Reward Mechanism in Multi-agent Information System Integration Based on Bilateral Moral Hazard

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Abstract. Bilateral moral hazard is constructed over undertaking information system integration and resource suppliers based on compensation. Invariable compensation is needed to encourage the participators in making appropriate efforts. From the angle of knowledge accumulation, the article built a remuneration model and further obtain the operational mechanism for such an integration. Conclusion indicates that the optimal effort level of original service provider and the intervention of remuneration does cast impacts on the integration process in terms of the commissioning party. Moreover, it brought forward the optimal system pathway on which best efforts could implement its functions with the effect of bilateral moral hazard.

Introduction

Integration of heterogeneous information systems has been highly addressed in the field of system engineering in recent years \[1\]. Owing that information integration is a multi-agent complex system, the process needs to coordinate related resources within multiple entities, and balance the interests of stakeholders. To ensure the involvement of service providers, the original system ought to provide economic commissions. In general, under the Fixed Contract Mode, the service providers in commissioning with the original cooperation pattern may face double moral hazard \[2\], and commissioning party may transfer possible risks to the original service providers.

For a long time, research on the bilateral moral hazard is more concentrated on the theme of supply chain and collaborative mechanism, and lack a deep discussion on system integration aspect \[3\]. Rosenkranz analyzes the phenomenon of opportunistic motivation in the cooperative R & D process \[4\]; Petra uncloses the governance factors enabling knowledge transfer within the inter-organizational development projects, and found that knowledge transfer towards participating firms cooperating is positively influenced when partners govern their cooperation by using mutual trust and contract complementary \[5\]; Mrozek discussed the cooperation strategies within supply chains and the impact for growth of the high-tech company \[6\]; Agrawal explores the market and economic conditions under which management of the upstream sourcing can add value to supply chains \[7\]; Jianxin uses the Principal-agent Theory to discuss the quality control strategy in supply chain under the condition of moral hazard and the corresponding impacts for supplier’s expected revenues \[8\]. These studies above are more centered on tangible products through price regulation mechanism rather than the service supply in information integration process, thus it is difficult to be applied in the complex circumstance of mutual reactions within information system.

In the outsourcing field, more researchers made their concerns around system mechanism building. Shehab discussed the risk evaluation and provided a framework towards a cost modeling for outsourcing ERP system \[9\]; Cullen defined the set of organization choices in crafting its IT outsourcing portfolio, leading to rationales for 31 different options in outsourcing \[10\]; Deng adopted a view to offshore information systems outsourcing from a vendor's perspective to explore the source of performance based on an empirical study, and highlights the importance of client-specific capabilities in terms of service quality \[11\]. From the present documents as a whole, less concerned the construction of information system integration in treating bilateral moral hazard.
Accordingly, as a supplement the study intends to build a bilateral remuneration model from the perspective of knowledge accumulation, and obtain the optimal level of effort in order to achieve incentive motivation.

**Model Assumptions**

To simplify the issue abovementioned, the model in the study at the outset assumes the following point: there are merely a commissioning party (subject $i$) and an original service provider (main $j$); the commissioning party makes knowledge sharing degree in information integration process of $\chi_i$ and contribution effort of $I_i$, while the original provider occupies the degree of $\chi_j (0<\chi_i<1, 0<\chi_j<1)$ and $I_j$ respectively; the learning ability for original service providers are $a_i (a+ b_i I_i)$, $a_j (a+ b_j I_j)$.

By the Knowledge Accumulation Theory, learning efficiency is affected by mutual complementarily of knowledge, commissioned party and the original system demonstrated more ability to learn than its own learning ability. Assuming costs in knowledge absorbing effort for the principal and original providers were:

\[ M_i = h \cdot I_i^2 \]  
\[ M_j = g \cdot I_j^2 \]

Where $h, g$, indicate parameters of cost for the commissioning party and original service providers in taking cooperation, respectively. In addition, considering the effect of knowledge accumulation, the principal accumulated knowledge for original service providers in information integration is defined below:

\[ U_i = I_i + a_i \cdot \chi_i \cdot (U_j^0 + I_j) \]  
\[ U_j = I_j + a_j \cdot \chi_j \cdot (U_i^0 + I_i) \]

If a fixed contract were used, the commissioning service providers to the original system is labeled as $T$ value point; when using variable contract, the commissioning service providers to the counterpart would be transferred into a compensation level of mutual effort by both parties involved; when both lead to a higher level of effort, the variable correspondingly increases in consistent with the effort, and the compensation reduced accordingly. The overall process is defined below:

\[ T = t + \Phi (I_i + I_j) \]

Where $T$ is the total compensation from commissioning provider to the original system, $t$ is the fixed compensation, $\Phi$ is the parameters of unfixed compensation, $I_i, I_j$ represent the force levels of commissioning service providers.

