:

\[ \pi_2 = \bar{q}[(1 - j_0 - \epsilon^*_2)(v - s) + (j_0 + \epsilon^*_2)v(1 - \bar{q}) - (1 - \bar{q})j_s - \gamma c_1] \]

The third term is the cost to the principal when the auditor judges the quality of the project as high when it is actually of low quality, and the other terms are the same as in (13). Plug in \( \epsilon^*_2 = 1 - j_0 \), we have:

\[ \pi_2 = \bar{q}[(1 - j_0 - s)(v - s) - (1 - \bar{q})(s + k) - \gamma c_1] \quad (14) \]

In the third case, for any \( \gamma \in C_1 \), the equilibrium is \( \mu^*_4 \in \arg \max (\psi_{31}, \psi_{32}) \) , \( \epsilon^*_4 \in \{0, 1 - j_0\} \), and the agent will always hire an auditor if \( j = 0 \); similar to \( \pi_2 \), the payoff function for the principal will be:

\[ \pi_3 = \bar{q}[(1 - s)(v - s) - (1 - \bar{q})(s + k) - \gamma c_1] \quad (15) \]
Last, for any $\gamma \in C_4$, the equilibrium path is $\mu_s^* = a_{3L}$, $\epsilon^* = 1 - j_o$, and the agent will not hire an auditor if $j = 0$. Thus the principal’s payoff function will consist of three terms, the gain when quality is high, the loss due to inaccurate judgment when the quality is low, and the cost of the principal’s effort:

$$\pi_4 = q - (1 - q)j_s - \gamma c_i$$  \hspace{1cm} (16)

Thus at $t=1$, the principal will optimally choose its level of effort contribution:

$$\gamma^* = \arg \max \{\pi_1, \pi_2, \pi_3, \pi_4\}$$  \hspace{1cm} (17)

The rest of the equilibrium path is given by the best response functions in the following stages as solved above. We briefly summarize the solution of the four-stage dynamic game as follows:

- Given any $\gamma \in \Omega$, we can solve for domains $B, \overline{B}, A_1, \text{ and } A_2$ using the appendix and inequality (6).
- For any $\mu \in \{B, \overline{B}, A_1, A_2\}$, we can identify $\mu_1$ with $i \in \{2, 3, 4\}$ from (9)-(12), and these are the best responses by the agent at $t=2$.
- For each $\mu_1(\gamma)$, we can further identify $C_i$ where $i \in \{2, 3, 4\}$, the support of $\gamma$ for $\mu_1$ as the best response functions.

For any $\gamma \in C_i$, obtain $\gamma^*$ from (13)-(16), and the optimal $\gamma^*$ over $\Omega$ is given by (17).

5. An illustrating example

For illustration, let $v = 2s = 2k = 8c_1 = 8c_2$; $p_{0o} = 0$, $p_{01} = 1/4$, $p_{02} = 3/4$, and $p_{11} = 1$; $j_0 = j_1 = 1/2$; $l_0 = l_1 = 0$ (perfect auditing). Therefore, at $t = 4$,

$$q = \frac{1}{3} \mu + \frac{1}{4} \gamma(1 - \mu) + \frac{3}{4} (1 - \gamma)\mu$$, \hspace{0.5cm} \hat{q} = \frac{1}{1 + \epsilon q} \frac{1}{1 + \epsilon q}$$, \hspace{0.5cm} \text{and} \hspace{0.5cm} \epsilon = \frac{1 - \epsilon}{2\epsilon} - \frac{1}{2}.$$

At $t = 3$, in case 1 where $0 \leq \epsilon \leq \frac{1}{2}$, since (6) always holds, $\epsilon^* = \epsilon$. From $0 \leq \epsilon \leq \frac{1}{2}$, we obtain

Thus, given the above parameters, the equilibrium path of this example is that $\gamma^* = 0$, $\mu^* = 0$, $\epsilon^* = \frac{1}{2}$, and the agent will not hire an auditor.

6. Conclusion and discussion

In this paper, we present a framework to model the effort contribution by both the outsourcing organization, and the service provider during IT
outsourcing process. We incorporate the unobservability of the true quality of the delivered project and the outsourcing organization’s tendency to degrade the quality of the project in our model. We solve the model as a four-stage dynamic bilateral effort contribution game. The function forms and parameters used in the model are very general, and the results shed more light on the interactions between parties involved during the outsourcing process. There’re some interesting extensions for this study that worth exploration in the future, for example, collusion between the principal or agent with the auditor, simulation of the outsourcing process to provide managerial guidelines for decision makers. In addition, as companies increasingly outsource to more than one contractor to spread the risk of potential failure, another interesting future research direction is to model the situation where a single principal contracts with multiple agents and investigate how the free riding and competition between the agents will affect the effort contribution from all parties.

References


Appendix

Since \( E = E(\gamma, \mu) \), thus given the domain of \( E \), we can solve for the values that \( \gamma \) and \( \mu \) take.

- If \( E \geq 0 \), and using (5) it follows:
  \[ (k - sl_l - kl_l)(1 - j_l) \geq (k - sl_l - kl_l)(1 - j_l) + j_l(s - sl_l - kl_l) \eta \]
  Denote \( [(k - sl_l - kl_l)(1 - j_l) + j_l(s - sl_l - kl_l)] = \eta \).
  Since \( s - sl_l - kl_l > 0 \), then depending on the signs of \( \eta \), we can solve for \( \eta \) correspondingly.

- If \( E \leq 1 - j_l \), then:
  \[ (k - sl_l - kl_l)(1 - j_l) \leq (k - sl_l - kl_l)(1 - j_l) + (s - sl_l - kl_l) \tau \]
  Denote \( [(k - sl_l - kl_l)(1 - j_l) + (s - sl_l - kl_l)] = \tau \), then depending on the signs of \( \tau \), we can solve for \( \tau \) correspondingly.

- Since \( \eta \) and \( \tau \) are constants and \( \eta \leq \tau \), then we can solve for \( \tau \) in the case of \( 0 \leq E \leq 1 - j_l \) as well.

Using the fact that \( \eta \) is a function of \( \gamma \) and \( \mu \) as in (1), then for each of the above inequalities, and given any \( \gamma \), we can plug in (1) to get \( A_1 \); we can obtain \( A_2 \) and \( A_3 \) in a similar way. The derivation of set \( B \) proceeds in the same logic: we can solve (6) for \( \eta \) first and then for \( \mu \) using (1).