**Model Building**

Assuming that the level of effort is observable for both commission parties, it can obtain the optimal value and get the revenue function in terms of expectations of the service provider:

\[ \dot{\omega}_i = U_i - C - t \]

\[ = I_i + (a_i + b_i) \phi_i \ast (U_j + I_j) - t \]  
\[ \dot{\omega}_j = t + U_j - M_j \]

\[ = t + I_j + (a_j + b_j I_j) \ast (U_i + I_i) - gI_j/2 \]

As the function indicates below, only the expected fund return is greater than the level of retained earnings (expressed with the $\zeta$), service provider could participate in the integration of information system. Thus, it could get the constraints of information systems for integration process involved.
\[ t + U - E \geq \zeta \quad (8) \]

When the effort level is unobservable, the commissioning parties may choose to maximize the expected revenue levels according to their efforts, and the issue can be optimized as:

\[
\max \Phi_i (I_i, I_j) = U_i (I_i, I_j) - C_i (I_i) - M_j (I_j) - \zeta \quad (9)
\]

\[
s.t. \quad I_i = \arg \max \Phi_i (I_i, I_j) \quad (10)
\]

\[
I_j = \arg \max \Phi_j (I_i, I_j) \quad (11)
\]

**Calculation**

The model could be calculated in the following part as the principle of balance. Given reward \( T(\omega) \) meets the revenue standard, the two commissioning parties expected revenue in information integration could be expressed as follows:

\[
\Phi_i = U_i - C_i - t \\
= I_i + (a_i + b_i I_i) E_j U^0 - \omega (I_i + I_j) \quad (12)
\]

\[
\Phi_j = t + U_j - M_j \\
= t + \omega (I_i + I_j) + I_j + (a_j + b_j I_j) E_i U^0 \quad (13)
\]

As model defined above, the two commissioning parties could choose the best effort levels based on the principle of Nash equilibrium:

\[
\frac{\partial \Phi_i}{\partial I_i} = 1 + b_i x_i U^0_j - \omega = 0 \\
I_i = \frac{1 + b_i x_i U^0_j - \omega}{h} \quad (14)
\]

\[
\frac{\partial \Phi_i}{\partial I_j} = 1 - g I_j + b_j x_j U^0_i + \omega = 0 \\
I_j = \frac{1 + b_j x_j U^0_i + \omega}{g}
\]

\[
\omega^* = \frac{g b_i x_i U^0_j - h + b_i^2 x_i^2 U^2_j}{h + g + b_i x_i} \quad (15)
\]

\( \omega \) is the decreasing parameter in the constructed function within commissioning parties, namely, when the principal value is lower cost, the variable \( \omega \) represents level of remuneration for both parties in the information integration.

Thus, the Nash equilibrium \( (I_i^*, I_j^*) \) is taken as \( \left( \frac{1 + b_i x_i U^0_j - \omega}{h}, \frac{1 + \omega + b_j x_j U^0_i}{g} \right) \), and level of efforts by both sides are effected by the cost parameters as well as the combined effect of compensation variable \( \omega \).

In addition, the maximize income in the parties linked could be expressed as

\[
\max \Phi_i = U_i (I_i, I_j) - E_i (I_i) - M_j (I_j) - \zeta \quad (16)
\]

By calculation above, we can obtain the conclusive points: optimal effort level by both commissioning sides are affected by the cost parameters, cooperation efficiency as well as the combined effect of compensation value of \( \omega \). Variable remuneration for both could also affect the optimal level of efforts.
Conclusion
From the model construction and analysis, principal and system service providers are the vital element to ensure the active participation of stakeholders for information integration, but the fixed remuneration compensation mode may cause the principal and the original service providers fallen into a paradox of bilateral moral hazard. The study concluded that: the optimal level of effort is affected by the cost parameters, learning efficiency and the effect of compensation. Cost parameters are negatively correlated with the optimal effort level, while the learning efficiency is positively correlated with the same factor, and the commissioning party increases the cost with remuneration. Meanwhile, the optimal variable remuneration is affected by the value of cost-efficiency. Namely, when the commissioning party and original system with cost-effective service provider were in low efficiency, optimal variable compensation may increase; when the commissioning party and original system are in low efficiency, remuneration can be appropriately reduced.

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References